Dr. Thomas A. Longo: On the development of TTL at Sylvania and a 16-bit RAM at Transitron

Edited transcript of an interview by David Laws in Palo Alto, California on Wednesday August 9, 2006.

T.L. - In 1950 I went back to Perdue to go to graduate school to work on my PhD in physics on silicon. The only reserve unit I could get into was one that had cryptanalysis as its basis in association with the National Security Agency. When you were in the Naval Reserve unit you had to take 2 weeks a year to go to some Naval establishment and I went to Fort Meade. There I became somewhat involved with a project called Lightening that was developing a variety of technologies for the first high really high frequency computers for cryptanalysis. In that same period of time I ran into Seymour Cray who had been doing cryptanalysis work in the army and was developing computers at Control Data for high performance computing.

When I finished graduate school I stayed on at Perdue for a while as an assistant professor. Then I joined a company called General Telephone who had a lab Chicago. I had grown up in Chicago so I went back there. While I was there, General Telephone acquired Sylvania, so I was transferred to Massachusetts at the beginning of 1960 to head up device research. Because of my interest in very high speed components for computers, I decided to develop an integrated circuit that would do what people were saying could not be done because the only thing out was DCTL and RTL from Texas Instruments and Fairchild – very, very slow and huge chips. They just took ordinary transistors and put them in integrated circuits. They kept the circuits very simple and they had poor margins etc, etc.

I said OK, I love a challenge. People said you could not do a sub-10 nanosecond integrated circuit, so I said I'm going to do it. I started that project by first developing the technology for mask making and for high frequency transistors. By the beginning of 1962 I had brought out a transistor that was the fastest in the industry called 2N2784, the first gigahertz transistor. I used that as the basis for a TTL circuit. I had read an application paper by Ruben Beeson of Fairchild. He used a 2N709 in a simple circuit that tied multiple emitters together in a multiple emitter configuration. These were discrete components but I wanted to do this in an integrated circuit. By the spring of '62 I had a simple TTL circuit that ran at 6 nanoseconds, but had terrible margins. I had been to the electronics show that was held every March in New York City. In a taxi cab on the way back to the airport I told a guy that worked for me "You know what we need to do is to put a Darlington on the output. We'll get fan-out and we'll get margin." A junior engineer also came up with the idea "Why don't we hang a transistor there so you have driving in both directions."

Well by January we had it. I visited Litton Systems and got it designed into the Phoenix computer. They didn't believe that it could do what I said it could, so I made them pay $300 for a chip and they designed it in. But the criticism that I was getting from government agencies was "Why are you doing something different. Why can't you just second source DCTL and RTL." The issue was that I used so many transistors. I was using 14 transistors in a dual gate. I had put in levels shifters and etc. I said "Hey my chip is smaller that Fairchild's single transistor chip." The whole idea was to get the parasitic capacitance very low. (This was of course before oxide isolation - we were using junction isolation). I got it down also by using epitaxial technology. That resulted in high-level TTL that I decided to call Sylvania Universal High-level Logic (SUHL) to differentiate it from plain ordinary TTL that had no margins and no fan out.

D.L. - Was that TTL the same as Jim Buie patented at Pacific Semiconductors?

T.L. - No his was a multiple emitter device with one inverter out. It had terrible margins.

D.L. - Did he actually produce a circuit?

T.L. - Yes by the end of 1963 he had a circuit. But it did not go anywhere because by that time I was talking about my stuff. Every October there was big conference in Washington called the PTGDE and I presented a paper on High Level TTL (Longo, T.A., Feinberg, I., and Bohn, R. "Universal high level logic monolithic circuits," Electron Devices Meeting, 1963 International, