INFORMAL REMARKS OF ROBERT W. GALVIN

PRESIDENT OF MOTOROLA, AT CONFERENCE

ON

"THE IMPACT OF MICROELECTRONICS"

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As a trustee of IIT I would like to express compliments to my associates here for the establishment of this conference. In an informal way I want to participate in welcoming you to a kind of conference which I hope will prove useful to all involved.

I have been asked to speak in the spirit of the case history. This is partially a case history of our company and partially one of the industry's entry into the microelectronics business. I think the most direct way to get into my subject is to reference the company case history to how we are getting into microelectronics and what we expect from it in the future.

At the end of World War II our company was essentially an equipment manufacturer. We were an assembler of circuits into end equipment for a variety of electronic markets.

Near the end of the 1940's decade some of our senior scientists observed the distinct change that was taking place in the science of crystals, the formation of crystals, the dislocation of crystals and the application of donors to various pure materials. These scientists came to our management and said: Gentlemen, there is a distinct trend developing. It is going to mature into the practical application of transistors, diodes and ultimately something else that we don't quite know how to define at this stage. If we are going to be able to maneuver with our competitors, if not out-maneuver them, we must be in a position to out-perform them with products having circuitry made from these distinctly new materials. We must be identified with this new art. We believe the company must attain this capability if it intends to be a leader in a variety of new and different equipments.

We accepted that recommendation and decided to make a modest investment of company funds in 1950 to do exploratory research in this field. We were fortunate in being able to attract to our Phoenix facilities a few very imaginative men. Certain of them came from universities such as IIT. These talented men were able to devise a distinct approach to a few kinds of transistors that looked promising.

Meantime, our equipment divisions spent considerable time observing and appraising what was going on in our modest laboratory activities in Phoenix.

In the early 1950's one of these divisions determined that there was a particular application of a transistor that would bear fruit as our senior scientists back in the 1940's had said it would in enabling us to come up with a distinctly better piece of equipment. This was a power transistor whose application was primarily in automobile radios. By the mid 1950's we found a practical way of producing this device and started to apply it to hybridization of the audio power end of our car radios. This proved to be a major competitive advantage.

With this initial success we were faced with certain additional basic decisions. Should we continue to be a supplier to ourselves of semiconductor devices, which had been our initial and exclusive objective. We put some thought and some numbers to this question. One of the things rather quickly evident was that as a market unto ourselves we were not sufficient. If we supplied only our equipment divisions that would not be enough to support the engineering budget necessary for a progressive and successful semiconductor manufacturer.

We reckoned that as a rule of thumb it was going to take at least 10 percent of our pricing formula to afford an engineering department. It's a pretty simple piece of arithmetic that if you're going to do ten million dollars worth of semiconductor business and roughly 10 percent of that can be appropriated for engineering, you can afford a million dollar budget in engineering. But, if you or your competitors cater to a fifty or hundred million dollar sales potential you can obviously have a five or ten times larger engineering operation.

We calculated that a very large engineering operation was necessary in our semiconductor division because of the breadth of the science talent required in order to be a success. The semiconductor business potential appeared almost unlimited and we could not see a practical means of targeting or specializing in one particular area.

Consequently, another question came up. If we wished to serve ourselves and others with semiconductor devices were we willing to broaden ourselves as a corporation and become a components manufacturer?

This was a major decision. Here was a corporation facing the question of changing from an equipment manufacturer exclusively to become both an equipment manufacturer and a components supplier.

Well, we did some long range planning with speculation on numbers for the future. The speculations and numbers weren't sophisticated nor complete but we did reasonably guess there would be a substantial use of semiconductors in the period 1960 to 1965. The market was going to be there.

We then had to ask the question, can a company like Motorola become an accepted component supplier? After all, some of the people we would be serving would be competitors. We had no experience in manning, staffing, managing and marketing components. However, we felt that these things basically would respond to a common sense approach and so we launched into the components business.

This has proven economically sound. As of now, approximately 85 percent of the billings in our semiconductor division are with outside customers. Only 15 percent of the billings are inside the company.

Of course, we had to change the nature of our original objective. Customers must be served. That's the first and ultimate purpose in business. We have had to share our technical innovations with customers rather than give them exclusively to our own equipment divisions. This has been a valuable trade off, and overall has been of value to the corporation.

The case history of Motorola entering the integrated circuit business has to start with the case history just recited of our company changing from an exclusive equipment manufacturer to a component manufacturer. This became a base for determining what the company should do in integrated circuits.

Although it is impossible now to reach an objective conclusion because conditions can never be repeated, I would say that if the corporation had not started in the semiconductor business ten years ago, the problem of getting into integrated circuits today would certainly be complex.

It is entirely probable we would be forced to decide against entering the integrated circuit business to the degree that we have. The reasons are rather obvious to an audience of this kind. They relate to many of the observations made by Bob Sprague. They have to do with the fact that the basic technologies, market place, processes, and the marketing methods in the semiconductor business are similar to the integrated circuit business.

