Fairchild Oral History Panel: MOS IC Products

Fairchild@50 (Panel Session # 7)

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Gil Amelio: Thanks everyone here for joining us today. What we're going to do is take a walk, as you have in some of the other panel sessions, down memory lane. What I find interesting about looking back over 50 years of Fairchild history and some of the things that happened along the way, is that we've all taken this journey together and we took a path that wasn't the easy path. We took the harder path and it's nice to look back on what happened, what you did, and what are some of great memories you had. Some were serious, and some were funny, and we're going to talk about both today. Our first speaker will be Rob Walker. He's going to talk about *The ASIC Story at Fairchild*. I think a story that hasn't really been told the way it needs to be. Federico is then going to talk about *My Fairchild Adventure and the Development of Silicon Gate Technology*, obviously one of the early pioneers in that area. Nick Phillon is going to talk about *MOS Around the World*, but I've invited him to comment on all the Fairchild technologies they tried to sell in Europe and what it was like in those early days of this industry. And then I'm going to do a little reminiscing at the end and then, of course, we'll have questions and answers. So with that I'm going to ask Rob to come up and tell you the ASIC story. Rob.

Walker: I'm going to talk about how Fairchild invented ASIC and CAD. By that I mean standard cell, I mean gate arrays, logic simulation, place and route, LSI type testers, (the Sentry line), and interestingly enough how many denied this ever happened.

Andy Grove [Voice from video clip]**:** Fairchild was famous for having it really right, but there were a lot of things that never went well like a lot of stuff didn't make it from R&D into manufacturing.

Interviewer [Voice from video clip]**:** Almost nothing made it from R&D to manufacturing. You are being too kind.

Rob Walker: Well, actually, some things did. The µA702 [for example] and being probably the first in Gate Arrays, in Standard Cell, in CAD and the Sentry testers, but you won't know about it if you read these histories. No one mentions a word about Fairchild and ASIC. Well, was it Carver Mead? No, Carver Mead got his inspiration from seeing our Micromosaic work. And this was before Synopsis, Daisy, Mentor, Valid… they didn't exist. Even Berkley was working primarily on SPICE circuit simulation. So, who was who in Palo Alto? Of course, it was all under Gordon Moore and Bob Seeds then. Bob Shriener, of course, was taking his orders from Nancy Weaver who's here as well as Maurice O'Shea. Hugh Mays ran CAD and he had Jim Koford and Ed Jones working for him. The late Bob Nevala was in charge of bipolar arrays. Jim Downey, who's sitting right down there, was in charge of the MOS arrays, and Bob Ulrickson had this group that was sort of a systems group, logic, whatever. And Harold Vitale is the guy that designed the first Sentry starting out with the 8000 series. Then there was me and Leo Kraft and Charlie Ellenberger who tried to build these things.

This photo was our first gate array in bipolar DTL, a total of 32 gates, in 1966. This was our 8000 tester, which then moved to San Jose and became the Sentry series. And back here you see one of our TTL arrays that Bob Nevala designed. We successfully moved to Mountain View under Wilf Corrigan. We had a variety of vice presidents. About every 18 months one would come stumbling in. Roy Pollock was one. I had Micromosaic and a whole series of senior application engineers, and they had people reporting to them. Bill O'Meara was one of our marketing VPs. Jack Balletto was another. As I said, Hugh Mays had CAD with Koford and Jones, and quite interestingly we two shifts of layout. We were running in '70, '71 with probably 20 mask designers on day and swing shift. By then, Jim Downey had taken over wafer fabrication. So we were doing seven prototypes out the door a month in silicon gate, PMOS, 300 to 600-gate complexity, and we were 90 percent right the first time; this was unheard of in the integrated circuit world.

These are some of our customers at the time [chart]. The COIN Program was a classified program that was very successful. We did some classified designs for Sandia. I recently got a call and a fellow from Sandia dropped by the house and he wondered about the lifetime of these circuits, because they're the trigger in our nuclear weapons. So they're still out there folks, but don't worry because it's Fairchild MOS, so you know not to worry. The deal was the customer pays for the design. We were like architects. We were very conservative on our design because there's no binning, there's no speed selection. You've got to be right the first time. Customer signoffs occurred at simulation, layout and shipping the prototypes and we wouldn’t start wafer fabrication without a test tape. Nobody else did this. And we used Sentry testers.

