RCA 1800 Microprocessor Family Oral History Panel

Dick Ahrons, Nick Kucharewski, Paul Russo, and Richard Sanquini

Moderated by:
Richard Sanquini
Stephen Diamond

Recorded October 5, 2017
Mountain View, CA

CHM Reference number: X8354.2018

Stephen Diamond: Good morning, everyone. My name is Steve Diamond. It's October 5, 2017. We're at the Computer History Museum in Mountain View, California to record an oral history of the RCA 1800 microprocessor family. We've assembled with broad experience in the RCA microprocessor family who will be talking to you today. Dick Sanquini, who is a partner at LiteCAP will be the moderator of the panel. Paul Russo, who was chairman and founder of GEO Semiconductor Inc.. Nick Kucharewski who is an independent semiconductor professional. Dick Ahrons, president of Daycon Associates. Thanks to all the panelists for joining us for this oral history. Dick, Sanquini, I'll hand the microphone over to you.

Richard Sanquini: Good morning. And thank you, Stephen. We're here to discuss RCA's 1800 family. This is the world's first CMOS microprocessor. And it had a lot of firsts in the industry, first in space, first in under the hood ignition control for automobiles. And as Steve pointed out we have Dr. Dick Ahrons, Dr. Paul Russo, Nick Kucharewski and myself Dick Sanquini. Now, what's the common thread between all of us is that we all had careers at RCA. And we, at various times, during a period of 1971 through 1985 worked on the RCA 1800 family. Today, what we're going to do is discuss the how and why RCA got involved in microprocessors. Then we're going to look at the commercialization and the challenges, technical challenges that we had in delivering the microprocessor. Also, we'll talk about some cool applications for the microprocessor including many pioneering firsts. And then the RCA contributions to the industry of which many were made with this family. And finally, we're going to talk about the RCA 1800 in light of a very successful / a very unsuccessful CPU in the industry but an innovative and very leading product that is still working today and we'll talk about that a little bit more. So what I'm going to do now is ask each of us to introduce ourselves individually. And we can start at your end with Dick. Dick, give us your introduction.

Dick Ahrons: Well, I've spent over 50 years in the semiconductor industry. I started from day one when I graduated and joined RCA Labs. I went to RCA Labs in 1954 and started with transistors. In fact, RCA was mainly like in TV. So I was doing TV horizontal deflection at that time and that was '54. I continued at RCA until 1964 when I transferred over to the RCA Solid State Division. And I ran a sizeable group there developing CMOS, different aspects of CMOS. RCA had many groups doing CMOS, including the product group. There was the Advanced Development which became the technical arm of RCA Solid State Division. And RCA Labs had many groups in addition. So a lot of fingerprints on the 1802. Subsequently, when I left RCA in '69, which is around the birth of Intel and I started my company and then ended up with Motorola in their semiconductor operation in Austin, Texas, which had two groups there. There was the CMOS group which competed with RCA and it had the microprocessor group. I happened to be in the CMOS group. But I also was very close with the microprocessor people and I saw Motorola's development of the microprocessor. And then the imminent Dick Sanquini got me back to RCA in about '78ish. And I spent about three-and-a-half, four years at RCA. And then after that went over the Burroughs and I did further work in the semiconductor field. So I've had a lot of background in processors, not only in RCA. And maybe my feeling of the 1802 was that it was successful but not super successful when you compare it to the Motorola 6800 family, Intel's i86 today but it was a success.

Sanquini: Okay. Thanks, Dick. And Paul.

Paul Russo: Okay. So let me start with my Ph.D. work at the Berkeley in the late sixties when actually a bunch of graduate students that I was part of, were working on the first generation of using computers to design LSI chips. And it was the first time people did that. And we had a stack of four boxes, 8000 cards to feed the mainframe and foot high things. And after that I spent a year teaching and taught the initial courses on computer design at Berkeley. And then I was hired by RCA Labs in Princeton to work on mainframe architecture systems and all of that because, as you know, in those days in 1970 in the fall when I joined RCA, they were a very large mainframe supplier. And we were all very keen and enthusiastic young scientists, so to speak. So on a fateful day September 17, 1971 I did my usual which I would go to the office on a Saturday for a few hours to catch up. So I bought my New York Times on the way to the office, parked my car. As I'm walking in, I read the headlines. RCA exits mainframe business. So I turned around and went back home. And that week, that Monday the whole big group was saying well, what the hell do we do now? And Joe Weisbecker who was one of the real inventive guys in that group-- it was funny, he looked down on Ph.D's. He thought academics doesn't help invention. And we'd always have these philosophical arguments. But he says, look, I've been working on this thing at home for a while. The idea because of LSI is far enough along, we can start putting enough gates on a chip to really have something that I'm going to call a microprocessor. This was before Intel ever announced their 4004. So our management, at that time, led by Bob Winder said, "Well, we just got out of the computer business. Okay. Okay. But don't tell anyone you're working on computers. And so we went off and did that and built-- and I got some pictures here we can discuss later, built a TTL version of Joe's architecture and started working after that on various uses for that including videogames, communication systems and so on. And around, I guess, a similar time the other groups as Dick mentioned at the RCA Labs who were also left with that little to do started focusing on the more physical design and semiconductor aspects of this. And then Somerville got involved which is the RCA Semiconductor Division and took it to become a real product. After that I focused mainly on applications. Now, the problem why I think it was not as big a success as it could have been I'll put the blame on the senior RCA management.

Sanquini: Can we-- because I want to introduce…

Russo: Okay. Sorry. We'll discuss that later.

Sanquini: We're going to get into it in a few minutes. But I think we have a good feel for your background. And that's what I was trying to do. So Nick, tell us about your background.

Nick Kucharewski: Okay. Well, I joined RCA solid state in 1973 as a design engineer in the custom chip group. In that group, I actually designed the first generation of the Chrysler lean burn ignition controller. And I also designed the first generation Bosch Motronic ignition controller. Both of those products would end up being the first generation followed by an 1802 based solution a few years later. And so we'll be talking about the 1802 based solution in a little bit. But that was actually pretty exciting. I also designed other custom chips for automotive applications, a few other different ignition controllers, dashboard electronics, things like that, communications chips, consumer applications, that kind of thing. And then I managed the custom design group for a few years and managed those kinds of products. And then I went on to manage what we called at the time LSI engineering which consisted of memories, microprocessors, microprocessor peripherals and custom chips. Following RCA, I was VP of technology centers, and VP and GM of communications products at VLSI Technology. So, again, as technology center VP I was responsible for tech centers worldwide and actually extended my custom capability with VLSI's semicustom tools and really try to grow that market. Following VLSI, I joined Xilinx where I was VPGM of the complex PLD business unit. Following Xilinx I was VPGM of microprocessors at IDT where we really exploited the MIPS RISC processor as our base processor family. I also ran a startup called Cognigine Corporation as president and CEO which was a network processor startup back in the good old days. Following that, I've consulted at several startups but what I really enjoy doing now is restoring antiques and building furniture. And I found that making sawdust has a lot of rewards over building chips and selling chips.

Sanquini: I like that. Okay. I'm Dick Sanquini. And at RCA I was the GM of the microprocessor memory business from 1975 to 1980. And today I'm a partner at LiteCAP which is an equity fund. And we focus on late stage technology startups. And what I do is help build these young companies and prepare them for IPOs or acquisition. So in between times I did work for National Semiconductor. I ran their microprocessor efforts, actually CEO of some startups and started doing what I do today in the year 2000 when I left National. Thank you. Okay. Let's get this started. Now, can we continue. How did the 1800 family get started? Paul touched on some of the things.

Russo: Yes.

Sanquini: Let's go back and talk about that.

Russo: Okay. So like I said on September 17, which I believe was a Saturday I had been at RCA about a year and we were these young keen technical people and we went in on Saturdays. I bought my New York Times on the way in. Reading the paper after parking my car, I walk into the building and I read the headline, "RCA Leaves the Mainframe Business." So we said we might as well go back home. And that week we were all wondering around. There were many groups at RCA Labs, you know, like Dick mentioned not just the architecture mainframe group who were focused on mainframe hardware. And microcode would speed up instructions and that kind of stuff. So we were all wondering around what do we do? Joe Weisbecker who was really one of the most inventive people that I've ever met and we were actually good friends. We had lunch every day and stuff and argued a lot. He said, look I've been thinking about this because he hated exercise. What he liked to do was lie on a couch and read. And he would read lots of stuff. And he was always tinkering and getting new ideas about electronics, in particular. He said, "Look, I've been sketching out something that I think we can now build in a chip that we'll call a microprocessor that we can use for games, for other applications and stuff."

Sanquini: So when did he do that? Because Intel takes credit for the first microprocessor. When did Joe actually lay out that idea?

Russo: I don't believe the 4004 Intel had been announced yet. And he started that work back in early '70, like probably a year-and-a-half or two before RCA exited the mainframe business. And he did it on his own because he was really involved with the mainframe group, mainframe hardware group. But I believe at that time there were a number of other companies also have the same idea, hey, LSI is moving forward. We can now create enough gates to do something that's programmable. But RCA because it was a pioneer in CMOS technology I said, "Well, let's do it in CMOS," which has many benefits. And that gave rise to the world's first CMOS microprocessor. And so once the thing became on the path to become a product, the solid state division really took over the lead and RCA Labs were mainly supporting them.

Sanquini: But in the labs, what specifically did you develop in the lab?

Russo: Okay. The first thing we developed was a TTL box about this size that was in effect a breadboard of what would become the 1800 series microprocessor. And the funny thing was which I mean these days I tell my kids that and they can't believe it, the way you entered 1000 bytes of code was with 8 switches and flicked them to 1 and 0 and push enter. Did it a thousand times. And we were getting so tired of that I actually designed a hex keyboard to speed it up by a factor of four. You can now could put in A, F or E whatever. But we used that and we developed games and other software on that to demonstrate all of the various things that it could do. And this also served, I think, to prove out the architecture, catch any bugs and so on as other parts of the labs and the solid state division began to create the real product. And other groups at RCA Labs mainframe guys starting writing-- I remember John O'Neil's Group and he ran the big software stuff, so running some software and assemblers and things. Because the history of programming was all machine code. And boy these days people say what is that? And then as it became real I became head of microsystems research and started focusing mainly on applications of microprocessors. And if we just turn the clock forward a little bit in 1979, a year before the IBM PC, my group actually developed a prototype home computer. We were going to use the 8080 from Intel. And we had Bill Gates there for a whole day because we were going to use DOS. We bring in the New York guys, the senior management to look at it and they said, "We can't sell this the way we sell TVs." TVs back then were basically furniture, huge bulky things. And that's when I said adios RCA. But I think that was the problem all along that the management in the seventies preferred to have Banquet Foods and Coronet Carpet and the Hertz Rent-A-Car as opposed to driving technology.

Sanquini: Okay. So let's get back to the TTL box. And we've got to an 1801.

Kucharewski: Let's get to 1801. At the time, RCA was really big in CMOS. We had a CD-4000 family of logic products in CMOS basically built on a ten-micron metal gate process. It seems like it's way huge compared to today's technology but that's what it was. And as Paul mentioned, RCA went out of the mainframe business but our design group down in Palm Beach Gardens had a bunch of engineers. And so there was a team down there that was assigned to work with the labs to actually build the CMOS version of Weisbecker's processor. And they used our ten-micron CMOS process. Ended up having built a two-chip system because with ten-micron you could not fit it all on one chip. And so they built a two-chip implementation of the 1801 which was then used as basically a tool for writing software as Paul mentioned, as well as demonstrating the chip capability to potential customers and things like that. The interesting thing is the first sort of demo product that Joe Weisbecker actually built was called FRED which stands for Flexible Recreational Educational Device. And this was a briefcase sized system that used a cassette tape for storing data. It had a video interface that hooked up to a TV. And so you can actually program and play games on a TV set with bitmap graphics which was kind of an interesting way to demonstrate this microprocessor, this brand new microprocessor. It was about that time that the division started getting really interested in this new thing called the microprocessor. And at the time, I was in the custom group and custom chips at the time were basically done by hand. They were laborious designs that took a long time and were error prone. And customers always wanted programmability. They could never decide exactly what they wanted. They always wanted another feature, another feature. And so from our standpoint, we started thinking about a microprocessor as a replacement for custom chips. Like we could do this in a processor, program a ROM, change the ROM program any time you want and add features. And so I personally started getting real interested in the 1800 as a replacement for doing full custom logic.

Sanquini: What kind of design tools did you have available? And could you talk a little bit about the methodology at that time?

Kucharewski: For doing a chip design?

Sanquini: Yeah.

Kucharewski: For doing the chip design, the methodology was really primitive. I mean we basically drew on Mylar with colored pencils. And then digitized it. And then plotted it out using a flatbed plotter. And had to check literally check by hand the layout design versus the schematic. We had to count squares which was basically squares of diffusion or whatever to back annotate schematics with resistances and capacities and stuff like that for critical paths. It was actually quite a manual process. But we got the job done and that was the bottom line.

Ahrons: Nick, you had mentioned to me that Andy Dingwall got into the design.

Kucharewski: Yeah, well, basically so after the 1801 and we started getting interested in it as a product.

Sanquini: And the 1801 used a metal gate technology.

Kucharewski: The initial 1801 used metal gate. And, again, it was not really a production worthy part. It was fairly large even at two chips. And really didn't have the operating viability that you needed for a real processor. And so it was actually team formed between the labs people and the solid state technology center to actually do an 1802 which would be a single chip version. The tech center and labs also developed the process for that. At the time, a metal gate was our process technology of choice. They developed our first silicon gate technology which we called C2L, or Closed CMOS Logic. And that process technology actually used donut shaped transistors where the inside of the donut was the drain, the donut was the gate and then the outside of the gate was the source plane. And so it's self-isolating. It didn't require oxide isolation. It didn't require diffusion isolation. And so it was a very high speed transistor. The problem is with multiple gates you had to design concentric rings of poly. And as you can imagine it really blows up pretty quickly. And so a four input gate was gigantic if you did it in a conventional way. So from a design standpoint we had to do some layout tricks and some design tricks in order to implement wide functions and that kind of thing. But it was a simple technology. It was only six photomasks which is amazing.

Sanquini: Six?

Kucharewski: Yeah, six photomasks.

Sanquini: Today, we have eighteen metal masks.

<group laughter>

Kucharewski: Yeah. And so it was really cost effective technology. But, again, it had some limitations in terms of density. So a combination of C2L technology and the design team was headed up by Andy Dingwall in the Technology Center.

Sanquini: Okay. Nick, we were talking about the Labs, the Tech center, the Semiconductor Division which was your home. And actually Palm Beach Gardens which was the manufacturing plant. And all of this contributed to the 1800. And we were talking about how did this all work together? And maybe we could pick up on that.

Kucharewski: Well, it was kind of an interesting challenge because, as we talked about, we had people in the tech center which was in Somerville. We had people down in Princeton Labs in the Solid State Division. And people down in Palm Beach Gardens. And it was kind of a distributed development team trying to put all of this stuff together. And so one way that happened was one of the folks from the labs Bob Winder actually came over to the division as the director of that product line and tried to pull together all of these various aspects of the Labs-- as I said, the labs did the C2L production development and the integration under Jerry Herzog. And we also, as Dick mentioned, brought the process up in Palm Beach

Gardens. So we actually built the fab down in Palm Beach in the old computer division building which was kind of an interesting challenge in itself, I think.

Sanquini: Why don't you talk about that?

Kucharewski: Talk about what?

Sanquini: The train station.

Kucharewski: Yeah, the fab down in Palm Beach was like 100 yards from the train tracks which is not the best thing in the world for defining fine geometry shall we say. But it worked. Right? It worked. It was a reasonable fab.

Sanquini: If the train didn't come, you were okay.

Kucharewski: That's right. You had to be doing your wafer alignments in between trains. But that's where we brought up the C2L process and that's where we ran all of the microprocessor memory products down in Palm Beach. And that was very successful. One way to do it is, I think, we transferred a number of people from Somerville down to Palm Beach to actually bring up the process.

Sanquini: Now, you talked about the disadvantage, the density disadvantage C2L. Can you talk a little bit more about the advantages though?

Kucharewski: Well, one advantage of C2L if you think about it so the gate was completely surrounding the drain. And so that made the drain capacitance fairly small. And so these transistors while they were cumbersome in being donut shaped, they were very fast. And so there's some speed advantages to that kind of geometry in addition, of course, having a six mask process it was pretty inexpensive.

Ahrons: Nick, we sold the 1802 on the basis of low power over and over again, CMOS lower power. Once described at the C2L process was generically one of the lowest leakage in power.

Kucharewski: Well, you know, most processors that were that large in geometry that were CMOS were low leakage. I think that's-- it wasn't anything inherent in C2L that was low leakage. But, again, the key thing that the COSMAC (Complementary Symmetry Monolithic Array Computer), the 1802 was a fully static design. And so it could operate down to DC. And so that was actually a real advantage for people. You could actually write programs. You could single step to debug and that kind of thing. You can interface, stop the thing at any time to your interface and really debug the process. So it was an easy part to design with. It didn't have a lot of quirks and things like that were present in a lot of the current N-channel processors. And so a lot of people liked it. And so we talked early on about space applications, automotive applications. Applications where the noise immunity, the single stepping capability was good and the wide tolerance of the temperature range. I mean it's fairly easy to do a military temperature grade ceramic packaged device that could operate in space, that could operate under the hood and that kind of thing.

Sanquini: So it's safe to say that the C2L 1802 had good speed power factor. Right?

Kucharewski: Good speed power factor.

Sanquini: That was a big advantage. The absolute value noise immunity you're saying is a big advantage of that. And then, of course, the fact that you don't have to consume any power. It will operate down to DC.

Kucharewski: Right.

Sanquini: Those are the major, I would say, issues if we take away from the1802. So that was an innovative way to make micros at that time, certainly the first microprocessor.

Kucharewski: And it was the first CMOS microprocessor. And so RCA with a CMOS technology reputation now having a CMOS microprocessor a lot of people looked at it for those applications that really could benefit from CMOS like space, like automotive, like some industrial applications, that kind of thing. But it was a real advantage. And so as a company we started to develop a lot of devices to demonstrate that processor. And Paul alluded to some of them but we developed a Micro Tutor to help in the classes that we taught on using microprocessors for logic design. In fact, that was the title of the course, Microprocessors for Logic Design.

Ahrons: I'd like to keep Nick's thoughts in mind because later on I'd like to say something from a marketing standpoint and what the customers were feeding back to us.

Kucharewski: Yeah, so we did that and Joe Weisbecker designed something called the ELF, which was a hobbyist type single board computer that was actually published in Popular Electronics magazine, to try to get a lot of people involved with understanding the 1802 and potentially using it commercially. He did several versions of the ELF also writing software that would run on the ELF. We did VIP which was a single board type computer that was a consumer single board computer that had graphics capabilities. It had HEX-keypads. It had a cassette interface for storing programs on it. And people could buy it in kit form for something like $275. And so it was another way to get that process routed into the mainstream.

And I think a lot of that really helped get the processor designed into a lot of broad applications. It's not necessarily high volume applications but a lot of different applications. I think that was a key thing.

Ahrons: Along that line I think it was Herzog's group that developed a game module. Okay. And I obtained that for the museum. It's now at the museum from Jerry Herzog. And by accident the Woz saw it and he said, "I played on that." Okay. So the museum does have the game module with the 1802.

Sanquini: So we kind of talked about the advantages of the CMOS microprocessor. And the ones you just described and what you're describing really kind of set the markets that we're going to participate in. I guess at a high level the 1800 family would really fit in-- well, from what you're saying would fit into hostile environments. And the two most hostile environments were the automotive under the hood applications and space applications. And that kind of leads us into, I think, some cool applications. And we might want to start with the under the hood applications. And maybe Paul, you can start on when you got involved and Nick.

Kucharewski: I think we actually started with the custom chip.

Russo: Sure. In that case, it was very revolutionary. It was the first use of a microprocessor for engine kind of control. And we basically supported the semiconductor division. But I can tell you some funny stories…

Sanquini: Before you do that let's hear-- it sounds like because I'm trying to get the timeline right. It sounds like your custom chip group developed a solution. And that you've got a lot aid, systems aid out of the labs. So why don't you describe that.

Kucharewski: As I mentioned earlier, designed the first generation lean burn system for Chrysler. And that was analog it was kind of a hybrid analog / digital system. And it did not do spark advance. So in that first generation lean burn system it still used the centrifugal advance in the distributor. But it was the first step to putting the electronics under the hood. And that ran in production for like three years. And then we went to the…

Sanquini: Well, on that chip, did you get support out of the labs?

Kucharewski: No. That was strictly a custom chip that had we done within the division for Chrysler. But along the same timeframe we were productizing the 1802 and went to Chrysler with basically an approach that said hey we could do an 1802 based solution that will give you a lot more programmability, a lot more flexibility. You could actually program spark advance using the processor and an external ROM that kind of thing. And so we started building on that kind of a concept. The interesting thing is we had a capability within the division at the time called automatic placement and routing. And these were standard cells that could be automatically placed and then routed from a schematic to generate a custom peripheral chip. The advantage there was a very fast turnaround time so that we can implement logic and turn it around relatively quickly in C2L, again, and actually provide an IO chip sample to the customer as well as having a microprocessor. The interesting thing there is that since we had built the first generation chip we had the experience in interfacing to all of the various sensors and transducers under the hood. And so that we took that interface experience, built a custom IO chip that we could then use to demonstrate true capability with the 1800 series. Along those lines, though, we had a group down in Princeton that had a fully outfitted car with all of the transducers, all electronics, and that kind of thing and expertise on the 1800 series within Paul's group. And so in concert with the Princeton guys we could actually bring a team to Chrysler and said look we've got system expertise. We've got an outfitted car we can demo on. We have the capability within the division to do the custom stuff. And we can put it all together and design a system for you guys.

Sanquini: Who was the competition?

Kucharewski: There was no competition. There was no competition at the time. TI was in talking to Chrysler about doing some other full custom stuff. But we had at the time the best CMOS microprocessor. And, again, this was going under the hood. In fact, it was going on top of the engine. So the Chrysler controller was actually mounted on top of the engine in the air stream in the carburetor. And so it was a fairly harsh environment to say the least both temperature wise as well as mechanical wise. But, again, we had the team between our group and the Princeton group to actually bring a solution to the customer and sell them on that capability.

Ahrons: You know, it's interesting that we know the CMOS microprocessor has got that noise immunity and you say to yourself, "Chrysler picked it up, why didn't Ford and why didn't GM pick it up"? The answer to that was what they did is they used an NMOS micro surrounded by separate CMOS ICs. The NMOS micro never talked to the outside world. It only talked through CMOS logic and RCA sold a lot of CMOS logic to these manufacturers.

Russo: So let me add a little humor and color to this, so as Nick pointed out. The big software group at the labs working on mainframes began to be dedicated to the microprocessors after the exit from the mainframe business headed by a guy called John O'Neil who was basically Bob Winder's peer in the software group. By the time we were doing the Chrysler project in support of the chip business they had developed an assembler on a mainframe. And I remember driving around with Toni Robbi who was the main software guy working on this project in a car and the software blew up. So we pull up to a phone booth, opened the hood, put the phone under the hood with an acoustic coupler to talk to the mainframe and download some code and the cars driving by seeing this phone in the engine were saying what the hell are these guys doing? So that was quite a real experience. And then we finally got it going. And I remember Toni would spend hours to save a few bits of logic because there was only 1K bytes of memory.

Sanquini: So getting back-- let's continue on the Chrysler thing so this took five years or four years to get a productized product into Chrysler?

Kucharewski: No, actually…

Sanquini: How many years did it take?

Kucharewski: It took less than two years.

Sanquini: When did you start and when did you-- I think we finally got to production in '79. Right?

Kucharewski: Yeah, '79, '80 is the real production. We actually started in the early part of '78 talking to them about the microprocessor system. The first generation lean burn environment had been in production about two years and they were looking at doing an enhanced-- either an enhanced version of that chip or the microprocessor solution that we proposed to them. And so it was kind of good timing. And we had the contacts. The key thing was we had contacts. We had contacts with Chrysler's electronics division. We had management contacts in Detroit. And so it was easy to talk to them about another generation of microprocessor. You asked the question earlier, well, why didn't GM do this, why didn't Ford do this? Well, we didn't quite have the same contacts within those companies either. We didn't have the experience, whereas, we had the experience with the CMOS custom chip. And so there was a comfort factor, I think, there with Chrysler and RCA in a lot of different ways.

Sanquini: Yeah, also if you go back in time little Chrysler was the innovator for the industry. Ford and GM lagged in terms of innovation. Chrysler continued. All of the new stuff, if you will, came out with Chrysler cars during that period. So they were the guys that were going to change the industry. GM was a big, big fish and they're not changing anything. They're making money. And by the way, this was one of the reasons Chrysler was losing money. They were out there with new technology quite often making big investments. I was always curious about their whole acceptance criteria for this new technology because that's a real high risk. Imagine, I mean at that period of time, making spark advance. And you basically-- that software better work. And there was no fault tolerant system. They only had the one 1800 CPU. So what I'm saying what was their acceptance criteria? What kind of grueling acceptance criteria did they put it through?

Kucharewski: Well, we supplied them plastic packages. They were not ceramic. They were actually in plastic. And they had acceptance quality criteria. They'd burn in and stuff like that. And to my knowledge they had really good results with our chips. I never really saw chip failures. Most of the failures, as I recall, were mechanical ones because there's so much stuff on this board. And, again it's sitting on top of the engine. And so you think about that. And you've got a PC board. And you've got lots of components besides the chips that are interconnected on this PC board. And it really only takes one solder connection to fail to fail the system. And so I think most of the failures that they saw were of a mechanical nature, not electronic nature based on our parts. But the interesting thing about the Chrysler system, though, is again, the spark advance characteristics were stored in ROMs. And so the actual system that was the Chrysler system were two ROMs, an offboard RAM, the 1802 and the custom IO chip. And so there were different ROMS for every engine transmission and rear end combination so that every four-cylinder, six-cylinder, eight-cylinder engine had its own ROM, every different transmission had its own ROMs, different cars with different load characteristics had different ROM codes and so we actually had to manage many, many, many ROM codes much like you would supplying ROMs to a game manufacturer. How many of the ROM Codes are supplied in any given month and that kind of thing. And so we actually had dedicated marketing people that would actually track what Chrysler was shipping in order to make sure that we were building the right mix of ROMs.

Ahrons: That reminds me of an interesting story, to back you up in that. When I was at RCA doing the marketing there, I analyzed what was going on overall. And Chrysler was building about a million cars. And we were selling them 1.2 million 1802s. Where the hell were the other 200,000 going to? Well, after investigation I found their module was so good that they ended off selling 200,000 modules to Volvo.

Russo: I didn't know that.

Sanquini: Oh, that's-- so Volvo was using it.

Ahrons: Volvo basically had the Chrysler modules in their car which had the 1802.

Sanquini: And Chrysler was the distributor for us.

Ahrons: They, the modules were manufactured and sold by Chrysler Sales. Yeah, it gave me the deal.

Russo: I didn't know that.

Sanquini: I didn't either.

Ahrons: Because I was surprised as hell because I said "where are these 200,000 going"?

Sanquini: Okay.

Russo: That was great.

Kucharewski: See the other interesting point is that in this exact same timeframe, again, we had built a Motronic system for Bosch that was also a full custom chip that had its issues and that kind of thing. It was much, much more programmable than the lean burn chip was. And Bosch wanted to do a lot of things differently. So we ended up selling them a microprocessor based solution as well, a similar structure, ROMs, RAMs, processor and custom IO chip. And so in parallel with the Chrysler design challenges, shall we say, we designed the custom IO for Bosch. They required a little less support from Princeton labs than Chrysler did. They had quite a significant group in Schwieberdingen outside of Stuttgart. But we did a very similar thing with them. And that also went into production. In fact, that shipped fairly limited quantities. I think it was only the six-cylinder BMWs that use the 1802 based Motronic system. But that ended up being in production as well in the early 1980s, probably 1983 kind of timeframe.

Sanquini: Well, that kind of solidifies the quality because Bosch was at the top in terms of quality.

Kucharewski: Yeah.

Sanquini: You know, about ten years earlier than back in the sixties, when I was doing real work as an engineer, I had the responsibility to develop a bipolar antiskid system from Bosch. And you mentioned Stuttgart, they have a track there. And I remember when we were signing this off they had built the module. The module was going into the car and I was called to go to the track. And they basically had the antiskid system in the car. And they make one turn on the track and the two people that were in the car get out of the car. And two other people go in. And they said, "Well, we didn't have the antiskid system enabled and so we didn't do a test with that. We just wanted to make sure everything was copesetic for the test." I said well, why did you change drivers? And he said, "They're not the drivers. They're the engineers that designed the system." And they took it through the driving tests. Germans: you design an antiskid system, you drive that car. The quality was always there.

Kucharewski: Yeah.

Sanquini: So I'm sure with the Bosch 1800 was really robust-- did you ever get to the track?

Kucharewski: Yeah.

Sanquini: Did they do that kind of test or something like that?

Kucharewski: I don't recall different driving teams necessarily but yeah we did the track which was kind of cool. I mean the Bosch system did a lot of stuff. I mean it was real capable system. But what was I going to say about Bosch? The interesting thing about Bosch is they were not on the engine. And since Bosch was a supplier to BMW they weren't as integrated with the car manufacturing. And so their module actually mounted on the firewall. And so mechanically it was a little more stable than mounting on top of the engine. Plus, at least to start production they started actually in ceramic packages. I think they moved to plastic, as I recall, but they actually started in ceramic just to make sure in the early part.

Ahrons: There's a big cost differential.

Kucharewski: Huge cost differential but they were more concerned with reliability and making sure that the initial ones, particularly the initial ones that they shipped were never going to fail, you know, that kind of thing. But there were two big design wins and under the hood applications for the 1802 which was clearly the first applications for processor under the hood. And so that was-- they were pretty good design wins.

Sanquini: Well, you know, during that period when I was the general manager, I had the responsibility basically to do kind of not so fun work. You had the fun, Nick. Okay. So one of the not fun jobs was basically raising the capital because we were shipping, I think, a million units. Chrysler was putting this across most of their lines of cars. And so in Palm Beach Gardens we didn't have enough capital equipment to do that. And you had to get that approved through the RCA Corporate Board: Banquet Foods, Random House Books and others composed the capital committee. And about the same time the person who ran RCA Solid State Division for 19 years, Bernie Vonderschmitt, was removed from his job. Okay. So you have RCA Solid state Division getting a new CEO (Dr. Pepper). He wasn't there yet. But Roy Pollock is and he is running the consumer division in Indianapolis and running semiconductors at the same time. That was Roy Pollock. We have no Bernie Vonderschmitt. I always would go to New York with Vonderschmitt. And he would be the calming figure, because he was recognized - and you probably know this but RCA, for his contributions to color TV. There was an industry war with CBS and different techniques to use. I won't go into all of that detail. But basically Bernie Vonderschmitt was key to color TV because he developed the vertical deflection systems for it, the TV. He had over 36 patents before they assigned him to start semiconductors. When they assigned him to semiconductors, he had only four people when he got there. There was Isreal Kalesh . He brought in Hesh Khajezadeh, and myself. I remember Murray Polinsky another guy who was a process guy. Anyhow, Bernie was the god who grew that business who was sacred is now gone. And he had tremendous influence on Princeton Labs. I would go down there, Princeton Labs they treated him very respectfully. And in New York and Rockefeller Center, at the Capital Committee Meetings he was a calming figure. And now I got Roy Pollock who is let's see, how could I characterize him? He's emotional. He is very articulate and a very good speaker. He appears to be a good leader. He only has one thing that is a big, big problem, he was weak in technology. Let me put it that way, very weak in understanding technology. And now he is the guy I have to go to New York with. And he's a great financial guy. And let me put it another way he doesn't really care about the technology if it's going to generate cash quickly. It's all about cash. So we go to New York. And we get the capital approved but basically they tell me I have to go down to Chrysler and get the money for the capital. And the capital is significant. So it's like $26 million. And at that time Chrysler is in a very precarious position financially. They're near bankruptcy. Lee Iacocca is depending on these new cars and these systems to really boost up sales. They had gone to the federal government and tried to get a $1.5 billion loan. And it was great controversy. They were in the news all of the time during that period. And now I have to go down there while they're on their backs and extract the capital dollars. And that was quite a negotiation with them and they were really ticked off. But the bottom line was after a period of time which is delaying the program they agree to actually send the dollars to our finance group, corporate finance group. And I'm told we have approval at that time. And so then one of my responsibilities as GM was manufacturing in Palm Beach Gardens. So the plant manager, a guy named John Kucker, I just called him and I said John it looks like we got approval and start ordering the equipment. We've got to get going. We're behind schedule. So he said, "Okay I'll get right on it." And I call him the next day and he says, "We don't really-- I'm not able to get the capital. I can't get it released." And RCA had this bureaucratic system. And he couldn't get the release to get the purchase orders. And I said, okay it's the damn system, RCA is a slug with regarding spending even approved cash expenditures. And the next day I call him and I said did you get approval yet? Did you get this thing ordered? He says, "No." And then it dawns on me that finance is not that happy. We've got all of this controversy about Chrysler going under any day and finance has the money in the bank and if we Chrysler go under RCA can keep the cash. And it just so happens Roy Pollock has two offices, one in Indianapolis and one in Somerville. And he had moved Bernie out so he had Bernie's office. He was temporarily running the division. So I was able to go up to him and nicely explain to him that by the time-- and there's a six-- as you remember, there were six floors in Somerville. And in this case, he was on the top floor. And I was on the third floor. I said I'm going to walk down the stairs to my office and I'm going to call John Kucker again. And I said, if he tells me that the funds haven't been released, I will call the New York Times and tell them we're going to take Chrysler out of the business right now because they're not going to be able to make any cars. And that's all I said. And Roy said, "Oh, you're such an emotional guy, blah, blah, blah." And he and I went back many years so I knew him well. He was a product marketing engineer when I was an engineering leader. So we'd go on the road together. So we knew each other. And then he rose to fame with all of his great communication skills. Anyhow, the long and the short of it was by the time I get down there, I called Kucker and the capital was released. We were able to get the capital and launch the business. But those are sort of the kinds of things that happen in big companies. And I think they saw a windfall. You know, the corporate finance group saw a windfall here if only Chrysler went bankrupt. But the program took off. And I left in 1980 and came out to National. But I think that program-- you said successful. That program was very successful.

Ahrons: Yes.

Sanquini: And it was very risky. And it was very successful.

Ahrons: You hear Dick's frustration in operation. And a little bit more on Pollock, well, later on Pollock was on the National-- on the RCA board of directors. And he was very significantly responsible for the sale of RCA to GE which I don't think very many ex-RCA people are in love with Pollock for doing that.

Sanquini: Yeah, I want to talk more about that. But I think we ought to talk a little bit-- to me I'd like to talk to a little bit more about other applications. Unless there's something else we want to add to Chrysler?

Ahrons: I agree.

Kucharewski: Well, the other interesting thing about Chrysler is that so now we're in production with 1802 with the peripheral IO chip. Now, Chrysler starts beating us up for price, of course. And so we ended up having to do a shrink every single model year just to keep lowering the cost but just shrinking the chip further and further. And, of course, as we got our new projection printers we had better capabilities so we can do finer geometries. And so I think we ended up doing three shrinks three years in a row of the 1802 and of the peripheral chip in order to stay ahead of the cost curve which is kind of an interesting challenge. Because at the time my design group was also trying to do new processors looking forward both in the 1800 family as well as in other families. And so it was kind of a challenge to fit in all of these cost reduction shrinks in addition to doing some of the new stuff we're trying to get done. But we did it. And we stayed ahead of the cost curve and I think we made some money.

Sanquini: Yeah, I think that was a profitable business, a very profitable business.

Kucharewski: So I guess to move to applications, I think one of the key things, you know, we talked earlier on about space and that kind of thing. In the Tech Center was a guy by the name of Roger Stricker and he along with Sandia Laboratories developed a rad-hard version of the C2L process and so that was really necessary for a lot of these space applications. And so that was done in the 1980ish kind of timeframe. And so we started getting designed into space applications. Again, we had a CMOS reputation. We had designed in other CMOS logic parts for some space applications. And so we were the first CMOS rad-hard processor available. And so we were a natural for space applications. So we started getting designed into a whole bunch of satellites. I mean dozens, if not hundreds of satellites used the 1802 over about a 20-year period. And so that was actually an interesting kind of design win because none of these things are very high volume. I mean I think the Galileo spacecraft used 20 1802s which as far as I understand was probably the largest chip count. But, again, it was only 20.

Sanquini: And that went the furthest, right? That's the one that went to Jupiter.

Ahrons: Can I continue on Nick? I'm going to do this from my approach which is more marketing and what we sold. So as Nick said, we're selling roughly a million or so 1802s to Chrysler. We probably are selling another half million to so many customers that none of us can remember and Galileo because it was very popular. But there was military. There were just special industrial products, military and aerospace. I mean we did very well in Europe. Okay. And so on. But it was still all small volume. Well, we had the completely development tool group with the software people and the hardware people. And there were times we made more money out of selling development tools than we did on the chips. Okay. So development tools was not a bad business. It added some money into the bank. And, of course, for a company like Chrysler you give them the development tools. For the military and aerospace that are only ordering a much limited amount of processors we sold development tools and they were profitable. So we developed a lot of customers, one big one and a lot of smaller customers.

Kucharewski: We were actually in a heart pacemaker, believe it or not. And, again, they wanted programmable capability Cordis designed this into a pacemaker as well as the out of body pacemaker programmer to actually program a chip inside the body. We designed into that too, the 1802. So lots of interesting applications.

Ahrons: We had lots, a wide variety.

Russo: I can comment on four that RCA Labs developed that were pioneering because they didn't exist before. The first one, of course, was Joe Weisbecker's dream always was to start seeing a programmable videogame platform where you can insert ROM cartridges to change games. Up to that time, they were all hardwired and all of that stuff. And that's how the Studio II was born. And unfortunately back to RCA management a year or so later of course, the consumer electronics business was not impressed by videogames and so it was handled by this special product division the guy that sold cables and all of that. A year later, Atari came out what a color version. And we had a color version running on the lab but RCA senior management in New York said, "Well, videogames are a fad." So they killed that. It didn't make Joe happy. But my group was pioneering new things. And one big issue in those days, RCA had a big business called global communications. And the standards in terms of the format for paper tape being sent back and forth and the transfer rate were different for the U.S. and for Europe. So a typical messaging was done by this paper tapes comes in, piles up on the floor which is different code and different speed than the U.S. standard. Then that would be read into another machine which would create a paper tape compatible with the U.S. standard and that's finally sent to the machine to transmit it. So we developed the first microprocessor based controller which was basically one of the early floppy disks which would grab the message coming in, no paper tape, buffer it in a floppy disk. And then be the buffer and the time and then create the other format and then ship it off. And that won an award in the early seventies in the-- what the hell was it? Anyway, it won a big award a this big show the first microprocessor controlled communication transport system. And then also in those days RCA Labs consumer electronics got so much attention RCA Labs was told hey, if you can find some project that will help CE, consumer electronics, it would be approved. So one of our guys said, gee, what can we apply microprocessor manufacturing automation? So he went out to Indianapolis and Bloomington to look around and they found that they're having big issues in both quality and cost of calibrating these coils that would converge the RGB colors. And because the poor woman there had to adjust three screws . And she had to go back and forth and adjust them all until everything looked okay. So we developed a machine using the COSMAC box that would have three screwdrivers and really quickly iterate and converged on them. So better quality at much lower cost. And that was deployed in Bloomington. And now the video camera business that made the high-end broadcast cameras had the same issue. They had set up an issue when they first put a camera in football game or some event it would take a technician half-hour, an hour to adjust everything. So again, we developed a microprocessor control calibration that would do it in a few minutes automatically. And so I'm trying to think was there anything else? No, I think those were the kind of things that were at that time in the world were very pioneering because no one else had done them. And I remember Pollock one time, I didn't know him very well, but one time I was on a plane to Indianapolis with him and he said, "This guy Russo is trying to put microprocessors everywhere." Well, I feel vindicated.

Sanquini: He said it as a negative, though.

Russo: Oh yeah, he sure did.

<group laughter>

Ahrons: I'm going to say something because we've got to get to the real life marketing world for the 1802. The 1802 could not compete in price point with NMOS processors. We were looking for applications that CMOS would give us an advantage. Now, Paul is talking about the 1800 microprocessor in every one of the applications. Paul just talked about there is no real CMOS advantage. And therefore, we have almost zero sales in those areas.

Russo: But we showed that it could be done.

Ahrons: Yes. RCA Labs while it was not a division of RCA solid state it was separate. And it had background to develop products which RCA could produce outside a RCA Solid State.

Russo: In fact, let me add to that, just add to this management issue. My group actually developed a home computer in 1979 one year before the IBM PC. We had Bill Gates there for a whole day, this young 22-year-old kid. He had just started Microsoft. We were going to use the Intel 8080 because we needed more horsepower than the RCA processor at that time. He had this working software called HEIC, home entertainment and information center. The big boys from Europe come down and like I said earlier and said, "We can't sell this like TVs." And that's when I was so frustrated seeing all of these things killed that I took off to GE at that time. Again, I think the senior management lacked the vision to see videogames and computers all being potentially huge businesses.

Sanquini: You know, he kind of summarized the apps and what you were saying is that because of the efficient architecture code was easy to write. The power we talked about, you could suspend the CPU. It was fast. It was C2L. And it was fast for CMOS. So the two markets were space and automotive and the noise immunity that you mentioned earlier.

Russo: That was a big one.

Sanquini: Yeah. What I'm saying is so in these two markets RCA was a leader in those two particular markets. I'd like to go back to the space because in the space area you mentioned a number of them. I think the OSCAR was the number one. That was the first one out in space. But the 1802, as you talked about, was in Galileo. And Galileo actually was launched in '86, I think, probably.

Kucharewski: Eighty-four.

Sanquini: Eighty-four. Okay. And I think it went and it went and it was supposed to go for four or five years. And it went until 2004, almost 20 years. So basically…

Ahrons: Almost 30.

Sanquini: Two thousand four from '84. Yeah.

Kucharewski: Well, '74 is…

Sanquini: Eighty-four, 30 year. And it actually made-- it went to 2.3 billion miles to Jupiter and finished its mission. That's what it did. And then the other one, I guess, is the Hubble Telescope. That to me is amazing because it's still up cranking. And that's 27 years.

Kucharewski: That's got the 1802 in it?

Sanquini: Yeah.

Kucharewski: I didn't know that. The Hubble?

Sanquini: Yeah.

Kucharewski: Awesome. Really awesome.

Sanquini: So that's probably kind of-- you look at where RCA is a leader. It's a leader post-- its' a little bit like a Unix operating system when you get a bug and you're going to die. This bug happened in 1985 but the applications still keep going for RCA's 1802 family. So I think that's quite amazing.

Ahrons: To continue on where Dick leaves off there, yes, the RCA 1802 had a phenomenal long life. I mean really phenomenally long. It surprised me when I researched it. And it was in a lot of, will you say, military applications and I always said it was hard to get designed into military, and equally hard to get designed out. So dear to you, Steve, I have here and I'd like to put it into the record the first page of an 1802 data sheet by Intel.

Sanquini: Intersil.

Kucharewski: Intersil.

Sanquini: That would have been a great Let's change it to Intel.

Ahrons: It's not a bad idea. But key is the date here. You're deflecting me, October 17, 2008. That's the data sheet for an 1802 eight-bit processor. And then the other thing to key on is why they did it. For use in aerospace, military and critical industrial equipment. As a high cost processor they were continuing that design in to the military. But this is 2008 we're talking about. It amazed the heck out of me. Okay. And so I want to put this into the record, the 1802 was produced in 2008 at least by Intersil it probably went on for a number of years after that. And I don't think we mentioned the morph of RCA Solid State-- RCA was bought by GE. GE splits off the semiconductor operation by putting in GE semiconductor which is a much smaller operation, merged it with RCA Solid State. Sells it to Harris. And then Harris is bought by Intersil. So that's why Intersil was producing the device.

Sanquini: Interesting. Really, really, interesting. So let summarize this session. So we have this product the 1802. And it has these characteristics that we talked about power, speed, C2L speed, low power, suspendibility, clean simple architecture you can code easily. And we have a leadership in position in space, a leadership position in engine control, electronics, or automobiles. Let's move on to what could we summarize the contributions the 1802 microprocessor family made to the industry? Let's talk about what's so important about this? What did it do for the industry?

Ahrons: Started CMOS microprocessors movement which by 1985 everything was CMOS microprocessors.

Sanquini: I think that's a very good point. But it actually I would say started in the eighties, in the early eighties.

Ahrons: No, this thing started in the early seventies.

Sanquini: No, I'm talking about the CMOS conversation by the Intel's of the world. I know when I came to National in 1980 everybody viewed CMOS as a boutique technology for all of the reasons we talked about. It was good for all of the reasons. Within a few years National designed always in CMOS. And the reason we did that is you couldn't get the density you wanted on the chips and the right power on the-- particularly if you're eventually going to have programmable CPUS which included demand page, virtual memory and interrupt controllers and floating point. So basically and I think RCA kind of led that revolution in that they, as you said, developed that technology and the world started to change that was a big, big issue.

Ahrons: To go along with that a lot of things, let's say in about '85 Intel comes out with the 386, the game is over. It's all CMOS from there on in. There's remnants of NMOS. But the world basically went to CMOS microprocessors. RCA started this going in the early seventies. And I think that's a great contribution.

Sanquini: Is there anything else we can add?

Kucharewski: I think that was the main thing. I think demonstrating the fact that CMOS could actually run under the hood and control engines was a pretty big deal. At that time, nobody had thought about or would attempt to do that with any sort of NMOS capability. So I think that proved to the world that this was a big deal.

Russo: Just think if RCA had not pushed CMOS-- if there's no RCA in Somerville that pushed CMOS would this transition have happened when it did in the eighties? Or would it have taken decades more for people to figure out this whole new technology?

Ahrons: It would have happened.

Russo: I think RCA was a pioneering entity in technology in the seventies in many, many respects.

Ahrons: RCA is one of the companies that has a not-invented-here approach. And basically CMOS was mostly invented and developed at RCA. So it was their thing and they pushed it beautifully.

Sanquini: Okay. So we got all of this good stuff RCA contributed to the industry. So why wasn't RCA more successful? Let's talk about that a little bit.

Kucharewski: I think one thing that needed to be done…

Ahrons: One of the things I want to say and say right away. There were more fingerprints on the birth of the 1802 than I've ever seen on anything. I mean just thinking of how many people worked at RCA Labs. And fortunately it was because of the demise of the computer systems division opened up a lot of people at RCA Labs. Now, if RCA Labs was a commercial division they would have laid off people. But RCA Labs doesn't lay off. So all of these excess people we, the RCA Solid State Division and the semiconductor world benefited at RCA Labs. Okay. The second thing is all along that same line, is you've got to remember I was at Motorola before I came-- returned to RCA. And I saw the Motorola operation in the 6800 which came out to be the 68,000 later on. It was a much more efficient operation. We, Motorola, had all of our design, all of our marketing, all of the things all in a brand new operation in Austin, Texas. And there was only two groups in Austin, Texas, the CMOS group and the microprocessor group. But these groups operated much more efficiently. I mean such as the fab was right there. Everybody talked to one another. I mean I see the difficulties that Dick had. I'm saying those difficulties did not exist at Motorola. They were much less spread out. And that's one of the reasons RCA was not as successful.

Russo: Let me add some color to that because there's a fact that probably most people don't know. Two facts. One is that in the seventies the patent revenue for RCA was humongous because they invented color TV, the tubes and the standards of transmission.

Sanquini: They generated the most cash per year of any division.

Russo: Yeah. And, in fact, that money flowed into labs and the excess flowed back into the corporate. So the RCA Labs with its 1500 people was actually not costing cash out from the corporation. It was bringing cash in because of all of the massive patents that they owned for color TV which caught fire. Now, why Welch what he did-- in 1980 I joined GE and I used to go to his meetings where the last day he gives his religious speech. And one of his religious speeches that Welch did was we're not going to be anything the guys in Asia are in because even though you can win through investment it's going to be a lower margin, and therefore it's going to hurt our stock price because his goal was to make GE the world's most valuable company which he succeed in doing actually. So there goes small appliance. There goes television. There goes semiconductor. He wanted to get rid of all of that stuff where GE could not have a huge advantage in things that took a decade to develop whether it's medical device, jet engines, broadcast, turbines, especially plastics, those kinds of things. And as soon as they bought RCA since I had been there I knew that all of these businesses were going to be gone. He had no desire. It points really to the fact that the CEO of the company when it was RCA with its perhaps lack of vision and Welch had a very focused strategy that didn't involve the things that people in Asia were focused, that changed history. If you had had different CEOs you would have had very different outcomes.

Ahrons: So the answer to the question…

Kucharewski: I think the lack of vision, I think, is a key thing because one of the limitations in 1802 was that it did not have memory on board. And so you had always had to have external ROM, one or more external ROMs, sometimes external RAM in addition to whatever peripheral interfaces you needed. And so the competition at the time were single chip microcomputers with on board ROM and on board RAM, that kind of thing.

Ahrons: It had eprom memory on board the chip.

Kucharewski: Dick calm down. So at the time we actually defined what we called an 1804 which was an 1802 with a 2K ROM on board with 64 bytes of RAM and with an enhanced instruction set that would do things that our customers wanted to do. We had onboard timer counter. We improved the DMA capability. We had BCD arithmetic. And a number of instruction set improvements. And so we defined this 1804 and actually built it in SOS. Now, in the late seventies, early eighties SOS was the future technology choice for RCA. And that was also driven by the labs unfortunately because it turned out it was not the future. And so in the early eighties RCA made a decision to get out of the SOS business. Unfortunately, we had designed a number of chips in SOS, the 1804 included. And so now we did not have a next generation 1800 series since we had to initiate a design of an 1804 in a bulk CMOS process. At the time, that's when the isoplaner processes started being developed and that was really the process state of the art. And so we actually had to develop what we call CMOS 1 which is an oxide isolated CMOS process in which we would design the 1804, again, in that process. And quite a bit different than the SOS process because the design techniques used for SOS were quite a bit different than bulk CMOS. Unfortunately, RCA in the mid-eighties timeframe began winding down any new development in processors, in memories, and basically in the division, the solid state division. And so a lot of what we felt were pretty good projects, we had RAM projects going on that were the 16K static RAM. We were looking at e-squared PROMs in combination with Princeton Labs. We were looking at the 1804 as well as the 16-bit version of the 1800 series. All of these projects were not approved by the division. So it was kind of a sit back and kind of milk it for a while. And at that point I was frustrated so I left RCA as did a number of other really good people just prior to the GE acquisition and the winding down, if you will, of the capability. And so the limitation, I think, for the 1800 series was, in fact, the lack of management vision, I mean upper management vision. Not people at my level or Dick's level but it was the people beyond that that didn't have the vision for what processors or for that matter any CMOS products would look like going forward. And so that's really what ended the life of the 1800 series in terms of ongoing enhancements and stuff like that.

Sanquini: Yeah, you know, I can add to that. I would say that my view I'd get up just a little higher level. In 1971 when Weisbecker invented his product, his 1800 series RCA was the Apple or Google of its era. They were the largest consumer company and the most technically competent. It was run by David Sarnoff who sort of founded it and ran it. And it was all about technology and bringing technology, the best technology and that's why they set up-- the Princeton Labs was his baby.

Russo: Yeah, it was called the David Sarnoff Research Center.

Sanquini: Yeah, I think he died in '71, While alive David Sarnoff inoculated the company with his energy and his vision. He would come around and he would be looking at our technology and you knew that you were a leader. Unfortunately, he died in December of '71 and his son Robert took over. Robert,was sort of a gadfly, and he was into the running big businesses as a highly diversified companies.

Russo: Conglomerates.

Sanquini: You've got to have a conglomerate and you've got to diversify. And he focused the electronics, he wasn't really interested in new technology even though he kept the labs and the labs kept churning but his focus was, as you said earlier, the licensing group which was the most profitable group in the company but they're the ones that licensed-- and the licensing was not just patents, I know because we had to in the semiconductor group provide assistance to people like, I mean the Japanese manufacturers, Sony.

Russo: We gave them everything.

Sanquini: Sony, we gave Sony everything and we helped them get into the TV market, audio, radio, all of that was licensed away and that was number one. Number two, he was focused on NBC, NBC generated a lot of cash, okay.

Ahrons: It was profitable.

Sanquini: As a gadfly, he was in the news a lot dating a number of differesnt record artists.. He was focused on RCA Victor Records, vinyl records at that time and Columbia vinyl records. So those were his interests.

Russo: That was playboy.

Sanquini: Yeah, those were the three and no risk. And meanwhile the labs were neglected by Robert.. I would go down there regularly with Bernie Vonderschmitt to look at the technology. I mean looking in the '70s, LCDs were developed, they had flat panel TVs developed, I mean, you know, it was all developed in the early '70s and they would, the labs would come to Bernie and he would try to go to New York with it and they would squelch it, okay?

Russo: Yeah, with plasma displays in <inaudible 01:24:44> '70s.

Sanquini: Yeah. So basically, with Robert Sarnoff, the whole company took a different twist during the period of '70s when he took over in '72 to 1985 when RCA was sold it to GE. But to me that was a tectonic shift, okay, in terms of it was the root cause of all the other issues that we saw. The company's DNA was changed. And what value does an executive on the board of Banquet Foods add to what we're doing or Coronet Carpets or…

Russo: Hertz.

Sanquini: …Hertz or books, this was really I think the big issue at RCA and the bureaucracy got to me, I left in 1980 primarily because Bernie was gone and I really didn't like what I had to go through with the Chrysler Business

Russo: That's the same year I left.

Sanquini: And so that was my end at that period of time. But, you know, all of us here worked during the period, I think it's kind of interesting, we all came out of Silicon Valley including Bernie Vonderschmitt at the age of 61 he started Xilinx,probably the most successful FPGA company in the world. And so you had all this talent coming out here and many more engineers that I don't even know right now that came out, your boss for a while, Alex Young. And I think I'd like to just take a moment to talk about, so what contribution did you deliver out here that you're kind of proud of, Nick, in your years out here?

Kucharewski: Well I think a number of things, I think I had a lot of experience in custom chips at RCA and frustrated with doing manual custom chips and so when I joined VLSI, we really drove very, very hard custom chip capabilities. Both from a design standpoint and tools standpoint as well as manufacturing and by having technology centers in customer locations, I think that was an important thing to actually bring the tools to the customers and the design expertise. Because we had designers at our tech centers, we didn't just have applications people, and I think that was pretty important. But I look at the rest of my jobs too and, you know, a lot of the VPGM jobs I did were turnaround type jobs, companies had problems, in the case of Xilinx, they were acquiring a PLD company, they needed somebody to run it and bring it inside of Xilinx. And in the case of IDT, we had microprocessor problems that needed fixing and so I did a lot there. And so I did a number of things that were turnaround type situations, product improvement situations, that kind of thing and a lot of the experience was at good old RCA, good old RCA training camp, I think that's true of a lot of people out here in the Valley, there's a lot of people that got trained by RCA back in New Jersey and then they brought that expertise out here.

Ahrons: My comment and I'll make an analogy to a football team, RCA had too many interceptions and fumbles and that cost them and that cost them from being the leader. The second observation is no present semiconductor company, okay, has a central research lab, that wasn't the methodology within the semiconductor industry, we see that in Silicon Valley but we also see that in TI and Motorola, there was no central research laboratory.

Sanquini: Intel has.

Ahrons: Hmm?

Sanquini: Intel has a central, they have a central.

Ahrons: It's small.

Russo: Yeah, Sarnoff was 1,500 people, it was massive.

Ahrons: Yes, and Sarnoff still exists, though it's not RCA but it still exists. Yes, and of course, all patents became the central property of RCA, okay, and there was a business model for that and more. Because when I joined RCA, I joined the group that was in that business, it was called the Industry Service Lab, they had a group in Princeton, a group in New York City and they administrated all the patents and they got-- and the process was not only to get revenue from royalty but to also gave away designs to get back more royalty so you got a lot more royalty by helping people in the industry. And it was a very concentrated thing because I remember in Somerville where Solid State Division was, they had to have a group there that supported the industry but that group had to be somewhat away from the mainstream, okay because there was a conflict of interest, for instance in the television it was obvious, RCA was the leading television manufacturer but the Industry Service Lab serviced all the other television manufacturers, not as much as Zenith, but all the little lesser ones and they would almost give them a design but they had to pay royalties.

Sanquini: So do you think that was a net plus or minus?

Ahrons: It was definitely a net plus from that group's standpoint

Russo: Overall minus, absolute minus.

Sanquini: No, I'm talking about RCA.

Ahrons: I don't think it was a real minus because when you've got the football, you've got to run with it, okay?

Sanquini: You don't think it's a minus to take this technology you spent hundreds of millions of dollars…

Russo: Over many years.

Sanquini: …and give it, okay with these licenses to some…

Ahrons: You weren't, you were charging for it.

Russo: Yeah, but we had Akio Morita who died recently, who was the Chairman of Sony, at that time he was Director of R&D for Sony Labs, I think sometime in the late '70s and he came through Sarnoff. At that time RCA was, I mean Sony was making these little Trinitron TVs, we showed them everything, everything and that was part of the strategy about license them anything, but at the leadership…

Ahrons: But Sony was a licensee or they wouldn't have let them into RCA Labs.

Russo: Well this might have been part of some other licensing-- maybe not for CMOS because they were showing everything and then it let these guys accelerate. And then there was another event in the '70s where RCA Labs had a layoff and laid off about 200 people that were involved with the TV business and Samsung established an R&D lab in Princeton, hired all those people and did not have to explain what they're doing (with ex RCA Engineers and RCA Technology they learned to design color TVs), ship the technolgy off to Korea and two or three years later they shut down the Samsung Princeton lab and three years later, out comes the first Samsung color TV. So there was not a lot of care, but the fact because RCA was a leader and you look at the Apples and other companies here, they were main leaders, there was very little focus on-- it was more how do you just generate cash.

Sanquini: I would be more harsh, RCA squandered their technology with those licensing groups…

Russo: Yes.

Sanquini: …they squandered it.

Russo: I agree with that.

Sanquini: Okay? And even on the-- I'll give an idea, even on the royalty side, I'll give you an example. When I was a young engineer at RCA, I had the responsibility for Delco and I was designing radio circuits at that time for Delco, okay? And so I'm designing these circuits and you use in addition to your own and

RCA's IP, you require Delco Specifications an AGC characteristic. I kept asking for the AGC Specification, but I couldn't get it, I couldn't get it. And finally, one day the Delco Engineer says, "Okay, I can give you the AGC characteristic," and he pulls this out of this drawer and it's dusty and it's old yellowed paper, okay, and the AGC characteristics on it, in the corner it says, "1936 Oldsmobile," okay, and I'm going, "Wow." This is what you're doing, okay so you're designing, you complete the chip and the audio design I used happened to be an RCA Murphy patent that was used for the direct coupled audio that RCA had developed and designed in. So Delco is shipping millions of radios. Down comes the licensing group from New York, comes to see me and says, "Gee, you did a really good job, you got your circuit in and, you know, you used the Murphy patent for the audio amplifier?" And I said, "Yeah, that's a big customer," we're talking about all GM cars. He says, "Well we're going to sue them." And I said, "You're going to sue Delco, we just did this." And I go to Bernie Vonderschmitt, my boss, "Bernie, help me, they're going to sue Delco." And Bernie says, "I don't think I can help you, Dick," because the Licensing Group was totally independent from the RCA Businesses. And they sued, won, and at that time was the largest suit against General Motors ($115M settlement), I was persona non grata at Delco for four years.

Ahrons: That's the penalty of that type of operation and…

Sanquini: But is that good for business, that's not good for business.

Ahrons: Later on RCA Licensing became more sensitive to that, it became more sensitive but yes, the New York guys were pretty brutal.

Sanquini: It was insane to have a…

<overlapping conversation>

Sanquini: It was just crazy. But that to me, it always starts at the top, First it rots at the top and that's Robert Sarnoff's leadership and he's getting the cash and he doesn't care about the technology, okay and that's what I read in all that.

Ahrons: Yeah. When you're, with your level when designing something and they're basically taking your creativity and crushing it, you know.

Sanquini: Oh, they didn't think anything of it…

Ahrons: I know.

Sanquini: …they were trying to explain to me that everybody does this, I go, "No, everybody doesn't do this."

Ahrons: But on the other side, Paul, that licensing income paid for your salary for a number of years because RCA Labs got its pay, okay, got its money from patents and government contracts, mostly patents, all the royalties paid for RCA Labs.

Sanquini: But Dick, because we didn't commercialize, the technology they were developing, we didn't commercialize it.

Russo: No, we missed opportunities, video game, personal computer, LCD screens, everything, they could have been the leader.

Ahrons: There's a lot of things that were not commercialized from RCA Labs and a lot of fumbles along the way. But things like TV, they did commercialize, okay?

Sanquini: Not LCD. Think about where they could be today in LCD.

Ahrons: They were too far in front in LCD, you know the story of marketing…

Russo: Or plasma, they developed plasma in the '70s.

Ahrons: …if you're too far up front-- they gave up on LCD well before…

Sanquini: Look what Samsung is doing with OLEDs today, they own OLEDs. They're going to make more money out of the iPhone X than Apple, okay, that's what they're going to do. I mean that was the position that RCA was in with their technology but we…

Ahrons: RCA had lots of good positions they didn't follow through on, such as LCDs but then they had good positions they did follow through on, okay? Such as Color TV. RCA developed a top notch military business and if you read the articles on GE, you mentioned why GE bought RCA, for two reasons, GE bought them for their military business which was a mistake because the military business went downhill for everybody and the other one was NBC.

Russo: NBC, correct.

<overlapping conversation>

Sanquini: Yeah, I believe the NBC…

Ahrons: Those two things they wanted, the rest they didn't give a shit about.

Russo: But just to show you the lack of vision, so before the big executives in New York in 1979 kyboshed the RCA Labs developed home computer, we're actually recruiting a guy from California, I forget where, Stanford or Berkeley and he had a job offer from Apple and from RCA. And we said, "Apple, RCA's going to crush them." Well he had good judgment, he went to Apple because six months later they killed the project at RCA.

Ahrons: We have to go back to Dick again. I got a couple of things, one of the things is the Sarnoff comments you made were totally correct, RCA lost its visionary, lost its visionary leader, it was like having a great coach and then having crappy coaches like the 49ers have done, okay, Sarnoff was a leader, he was the one that stole RCA from the rest of the industry and that was based on patents because GE, okay, and you can remember this, GE and Westinghouse and there was a few others formed RCA and gave it all the electronic patents for like a number of years, okay, that's Sarnoff, that's his vision, he made RCA, okay, and he was a visionary and when they lost him and his son, RCA lost its vision. To take stuff from RCA Labs and start a new business, if it wasn't the PC, why didn't they do the games or why didn't they do this and that, their batting average went real low. The other comment was as Nick said SOS, well Sanquini, Dick, you blew up SOS and I was your cheering section.

Sanquini: Well yeah, I blew up SOS…

Ahrons: It was the right move.

Sanquini: …first of all, I didn't but it was blown up and I was there when it was blown up.

Ahrons: Well you…

Sanquini: But wait, let me tell you how I felt about it, the problem we have with SOS is not the technology itself it was the fact that you couldn't compete wafer wise with bulk CMOS. SOS substrates cost 16 dollars at that time and we made the SOS substrate ribbon, we made the ribbon in Lancaster, PA and so our SOS substrates were 16 bucks and 4 bucks for a bulk CMOS substrate. And the rest of the industry is working and cost reducing bulk CMOS and you have a small group in Princeton which is small compared to the whole industry developing bulk CMOS technology. One thing I learned from the exercise, you don't go it alone developing technology if you're a company, I don't care how good your technology is, you have to have the industry with you, you can't come in with all these various-- look at all the companies that have failed with specialty kind of processes.

Ahrons: Well along that line, I saw frustration which matches, do you remember what happened and really killed SOS was we were on three inch wafers, we had to go to four on the SRAM, there were no four inch wafers and we'd have to go it alone and I think that was one that…

Sanquini: The going it alone was the problem.

Ahrons: Yeah.

Sanquini: That was the problem that you had with SOS._________.

Ahrons: And I'm just trying to emphasize that that was the case, that we were a loner in the industry on that process.

Sanquini: Yeah, I think there are the vision issues which are the big issues, the individual and that kind of filters down into the top management, the bureaucracy of a diverse conglomerate if you will. I always look at-- you look at successful companies like Intel, they were one product and then maybe two, right, okay, it was memory then-- first memory then micros, okay and two products, everybody in the company knew what the vision was, okay, and what they had to do and Andy Grove in his book talks about when they went from memory to micro, I think he said with Gordon Moore, he was sitting there and said basically, "What would we do if we were two new CEOs, we would fire us and probably come in and focus on microprocessors," and that's what they did.

Ahrons: They did.

Sanquini: They did that.

Ahrons: In the late '80s, or '90s I was doing intellectual property stuff for National at-- I got some numbers, National had 10,000 different die, okay, that means generic die, how many did Intel have, with the-- you can probably count them on hands and toes the amount of different product die they had, it was an amazing difference but that was the analog business of all these little chips of different ones.

Sanquini: Okay, I just want to-- I had asked-- Nick told about his contribution to the industry, you've talked about-- what specific contribution are you most proud of that you made to the industry?

Ahrons: Well it's one I'm working on right now, I think I talked to you guys about and I am the IEEE Milestone Coordinator for Santa Clara Valley Section and we got a big double header milestone coming up next May and the two milestones there are the birthplace of Silicon Valley which is Shockley Labs, now Shockley screwed up and Moore's Law which was very successful. So we're doing those two together and I'm right now in the middle of that and it may be my last big push but I'm really proud how well it's going and this ties in with the Computer History Museum, they will be doing a big evening event on it with the panel. We hope to get Gordon Moore, okay, if Gordon's in decent health, shape. And I'm sort of-- it's like my going out, I'm 86 and I'm getting a little old.

Sanquini: No, you're young. Okay, Paul, how about yourself?

Russo: Talking about RCA?

Sanquini: No, I'm talking about you, you came out here and you're a serial entrepreneur, I'm really asking, what were you the most proud of?

Russo: I guess the two or three highlights, one was as soon as Royce Becker raised the idea, I got it right away and said, "This is it," and put all myself through that whole space of microprocessors. And then when I left GE in '86 to start Genesis Microchip, what the VCs accused me of probably correctly, that I tend to be very good at guessing what the future is going to be but I tend to be always a bit early. So we started developing scaling technology, had trouble raising money like any chip business in the late '80s, but then we saw flat panel displays coming and we had the best scaling technology and remember they were 1,500 dollars for a little display and we were arguing with the graphics guys because they said, "Why did you use the scaling of the monitor, we're the graphics guys, we'll render it?" then we said, "No, you have to have scale in the display to make it look good, optimize it." And all the LCD makers were saying, "Oh, your chip's too expensive," and then Apple put us in their first flat panel monitor. Within 18 months, we had 80 percent worldwide share.

Sanquini: And that was a huge success.

Russo: And then the other thing that in retrospect I'm proud about although I question my own judgment sometime, in '08 when the Sutton Company blew up, they had a geometric processor, no one had the vision because we were selling a few to the military guys for headsup displays and stuff, distortion correction because we can do it with no latency and Qualcomm bought the commodity business in Silicon Optics for 60 million because I paid two million bucks more to get all the geometric processing technology, it didn't. So we acquired that for less than two million dollars, patents, inventory, customers, and now we're going to be in every car going forward, we started shipping because now not only for the camera and giving different views and then warping and all that but also on the factory floor, with our technology you can do auto calibration, you don't need guys with screwdrivers to take care of the manufacturing stuff. And when we start talking about that five, six years ago, no one knew what auto cal meant, now all our customers want auto calibration because it saves them money on the factory floor, no people.

Sanquini: Sure, sure, it's a big deal.

Russo: And the same kind of thing with the same boys, like we already understand the problem from about graphics guys at Genesis, now we were arguing five years ago with the NIVIDIAs of the world who said, "We're going to do everything in our main computer," we said, "No, you got to have smarts on the edge because if you've got seven, eight cameras, how is the big computer going to process everything in real time and if you have a mirror and you want to replace it with a camera, that's the speed of light, you can't have any latency." So our geometric processing is actually a parallel engine that you can program to do trillions of transforms but it acts like a scaler, it does it one-60th of a second. And so we were dominating on it now but no one saw that. But it was tough because I guess we were probably a bit early and '08 and '09 were not the best years to raise money for a chip company. But those are probably the three things that I think in hindsight I feel good about.

Sanquini: I'll talk a little bit about myself. The thing I feel pretty good about, at National we came very close but we didn't get the brass ring, okay? Coming close, the 32,000 family was the first 32 bit Micro out in the world at that time. It took us a long while to actually get-- we had to design our design tools, our simulators, all of that had to be done, all our tools had to be devloped in concurrently with the chip designers and we had our own tool group and we would take six, seven, eight revs to get a product out, it was terrible. By 1984, we had all our tools in place and we got a product out that was called a 532, 32,000 532, which came out, ran UNIX on the first chip. And we had been working with Burroughs, Burroughs Rancho Bernardo and Colorado Springs designing in the 32,000 Family, It was a two year design cycle. And I thought this was going to be it, the 386 wasn't out yet and Intel was really slow and they really had 286 which wasn't really a-- really it was lame, I guess all I can say. So we had this thing all wrapped up, we thought we could get Burroughs and start turning the industry because there wasn't a 32 bit out yet. And National Semiconductor didn't really have-- we had relationships with as I said, Rancho Bernardo and Colorado Springs but in Detroit, that's where all the power was and the power, there was-- the Chairman was a guy by the name of Blumenthal, I'll never forget these guys' names going to the grave. Blumenthal was the Chairman, the CEO was a guy by the name of Caswell.

Diamond: George Caswell.

Sanquini: You knew him. Okay Bob Noyce and Gordon Moore, make a trip, they know these two guys, they make a trip out to Detroit and convince them-- remember, this is when the design is all done, we're ready to manufacture and ship. Okay, at Burroughs, Noyce and Moore pitch them to wait for the 386 … Noyce was good at the software compatibility pitch, okay, and you get a lot of software, these products were UNIX, UNIX based products and so he had a lot in his software pitch directed to Unix.. Anyhow, the long and short of it was they convinced them that the 386 would be out in six months and that they should kill the program with National Semiconductor. And I'm at National, I get a call from our field guy, Curtis and he says, "You lost the Burroughs business," I said, "Oh, you're crazy, we didn't lose the Burroughs business." I mean we knew all these guys and he said, "Yeah, you lost it." And it turns out we did lose the business and that was the end of the 32000.,Intel it didn't come out in six months but it did come out in a year with the 386. And Compaq immediately used it. That marked the end for all of us, Zilog , Motorola. And we converted 32000 at National to the embedded market.

Ahrons: You want to know the rest of that story because I was at Burroughs at the time?

Sanquini: No, this is my thing I'm talking about.

<laughs>

Ahrons: Okay, but I was at Burroughs at that time.

Russo: Oh you were?

Ahrons: Yes.

Russo: Dick, you're the moderator, control your panel.

Ahrons: You weren't going to win, there was no way you were going to win.

Sanquini: Okay, so I really was proud of that because it was a long struggle, unfortunately we were unsuccessful but we got our revenge, I won't talk about that here. We got our revenge with the Pentium (noted in the National Semiconductor Oral History at the Computer Museum). So the other breakthrough that was really kind of great for me to work on was PortalPlayer iPod Music Players, PortalPlayer made the silicon and the operating system for the first iPod while I was the Chairman and Interim CEO for that company. And that was exciting because in this startup, we had a CEO who had a vision for media, remember, this was 2000, and memory, we couldn't put much memory on a chip at that period of time. But we had developed a platform to put media on a chip and we had worked with IBM in San Jose who had made hard disk and they had a one inch by one inch hard disk so we could put four gigs on a player and get 12 hours of music out of that thing. Anyhow, an RFQ is sent out by Apple and so we do this independently at PortalPlayer, Apple gets a guy named Tony Fadell who has been trying to pedal his idea for a music player, they eventually call it the iPod and they send out an RFQ to all the big semiconductor manufacturers. And all the semiconductor manufacturers, I'd have to say, they were consistent in saying, "What a bunch of crap this is, a music player, it's going to take us three years to develop this platform." And we were able with Tony Fadell and he reported to a guy named Jon Rubenstein who reported to Jobs, we were able to go there, show them our platform and we told them that we could get them in production quickly. It was August, production for Christmas was possible, all they had to do was the navigation software. Remember the first iPods had a circular sensor on them, okay, and they had to develop the navigating software. Anyhow, that was great because that was done, it launched the company and the whole business that we were tied to so that was really exciting.

Ahrons: Okay, I came from Burroughs to National, okay, I got the talking to Annie and so on, I just said, "National should have won that shootout at Apple," National had the processor in CMOS, qualified and they lost to Motorola which came in with a big breadboard which was a rack of TTL, that's all Motorola had for the 68,000 at that time, a working rack of TTL. You, National, lost it at the marketing level and the management level, Motorola Semiconductor was a great marketing company and they sent such big teams in. Motorola marketing could bring in top management, there's no question, that top management was ready for a call and would go on to the customer versus Charlie Sporck who really didn't want to have as much to do with marketing. But Charlie was that great manufacturing guy.

Sanquini: Okay, I think we're ready to wrap this up. Before we do this, anything you want to add Nick to what we talked, anything?

Kucharewski: I think the biggest, as I said earlier, I think the biggest issue I had with RCA was this devotion to SOS, I think that really, really killed us because we spent so much effort designing products in SOS, none of which ever made it to production and that was effort that could have been spent designing enhanced 1800 series products in bulk CMOS. We did time keeping circuits in SOS, we did an 8085 in SOS, we did a RAM I/O and ROM I/O in SOS, all kinds of stuff, I mean that was the technology and you could talk about lack of vision well that was sort of anti vision because we had so many in the labs with an SOS vision that for some reason, everybody bought into. Maybe it was a lack of knowledge but that sort of became the technology vision that that was going to be the VLSI technology of the future and I think that's really what sunk us because we spent man years, many, many, many man years designing products in SOS that never went anywhere that could have been spent designing other products, so that was sort of the beginning of the end I think because by the time we tried to recover into bulk CMOS it was too late, the industry's just passing us by and I think that was the real killer, that was the real killer, we had good people, good architecture, I mean the 1800 series could have lasted forever, we could have done 16 bit versions, we could have done 32 bit versions of the same fundamental architecture because it was really, really good controller architecture.

Ahrons: But you and I tried to get that 16 bit going and we couldn't.

Kucharewski: Well that was a lack of vision, but I mean that was too late, the industry was already starting to bypass us. We second sourced the 6805.

Ahrons: I had come from Motorola and I knew they were working heavily on a 16 bit version of the 6800. And you couldn't move RCA and I couldn't move RCA, that's the result.

Sanquini: Paul, you have any…

Russo: I just want to mention, my saddest moment was actually leaving RCA. I was being recruited by GE and I viewed GE as low tech and RCA as the world leader in technology but they gave me, you know, I ended up arguing with Welch for an hour and I said screw that job and they made me an offer I couldn't refuse. But I was really sad to leave it because I felt that as you said earlier, that there's this massive opportunity that was squandered, RCA could have been a leader in personal computers and flat panel TVs, all the new stuff and it was sad to leave that?

Sanquini: Dick do you have some last, any other…

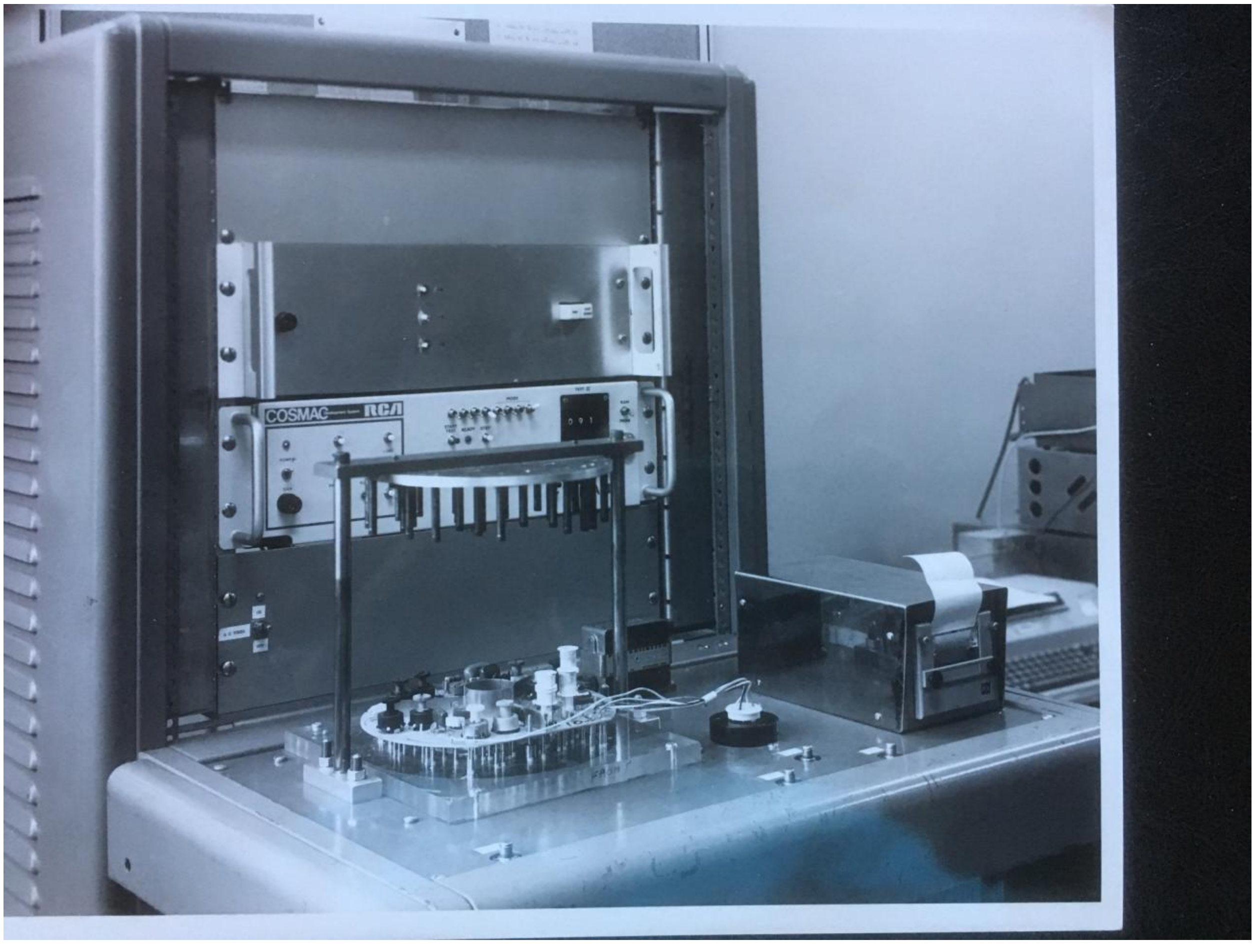
Ahrons: Yeah. Well, one of the things, and I just remembered that I was real happy and proud about when I left Motorola, I left the CMOS operation and during the time that I was there, I was one member of this team, it was an excellent team, balanced all the way through with our production right there. We started with almost zero revenue in CMOS 4000 series because the operation was new. When I left to come back to RCA, we had exceeded RCA in their own domain in the 4000 series with logic. W, Mpotorolae had more revenue than RCA had, okay, we became number one, RCA became two. And this says, you know, once you have the momentum, you've got to continue it, okay, You've got grow, grow or die and RCA had some reason for giving up the growth.

Sanquini: You know, thank all of you today for describing how this 1800 series got started and that was very interesting Paul, Dick, and Nick. And the 1800 family I think we talked a lot about, its attributes, its place in two major markets, Automobile, under the hood ignition and Space. And I'd like to end with a positive note, okay, we talked a lot about management, okay, and I think we're kind of in agreement that the vision was lost in management, when we say management, we're talking about Corporate Management of the corporation, really failed in terms of taking the technology to market. But irrespective of the management incompetency if you will, we still have, and I was really heartened to see that we have a Hubble telescope out there that doesn't care about management and it's just cranking along and it's been up there for 27 years. And recently, there was a PBS show on some of the data of dark holes that this telescope has picked up and the number of galaxies around all of those stars, it's contributing heavily to the world and to society with its work over the last 27 years. So on that positive note, I think that's probably the major, one of the major things that the 1800 has done for society, I don't know of any other microprocessor that has done so. Thank you guys.

Diamond: Thank, Dick. Thanks to the panel, it's been a fascinating discussion of groundbreaking, really a revolution in the microprocessor business and leading into a lot of other areas that we're still taking advantage of today so thanks to all of you.

END OF THE INTERVIEW

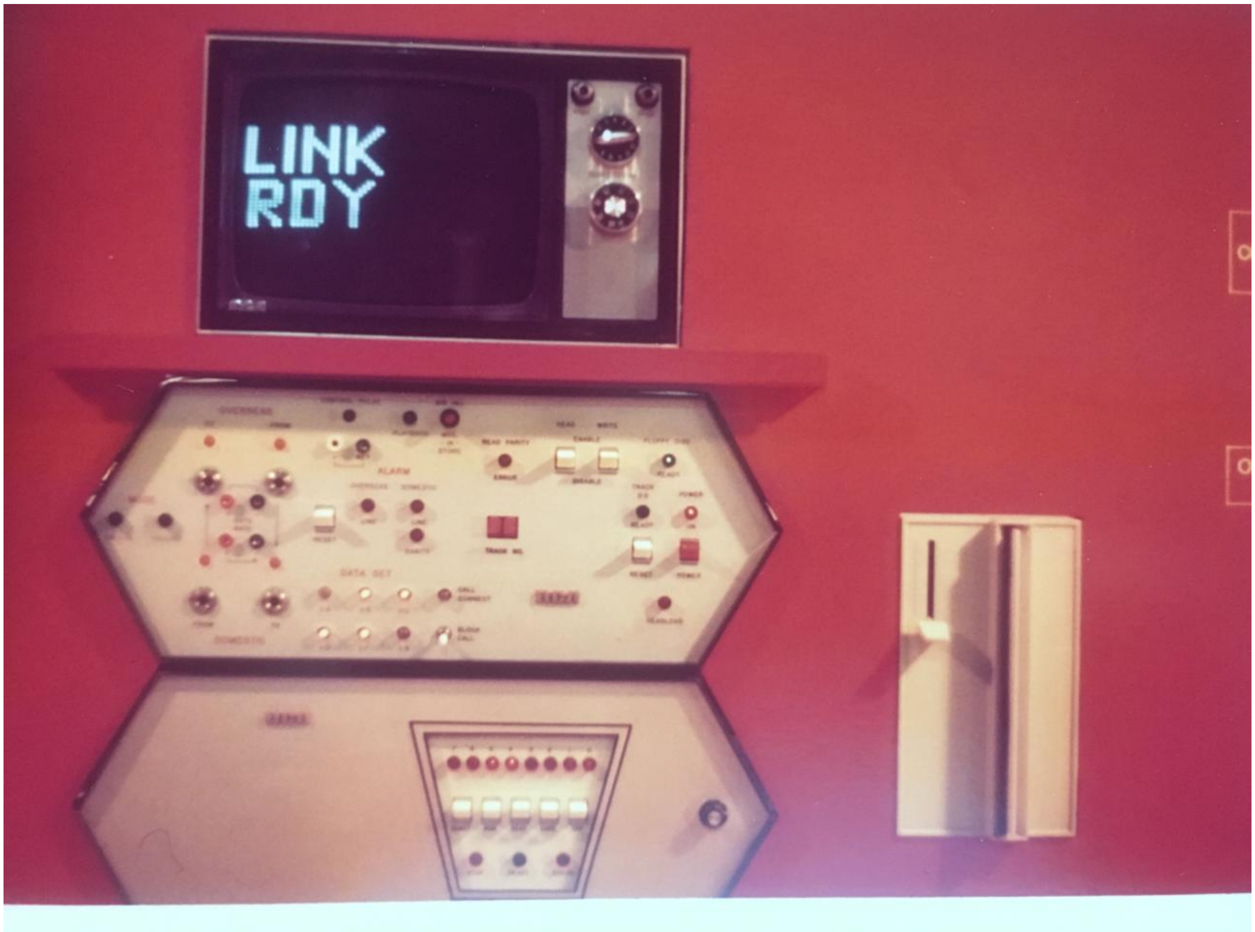
Appendix



Source Paul Russo: BLOOMINGTON TV FACTORY AUTOMATED R-G-B CONVERGENCE ADJUSTMENT. FIRST USE OF COSMAC SYSTEM FOR FACTORY AUTOMATION.

Source Paul Russo: CLOSE-UP OF TV FACTORY MICROPROCESSOR-BASED AUTOMATIC CONVERGENCE ADJUSTMENT. BLOOMINGTOTN INDIANA RCA TV FACTORY.

Source Paul Russo: FIRST MICROPROCESSOR-CONTROLLED GLOBAL COMMUNICATIONS LEASED CHANNEL CONVERTER WITH FLOPPY DISC. MICROPROCESSOR-CONTROLLED STORE AND FORWARD BIT RATE AND FORMAT CONVERTER TO REPLACE MULTI PAPER TAPE SOLUTIONS.



Source Paul Russo: CLOSE-UP OF FIRST MICROPROCESSOR-CONTROLLED GLOBAL COMMUNICATIONS SYSTEM BASED ON 1802 MICROPROCESSOR AND ONE OF THE EARLIEST FLOPPY DISC DRIVES.

Source Paul Russo: GLOBAL COMMUNICATIONS 1ST MICROPROCESSOR CONTROLLED BIT RATE AND FORMAT CONVERTER TO REPLACE PAPER TAPE SOLUTIONS CLOSE-UP OF SYSTEM BOX WITH FLOPPY DISC CONTROLLER.

Source Paul Russo: FIRST TWO-COSMAC SYSTEM
MULTI-PROCESSOR SYSTEM: TWO COSMAC 1802-BASED SYSTEMS TALKING TO EACH OTHER TO ACCELERATE COMPUTATION.

Source Paul Russo: STUDIO II CONSOLE: WORLD'S FIRST VIDEO GAME CONSOLE WITH PLUG-IN ROM-BASED CARTRIDGES FOR GAMES. BLACK AND WHITE, 64X32 DOTS DISPLAY.

intersil.

CDP1802AC/3

Data Sheet | **October 17, 2008** | **FN1441.3**

High-Reliability CMOS 8-Bit Microprocessor

The CDP1802A/3 High-Reliability LSI CMOS 8-bit register oriented Central-Processing Unit (CPU) is designed for use as a general purpose computing or control element in a wide range of stored-program systems or products.

The CDP1802A/3 includes all of the circuits required for fetching, interpreting, and executing instructions which have been stored in standard types of memories. Extensive input/output (I/O) control features are also provided to facilitate system design.

The 1800 Series Architecture is designed with emphasis on the total microcomputer system as an integral entity so that systems having maximum flexibility and minimum cost can be realized. The 1800 Series CPU also provides a synchronous interface to memories and external controllers for I/O devices, and minimizes the cost of interface controllers. Further, the I/O interface is capable of supporting devices operating in polled, interrupt-driven, or direct memory-access modes.

The CDP1802AC/3 is functionally identical to its predecessor, the CDP1802. The "A" version includes some performance enhancements and can be used as a direct replacement in systems using the CDP1802.

This type is supplied in a 40 Ld dual-in-line sidebrazed ceramic package (D suffix).

Features

For Use In Aerospace, Military, and Critical Industrial Equipment

- **Minimum Instruction Fetch-Execute Time of 4.5µs (Maximum Clock Frequency of 3.6MHz) at V_{DD} = 5V, T_A = +25°C**
- **Operation Over the Full Military Temperature Range . . . . -55°C to +125°C**
- **Any Combination of Standard RAM and ROM Up to 65,536 Bytes**
- **8-Bit Parallel Organization With Bi-directional Data Bus and Multiplexed Address Bus**
- **16x16 Matrix of Registers for Use as Multiple Program Counters, Data Pointers, or Data Registers**
- **On-Chip DMA, Interrupt, and Flag Inputs**
- **High Noise Immunity . . . . 30% of V_{DD}**
- **Pb-Free (RoHS compliant)**

Ordering Information

PART NUMBER	PART MARKING	TEMP. RANGE (°C)	CLOCK FREQUENCY AT 5V	PACKAGE	PKG DWG. #
CDP1802ACD3	CDP1802ACD3	-55 to +125	Up to 3.2MHz	40 Ld SBDIP	D40.6

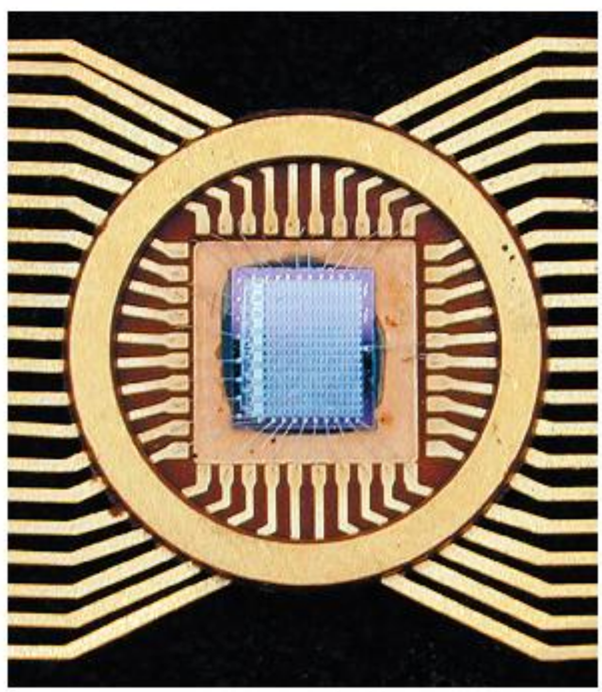
NOTE: These Intersil Pb-free Hermetic packaged products employ 100% Au plate - e4 termination finish, which is RoHS compliant and compatible with both SnPb and Pb-free soldering operations.

1

CAUTION: These devices are sensitive to electrostatic discharge; follow proper IC Handling Procedures.
1-888-INTERSIL or 1-888-468-3774 | Intersil (and design) is a registered trademark of Intersil Americas Inc.

Source Dick Ahrons: Intersil CDP1802 Datasheet with 2008 date. Demonstrates the longevity of the 1802.

RCA COS/MOS 288-bit RAM Array 1968. Gift of Richard Ahrons



Source Dick Ahrons: First CMOS SRAM Memory. Paper and photos by Stan Katz and Abe Yung of the first CMOS SRAM by my group at RCA. IC is on display at CHM. Note the 1968 date.

coordinated software and silicon technology development program has been completed, permitting the design, fabrication, and testing of custom ROM designs with no design-engineering involvement. Four custom 1024-bit ROM chips were supplied to the ATL activity in Camden.

A joint program was also established with Palm Beach Division for the implementation of the FRED computer with monolithic LSI techniques. The microprocessor has been partitioned in two COS/MOS chips to be fabricated in early 1974. Both chips are approximately 250 mils on a side and contain over 3000 transistors. One chip contains the ALU and control logic in a 40-pin package. The other chip contains the register matrix and associated control logic. The entire system is designed to operate over a 5-12-volt range and is compatible with T^2L levels through the use of a separate 5-volt supply line.

In 1974 the silicon-gate technology required to fabricate LSI will be refined to a higher yield process, and additional complex structures will be made in the beam-lead format. The density improvements of the new technology will be demonstrated by the fabrication of a 1024-bit RAM, a 4096-bit ROM, and the chip complement needed for the FRED computer microprocessor.

For further information refer to:
V. Alfisi, J. Oberman, W. Rosenberg, B. Baptiste, or A. Dingwall (Somerville).

10.5.4 Linear MOS Technology

A solid-state rf switch that exhibits low ON resistance (3.5 ohms) and high OFF isolation (40 dB) over the 30 to 80 MHz band has been developed for C&CS for low-power military communications applications. The technology used to fabricate this switch is based on that used to manufacture commercial VHF dual-gate MOSFETs. In 1974 an integrated circuit that will incorporate driving devices and circuitry along with overload protection will be developed.

COS/MOS technology was extended to the design and fabrication of a stabilized Op-Amp chip. Samples of this device are to be used in ATL programs at Camden. SSD Linear Engineering has substantial interest in marketing an RCA chopper-stabilized Op-Amp. In 1974 this design approach will be extended to the fabrication of a high-performance chopper stabilized A/D converter.

For further information refer to:
R. D. Dawson or A. G. Dingwall (Somerville).

10.5.5 Charge-Coupled Devices

The CCD technology offers unique capability for signal processing in areas of variable delay line and transversal and recursive filter application. The extremely high packing density is attractive for achieving the objective of replacing high-capacity memory drums with solid-state shift registers. During 1973 the two-phase CCD technology was transferred from Princeton to Somerville. Feasibility of both a 621-stage analog delay line and a 1000-bit memory element along with input/output and regenerate stages has been demonstrated. During 1974 efforts will concentrate on defining a pilot-line process for the Video Disc 621-stage analog delay line, development of a one-microsecond delay line for TV signal processing, and the cooperative development of a 32000-bit CCD memory chip.

For further information refer to:
R. Dawson or J. Preisig (Somerville).

10.5.6 Yield Improvement and Process Control

During 1973 in conjunction with the SSTC Design Automation Activity, a program was developed for the plotting of circuit yield and parametric information by wafer position. This will be a powerful tool for deskilling yield analysis and improvement efforts on complex devices. In 1974 this approach will be applied to the cost reduction of specific commercial COS/MOS and bipolar products for SSD.

For further information refer to:
W. Rosenberg or F. Lee (Somerville).

10.6 Integrated-Circuit Technology

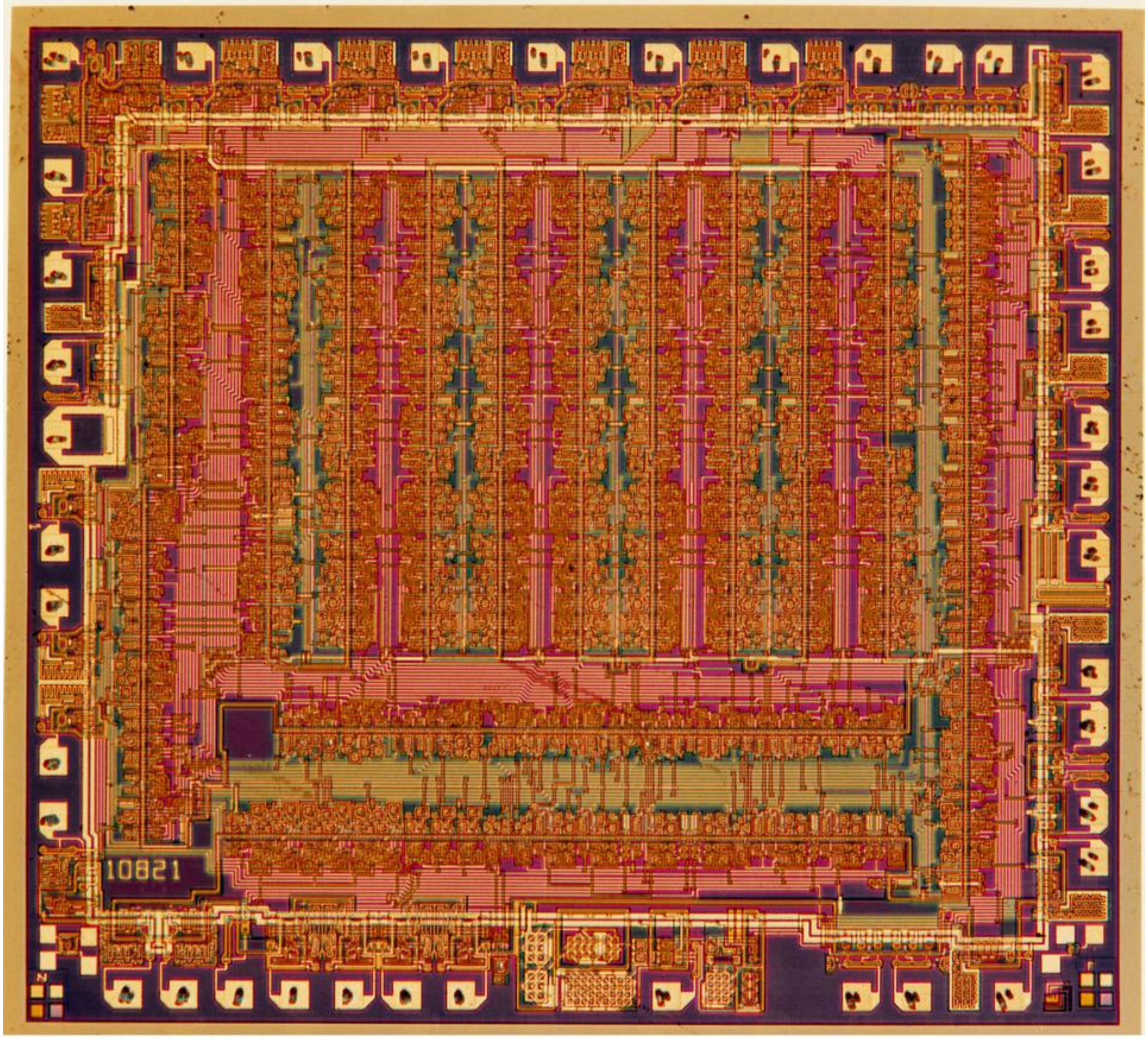
10.6.1 Silicon-on-Sapphire Technology

The cost at a given performance level determines, in large measure, the market potential of an integrated-circuit technology. MOS technology has long been acknowledged as the least expensive technology, but at some sacrifice in performance. Conversely, bipolar technology has offered a higher performance at higher cost.

Figure 10.1 is a graphical display of the relative performance levels of various integrated-circuit technologies currently utilized.

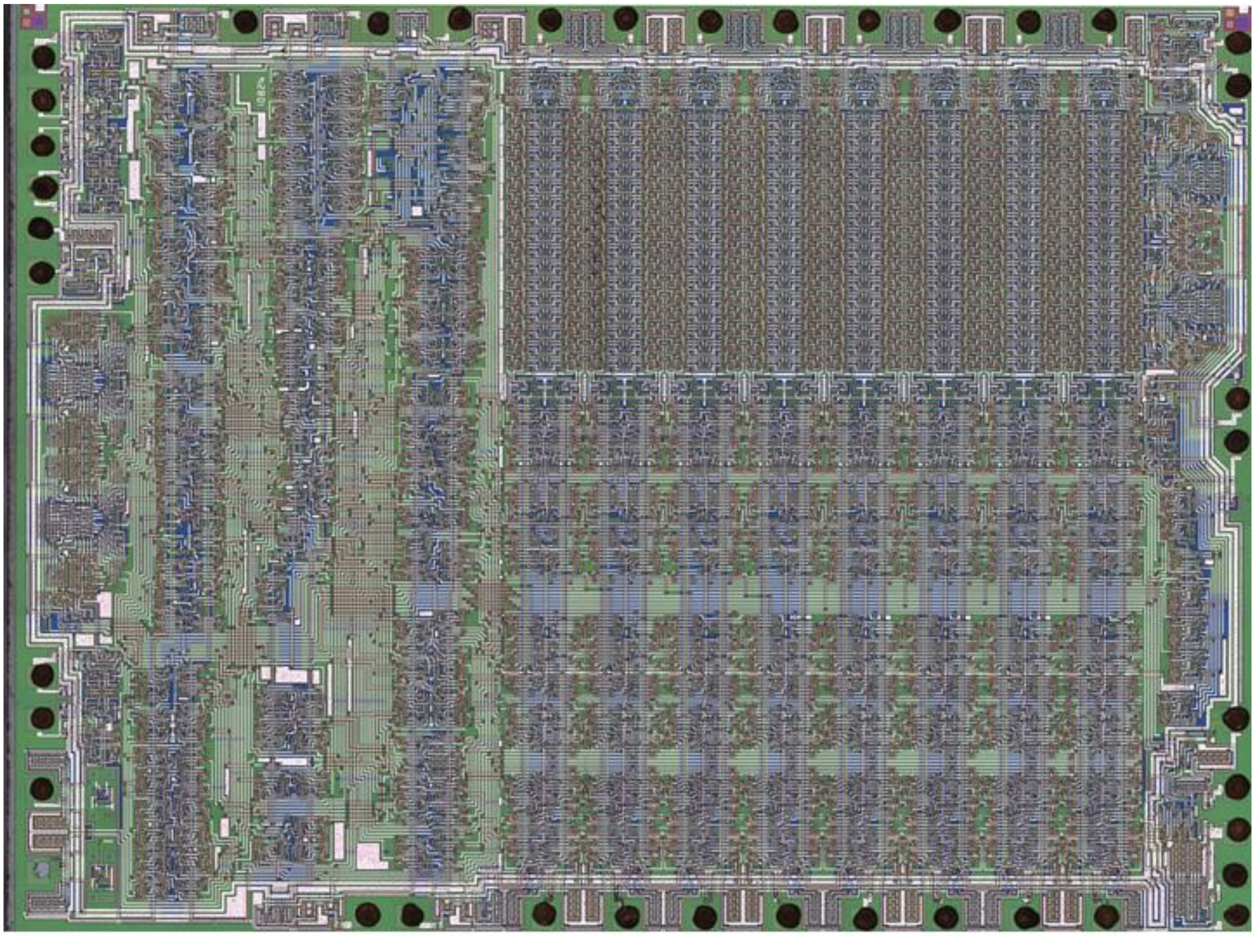
148

Source Dick Ahrons: RCA Laboratories Research Report 1973. May be from Jerry Herzog.



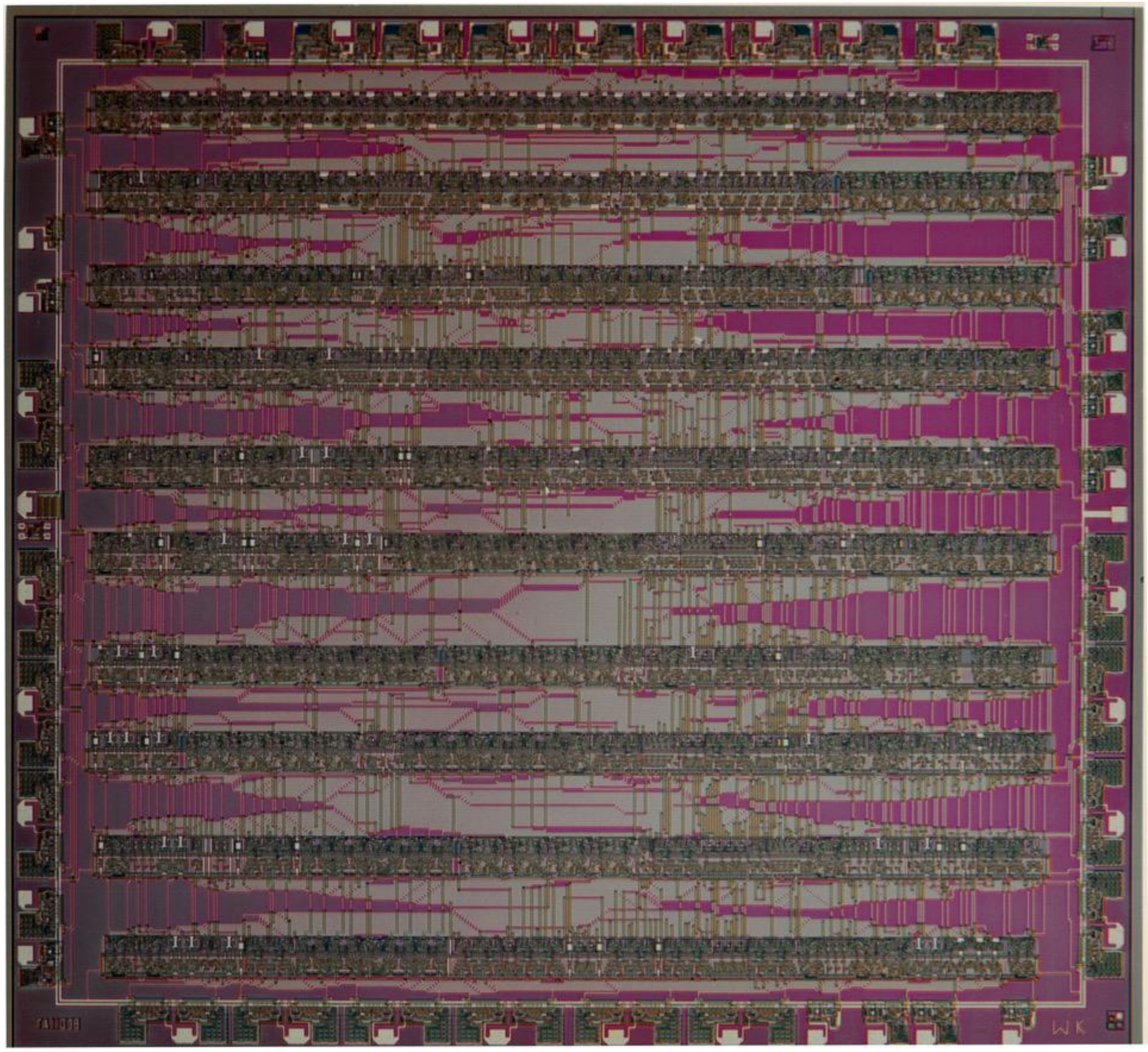
Chrysler Lean Burn2 Custom I/O Chip
Layout Handpacked for Cost Reduction

Source: Nick Kucharweski



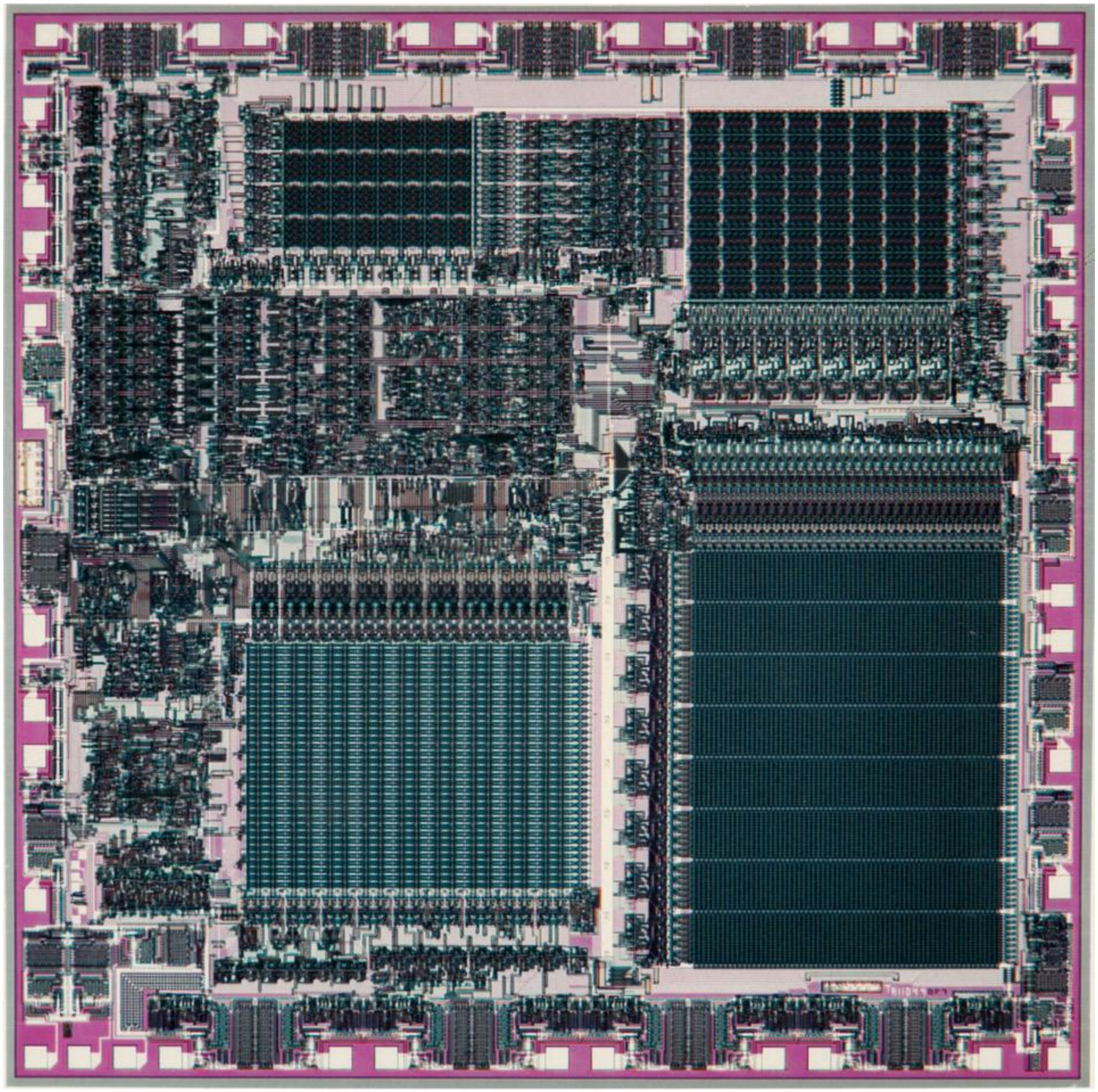
CDP 1802 Microprocessor
CCL Technology

Source: Nick Kucharweski



Bosch Motronic Custom I/O Chip
Layout with APAR (Automatic Placement And Routing)

Source: Nick Kucharweski



CDP1804 (1802 with 2K ROM, 64 B RAM, Enhanced Inst. Set)
Bulk CMOS1 Technology

Source: Nick Kucharweski

COSMAC (Complementary Symmetry Monolithic Array Computer)
Microtutor 1 (1801) Microtutor 2 (1802) ELF Hobbyist Machine

Source: Nick Kucharweski