Now that we have made the decision to enter the integrated circuit business we can respond to the question: Exactly what are the business reason that impelled us? Well, the first was to protect our business in the semiconductor industry. There will be an impact on the transistor business caused by integrated circuits sometime during the next ten years. We anticipate an impact not only on components in general but on the transistors of the discrete devices. The integrated circuit business will be an obvious extension of our semiconductor business.

As for our position as an equipment manufacturer, we feel that we have to be in the integrated circuit business for the same reason we went into the semiconductor business ten years ago. We feel we must have an additional incremental marginal control over the circuitry that goes into our equipment. Of course, we do buy semiconductors from other manufacturers. We will be buying integrated circuits from other outside suppliers and other multiple components from many suppliers. But it's only a marginal increment that each equipment division seeks, to provide a marginal advantage over its customer. We hope that from time to time as a result of being in the integrated circuit business the equipment divisions will have some marginal incremental distinctive advantage over their equipment competitors.

The third reason we decided to get into the integrated circuit business is that there is going to be a significant market for a variety as well as absolute volume of the many kinds of micro circuit or integrated circuit devices that are going to emerge. The need is already quite obvious in the more sophisticated areas of electronics--computers and military systems in particular, but industrial systems also. The need for reliability is quite obvious to this audience. Whether or not integrated circuits in their various forms are going to fulfill all the promise of reliability and the necessary extension of system complexity, is not fully predictable at this time. However, I think it can be readily accepted that there is no other potential solution on the horizon for the problem of adding to the complexity of our products and solving the reliability problems.

It is our view that integrated circuits in various forms are going to be low cost devices eventually. This is not going to be true in the next five years, perhaps not in the next ten years. We don't yet know <u>how</u> they're ultimately going to become low cost devices. But, it was only four or five years ago that the process of epitaxy came on the scientific scene. There's probably something else simmering in someone's laboratory that will allow us a major advance like epitaxy in the next ten years. The development of various technologies in the course of time are probably going to pull together to make integrated circuits inherently low cost. There is a little bit of faith and a little bit of hope built into that kind of a speculation, but our estimates are not based entirely on faith and hope.

You know the essential material contents of an integrated circuit. If you can take them down to their essentials there are fractions of pennies in certain of the devices and only pennies in others. The labor costs are minor, and if, indeed, we can solve the problems of processing, mechanization, and automation, with sufficient flexibility, the cost of integrated circuits can become simple.

I think there is a problem in the management of inventory. Inventories, particularly at the level of the processor of the circuit itself, present opportunities for important marginal improvement in the investment phase of our business. However, we must be quite realistic. This business is going to be a high investment business in contrast to--if I may oversimplify--the assembly of radio sets back in the 1930's.

The high investment will be a product of the kinds of equipment and the variety of equipment we're going to need in order to develop, as well as produce, the products involved. The engineering costs in integrated circuits are substantial.

A few minutes ago, in doing some simple rule of thumb arithmetic I indicated that we assumed there would be an engineering cost of something like 10 percent of the device. Actually it's higher than that. In an integrated circuit there's no point in even naming a figure at this time because in some people's business it's as much as 100 percent.

In any case the integrated circuit technology requirement as a part of the pricing formula is going to be very high.

In the course of the next few years the integrated circuit manufacturer will have some very major problems to solve if he is to operate at a profit. Our company right now is not operating at a profit in the integrated circuit business. We're losing substantial dollars. We don't expect to make money until 1964 or 1965, and probably 1965.

One of the major things we must learn in order to effect our yield is the elimination of stray couplings. I can remember, when I first started in our company, seeing a fellow using the screw driver to move a wire out of the way in order to eliminate the coupling of one circuit from another. Obviously, you can't do that in the integrated circuit business. This must be thought out, designed into a device. Just eliminating the stray coupling in integrated circuitry is going to be a fantastic problem.

This suggests a premium on determining the simple integrated circuits to use at first. In all probability the more popular type of circuit the next five years will be what we refer to as the chip circuit because there is sufficient know-how in its technology at this time.

Of all the problems we face the most important is the marriage of the objectives of the classical circuit engineer with the device or integrated circuit designer. Again referring to Mr. Sprague's talk, he indicates that the component industry has developed a means of collaborating productively with the equipment manufacturer over a long period of time.

I think that problem is probably an order of magnitude more difficult when it gets in the integrated circuit area because now we're really going to call upon the circuit engineer and the equipment manufacturer to have a much more basic understanding of mathematics, chemistry, physics, encapsulation, surface passivation and so on. And the engineer must properly interpret or communicate his needs to the integrated circuit manufacturer, if there is to be a vendor-customer relation. We must find a way of bringing about adequate communication between these two parties, whether it's among divisions within a company like Motorola or with outside customers where geography and many other factors will inhibit relationships. Unless we solve this communication problem adequately the predictions shown on the screen here today are going to be slow in coming.

Let's face it, there is inertia at the circuit engineer's level at this time. I don't know whether it's complacency or an atmosphere in which some fellows don't know how to grasp the problem.

In our company we're trying an experiment you might be interested in knowing about. Our Semiconductor Division, the division that will be making and selling integrated circuits to equipment manufacturers, has embarked on a program to teach our customers how to get into the integrated circuit business.

Within the last few weeks we have announced a course to be given in Phoenix at a fee. It's actually a series of two courses running two weeks and one week, one right after another, wherein a customer can send any type of an engineer he thinks would find it useful to learn how to make integrated circuits. He has to learn the language first, so to speak, and then he actually ends up producing integrated circuits on laboratory equipment.

We hope the result will be a stimulation of interest in integrated circuits and the sciences. We think there is much learning that has to happen in the minds of our customers. We hope we can stimulate some of them to establish integrated circuit pilot activities of their own.

There is a risk that we may put some of them in the integrated circuit business and lose some of our own. We take that risk because something has to be done to move the equipment engineer further along in his interest if he is going to be using integrated circuits five and ten years from now.

Implicit in this kind of program is our philosophy. This new business will go as far as the component manufacturer and the equipment manufacturer find their roles in the science of tomorrow. There will be some customers using basically standard integrated circuits to a significant degree, a part of this 15 percent to 40 percent market. There will be customers who want custom design of integrated circuits made by their supplier. There are going to be situations where certain equipment manufacturers have their own integrated circuit design teams and pilot operations where they design the basic device to be reproduced by their supplier. There will be additional equipment manufacturers who will elect to go into the supply of some of the integrated circuits for themselves. Finally, there will be some component manufacturers who will see an opportunity to capitalize on certain of their integrated circuits and go into the equipment business.

All five of these things will probably take place. If we placed these on a curve as we traditionally do in laboratories and could somehow factor them into a bell curve, some place in the middle, as it normally occurs, will be the point at which the greatest collection of activity will take place.

It's quite evident, if one wants to engage in just the pure philosophy of economics, that everybody in the equipment business can't afford to be in the integrated circuit manufacturing and design business. There just aren't that many dollars in the American or in the world market to afford American electronic industry investing to that extent. So, there will continue to be specialization, but the specialization is going to be much more sophisticated than it has ever been in the past.

There is a basic principle that the equipment manufacturer should apply in determining the role of his company in this revolution or evolution. The equipment manufacturer must have basic control over his circuit. Once he loses this he loses his birthright.

I believe the equipment manufacturer can have control over his circuit, even if a somewhat larger proportion of the circuit is manufactured in a vendor's place of business than is currently being assembled in his own manufacturing shop. If he is the circuit determiner to a sufficient degree he can maintain his individuality at the market place. But the equipment manufacturer can't reach that point unless he learns how to design the circuit, unless he trains his people and acquires the talents that are basically found in the integrated circuit or component or semiconductor manufacturer at this time. And these are the barriers.

The integrated circuit businessman must understand the semiconductor technology and all of the basic ramifications. He must understand thin-film technologies and the combined marriage of these two talents, and the passivation of surfaces. There must be a basic understanding of the various kinds of substrates necessary to carry certain kinds of circuits. There must be an equipment and systems understanding which the equipment manufacturer already has and indeed the component manufacturer must possess to a much greater degree than in the past. One of the technical things we should keep in mind is that we don't just have one kind of a circuit to cater to. Engineers would probably agree that there are about thirty, in fact we've categorized them as thirty. Thirty basic circuit functions, which we've learned to employ in equipment over the course of roughly fifty years of tube technology. The semiconductor type of integrated circuit at this time, as a rule of thumb is capable of serving only six to ten of these kinds of circuit functions.

Any engineer in the audience can take some issue with that in particular situations. It is possible to reproduce most of these thirty functions with a semiconductor base integrated circuit in the laboratory under unusual or ideal ambient circumstances. The semiconductor base integrated circuit at this time is a specialized device that can best cater to the digital or non-linear type of circuit application. The so-called thin film or passive based integrated circuit appears to be desirable in serving the balance of the circuit that would have to be served in the course of the next couple years.

What this tends to suggest, therefore, is that if we are to find early applications of integrated circuits in our equipment then we must respond to the question: what kind of integrated circuits will we use and not what kind of singular integrated circuit will we use?

I see all these different kinds of products that were listed on the board behind me as being a part of the future of the microelectronics or integrated circuit business in the course of the next ten to twenty years. I think thin film circuitry will be used twenty years from now. I think some individual components will be in prominent use twenty years, and I see a very large growth in the integrated circuit business if we can resolve certain of the problems that I've touched upon.