Here's our 90th Micromosaic [Chart]. You can see it's got the 90 on it and it's the Z version, which is the first step. I think this was for Bunker-Ramo. Then, it was all shut down. Why? Well, our PMOS technology was not as fast as NMOS and, of course, it wasn't nearly as fast as bipolar. Intel introduced microprocessors, and they could handle the low and medium speed applications. Bob Ulrickson and Lowell Turriff dropped the price of MSI to a dollar fifty cents or something like that and, of course, one of the reasons was that it was Fairchild MOS. So, at any rate, ten years later we started LSI Logic with the same design philosophy, a lot of the same people except we had a license from Toshiba for a very high speed CMOS that was as fast as TTL and in some cases faster than ECL. We did over 12,000 designs, and we did it at a peak rate of 10 a day, and 96 percent were correct the first time. So it proves that the techniques that we came up with at Fairchild didn't last at Fairchild, but they worked at LSI Logic. And then, interestingly, in the mid '80s Intel entered the ASIC business and...

Interviewer: [voice from video clip] And you've been a master of it.

Andy Grove: [voice from video clip] We were masters of it when we had it right, but we were not such masters of it. To give you an example, back in the mid '80s we aborted a fairly sizeable effort to get in the ASIC business, and we thought we could do it with the manufacturing mentality and organization that we had developed and we couldn't. Manufacturing in an application specific chip business is by necessity different. What’s important is different. How you organize is different than in the single product, high volume, high value arena. So we got it right, but we didn't really understand exactly what it was that we got right.

Walker: So Andy [Grove], this was all developed in the same building in Palo Alto where you were working, so next time pay attention. Thank you.

Amelio: Thank you Rob, good job. At this time I'm going to turn the floor over to Federico Faggin to talk about his adventures.

Federico Faggin: Okay, thank you. Well, ladies and gentleman, it's a pleasure to be here to talk about the Fairchild legacy. By way of background my introduction to semiconductor goes back to 1967. As a solid-state physicist I joined SGS Fairchild. Fairchild owned 30 percent of SGS Fairchild in those days. And I developed their first MOS process technology and also two integrated circuits. Almost everything that I knew about MOS I learned from work that was done at Fairchild, specifically work done by Bruce Deal, Andy Grove, C. T. Sah, Maija Sklar, Ed Snow and many others. Basically, Fairchild developed the most cogent understanding of the silicon-silicon dioxide interface that existed in the mid and late '60s. I joined the R&D group of Fairchild in 1968. I was supposed to stay six months and go back to SGS Fairchild. I'm still on my sixth month. And in 1968 what I found is that Fairchild was still, despite some rough spots, the Mecca of semiconductor technology.

If we look at the technology at the end of '67 we find that bipolar technology was pretty much used for 95 plus percent of all integrated circuits. The market for digital ICs was dominated by TTL bipolar, and there were many medium scale integration functions that were becoming available rapidly. MOS technology was considered a Cinderella of the semiconductor technology. It was beginning to emerge as an alternative technology, but it had very low speed, and the reliability was still not very good. LSI, which stands for Large Scale Integration, was an integrated circuit with more than 1,000 transistors - by the way, we put more than several billion [on a chip] these days - more than 1,000 transistors per IC were predicted to occur soon.

Now, MOS technology at the end of '67 was fundamentally dominated by metal gate, high threshold voltage P-channel. It was in production at several companies, but those devices were slow and every once in a while somebody would lose the recipe and you had a disaster on your hands. MOS business was primarily concentrated on custom circuits, basically circuits that were done for a lot of government agencies. In particular AMI, American Microsystems Inc. made a big business out of that. And in the area of standard circuits, memories were dominated by read-only memories. And the only read-write memory that was possible in those days was the shift register. There was a fair amount of business in that. Working random access memory actually had started at several companies and Intel was one of them. The holy grail of MOS technology was already recognized at that time. People understood that if you were able to make a low threshold voltage, self-aligned gate MOS devices we would actually be able to bring the whole potential of the MOS technology to bear. And there were several approaches that were vying for that type of solution.

As we now know, the silicon gate technology was the technology that eventually won the day. Early experiments were done at Bell Labs, experiment with Sarace and others. Tom Klein also made some early experiments at Fairchild, but fundamentally all they did was to prove that you could, in fact, do self-aligned transistors under very favorable conditions using amorphous silicon. When I joined Fairchild in '68, I was given a project to actually develop a true [silicon-gate] process integrated circuit and bring it to production. And I did pretty much all of that in the period from February to July of '68, creating the process architecture, developing the detailed process technology, and designing the 3708, of which I will say a few words later. And by the end of '68 we actually sold 3708 chips commercially. That was the world's first semiconductor device using self-aligned silicon gate [MOS]. Here's the 3708 [Chart]. It is a multiplexer. Here you see the eight big transistors. Those are the eight channels that multiplex packets of data. This is a decoder. It decodes one of those eight. And this device was difficult to do right. There was a metal gate version that production had trouble in meeting the spec because these transistors had to have very low leakage. Also they had to have very low ohmic resistance. And of course the reliability had to be very high. We were able to achieve all of those requirements, and the speed also, by the way, was supposed to be much higher than we were able to achieve [with the metal gate process]. We achieved about five times the speed of the metal gate version, and the leakage was about 100 times less using silicon gate technology. This technology was presented in October of 1968 in Washington at the IEDM. And, of course, from that point on it was beginning to be recognized as the technology for making MOS devices. And, of course, Intel took this technology and developed it as well.

So if you look at the silicon gate versus metal gate, we basically had transistors that were three to five times faster because of the self-aligned gate. We could make aluminum go over the gate that was buried. Also, another invention of mine was the buried contact, by which we could make a poly-to-silicon contact directly and have metal going over it. Therefore we could achieve two times the density of circuits for the same amount of silicon compared to metal gate. And that's why we could do the microprocessor in 1970-1971 with this technology. The silicon gate being a refractory [material] allowed us to perform gettering. That would reduce the leakage, achieving up to a thousand times less leakage than with conventional metal gate technology. That was very important for dynamic circuits like dynamic memories and dynamic shift registers that were important at that time. We could also cover the silicon gate with thermal oxide and then vapor deposit oxide on top of that gate to make devices that were much more reliable. And this allowed us to create floating gate structures that were the basis for non-volatile memories that today are used in extremely large volume. Also, CCDs were made practical by using silicon gate.

So the bottom line was that the silicon-gate MOS technology truly provided a quantum leap in price-performance over metal gate and unleashed the full promise of the MOS technology. This photo is an *Electronics Magazine* front cover that refers to an article describing the silicon gate technology and the 3708 authored by me and Tom Klein [Chart]. The two years that I spent at Fairchild were absolutely outstanding for me. My career was really shaped by those two years I spent there. And they were years that were very important for the industry as well. A number of companies were formed out of Fairchild alumni, including Intel, AMD, Four Phase Systems and Precision Monolithics. All these companies were formed in the two years that I was at Fairchild. And these companies have spread microelectronics far beyond what Fairchild could have done by itself. So by creating the entrepreneurial spirit in a number of people, the microelectronics revolution spread much faster than if this company did not exist. Fairchild's contributions to the microelectronics revolution have been fundamental. I don't think that there is another company that did more to create this industry than Fairchild in its first 12 years of existence.

Thank you.

Amelio: Nick Phillon are you ready?

Nick Phillon: First of all, I'm very honored to be a part of such a distinguished group. A few minutes ago I met Jim Downey and I said, "They have me in the MOS group. What do I know about MOS?" And Jim said, "Can you spell the name M-O-S?"

To tell you a little bit about myself, I worked 23 years for Fairchild, half of that in the United States and half in Europe. I joined Fairchild as a product engineer at the diode plant. Then I came to Mountain View and worked on NPN transistors, PNP transistors, then on a very sophisticated logic - RTL and DTL (!!) - until I moved to MOS marketing. And I spent the last couple of years in the United States in MOS marketing. My function was to promote the products that we were making in those days. I was also supporting the European market. And I made several trips there bringing to various European customers the products that we were making. It was a very exciting time. One of my functions included participating in the announcing of new products. I remember one of them was the famous 1K dynamic RAM that was a replica of Intel's, except ours was supposed to be better. And I remember bringing the advertising people from Los Angeles before the big announcement. I had to make some huge timing diagrams on the wall to show them how our device was better than the Intel device.

Another product I remember that was fascinating was the FIFO. Probably Rob invented the name and, of course, it described the function, but for me it was interesting name. During that time one of our biggest customers in Europe was Olivetti. I had gone there several times bringing them new MOS products. And they were looking for someone to design a chip for a new calculator. At that time calculators, I think, were down from five chips to three chips. And we proposed that we use silicon gate to make a one-chip calculator. And I don't remember the name of the engineer that was, I think, under Rob that designed it. An Olivetti engineer came and spent maybe a few weeks of describing what the function should be, *etcetera*. And of course, CAD was starting to be used. We all waited to see if this chip would work, and it worked the first time. And we were very amazed, this silicon gate one-chip calculator. And so Olivetti really produced this, but by then the prices of calculators were coming down very quickly. Our chip had the disadvantage, at least initially, of being very big. The yields were low. We could not bring down the prices fast enough, and so it didn't work out in big volumes.

After that I went to Europe. I was hired by Bob Blair. At that time he was running marketing for Europe and the general manager was then Don Brettner. And I was supposed to be the MOS marketing manger for Europe. At that time the European marketing was in Wiesbaden as the central point. A couple of months after I arrived they decided to decentralize marketing and I became the marketing manager for Southern Europe in Italy where I stayed eight years promoting all the products of Fairchild. Then eight years later when the new Wasserburg facility opened I went there to become the digital marketing manager. By the way, I'm sure most of you know the first semiconductor plant that Fairchild built [in Europe] was in Wiesbaden. It must have been about 1963. And it was in conjunction with Olivetti. That plant closed some years later. It was bought by a pharmaceutical company. They still use that facility.

So when I went to Wasserburg there was a new assembly and test plant, a very beautiful building, and they were making digital products. They were assembling and testing. The problem was that they were buying die from the U.S. and assembling and testing in Wasserburg. And the price of the die was higher than what we were getting for the finished product in the market place. So at that time, the general manager of Europe was a guy called Guy Dumas a Frenchman with a PhD in Physics from the Sorbonne. Tom Roberts was coming to Europe to see how we were doing, and I said, "Can I talk to Roberts explaining the problem?" And he said, "No, no, no, Schlumberger does not allow discussion on transfer prices." So anyway I insisted and he said, "Okay, mention it." And so Roberts came and I mentioned the problem. He said, "What are you doing here? You should go to South Portland and negotiate pricing." So that's what I did. And after that we broke even, let's put it that way. However the plant was serving the European customers better, but we were pushing for a wafer fab in Wasserburg. And finally Roberts, when he saw that things were improving said, "Okay, give me the make-up of the market, staff, engineering, etcetera and I will approve it if it seems reasonable." So he made all kinds of calculations of what the costs will be. For example, one of the savings was the import duties, and I'm talking back in 1983 when we were paying almost $8 million dollars a year in import duties. So that would be the saving if we made the chips in Europe. So it was approved that we build a wafer fab, which we did. And in the middle of it CMOS was coming up. The only other place that CMOS was made was in Portland, Maine in a very old facility. So it was decided that we should be making CMOS in Wasserburg for Europe and perhaps for the U.S. until the U.S. increased their capacity. And so the plan was changed. The equipment was bought, different equipment for CMOS. They sent engineers to the U.S. to be trained in diffusion, etcetera. And before we started the company was sold to National. And every one of us lost our jobs. The plant closed and Schlumberger sold the buildings to a company called Wacker Chemie, which makes silicon wafers. So this is in brief what I have to say.

Amelio: The timing here is interesting because I got my Ph.D. in 1968 and I went immediately to Bell Laboratories. So I was working on some of the early technology there during that time. And, of course, I was reading about what the guys in Silicon Valley were doing. The work I started at Bell Laboratories was the CCD work. I think many people know that we created it in 1969, and then ultimately went public with it in 1970. Following that I had this great urge that I wanted to make things and not just do research.

So I got beckoned to Silicon Valley and to Fairchild Research Laboratories. This photo is me in my laboratory circa 1971 when I showed up. At that time I had two responsibilities. I was running the CCD project, number one. And number two I was running the model lab. We had a small fab line there that we used to try out new processes that ultimately would get transferred to the manufacturing facilities. And I was in a great spot there because anyone who had a cool idea had to come to me first before they could run their wafers in our model line. And it was a good fortune for me because I got to see a lot of brilliant technology and great ideas and we got to make a lot of those things in this lab. I think the team we had at that time was an incredible group of people, very unique and very creative in doing some of the really great work of the time, including very early work on CMOS and some advances in linear technologies and other things like that.

This phote is me in New York in 1973 spreading the word. One of the things we tried to do at Fairchild in those early days was to talk about what we were doing. So frequently we'd be invited to various conferences of one kind or another and would go to them. This [photo] was after I became head of the MOS division. In 1977 Wilf Corrigan asked if I would take over the division. And, of course, you know, the '70s was the era of the movie series *The Godfather*. And so the challenge was this. We at MOS were sort of always the underdogs among the divisions, with bipolar being the high fliers. And so we figured when the sales conference came up we had to do something to get the attention of the salesmen so they would work as hard selling our stuff as they did selling the bipolar stuff. So we came up with this idea to do a skit at the sales conference in the full regalia of the Godfather theme. And this was my staff, the people who ran the MOS division at that time, and you can see some familiar faces. Doug McBurnie, John Husher came over from Linear to join us, George Urbani, Finn Wilhelmson who came over from the Discrete Division, Lou Chetaud and Frank Bower… and of course me. This is all of us at -- and I'm joking, of course -- holding a staff meeting. And then here's another one taken at the same time with the same theme. I found this as I was rummaging through some drawers and I thought everyone would get a kick of this.

Despite my “checkered” past, in 1978 I did become an IEEE Fellow for my work in CCDs, and I think that I was just one of a very, very long string of prominent technologists at Fairchild that got so recognized, and as Federico pointed out, created the foundation, the seminal technologies that led to the explosion of this industry years later. I just might point out one thing that we sometimes forget, and that is in 1971 Fairchild was the third largest semiconductor company in the world. And sales that year were $196 million dollars. We've come a long, long way since then. And so we were a small industry. The $250 billion dollars that the industry does today started with the seeds that were planted in those days.

After Schlumberger bought the company they mixed everything up, and I wound up running the MOS microprocessor group and you can see I'm talking at a press conference there. I look like I'm in disguise because I'm wearing those big glasses. And, of course, my remarks are so compelling that Van Lewing is sitting there hypnotized by it [grin!]. Van was our marketing guy at that time. We had a great time in Paris… we might have even sold a few microprocessors at that conference. I'm just going to close off the reminiscing part with a series of business cards. Now those of us who were at Fairchild for any period of time know that you probably averaged a new business card every six or eight months. I think that is the way it worked in those days. This is a small selection of some of mine through the years from the very early days to right up to the Microprocessor Division. I thought this would be fun.

I survived 12 years at Fairchild because I moved a lot and a moving target's a little harder to hit so they'd pick on somebody else that wasn't moving quite so fast. I'll have to say this about the MOS work there. I ultimately left in 1983 to go run Rockwell Semiconductor and then later National Semiconductor. I think the work we were doing towards the end of that period was really laying some foundations for some very good MOS production capability. Because where we always came up short against a lot of our competitors was not in the innovation, but in the manufacturing of that technology. And I think at that era we were finally getting plants like the ones we had in Wappingers Falls, and ultimately in the west coast in Silicon Valley to finally start to produce at the kinds of yields and with the kind of productivity that allowed that division to prosper. Finally it was in the late '70s and early '80s that that division finally became profitable. It was in the earlier '70s that you could always count on it being the division that was losing money. And, of course, that meant that when the end of the year came and it was time to try to work on your budget for the following year, especially for your capital budget, MOS was always at the bottom of the heap. But finally we got this business making money.

I guess the last thing I have to point out is that, as you know, I went to National and National, shortly before I went there, had acquired what were the remnants of Fairchild, and so I had a second chance to do and see a lot of the people that I worked with in an earlier era. We had that facility in South Portland. We had a lot of the other people. A lot of the plants were gone, but a lot of the people were still there. And it was a real privilege for me during those years to continue to work with the friends that I had made so many years before. The enduring memory I will always have of Silicon Valley, and I think that makes us unique, is that we are all committed to this industry, and it really doesn't matter what business card you're carrying because you were committed to a mission. As I said in my beginning remarks, this is a journey and we're on this journey together. Sometimes you do it at one place and sometimes you do it at another place, but we're all moving forward together on this thing.

I tried to retire in 2004 and I flunked. And in 2005, the beginning January, in fact, right after the holidays I founded a company called Acquicor Technology and used that company to raise some money. Then I went out and bought a semiconductor company, changed the name to Jazz Technologies, and that's what I'm doing now. I'm back where I started. I'm making chips and I have “silicon under my fingernails” and I love every minute of it. Thank you for joining us.

Thank you all very much for coming.

END OF INTERVIEW

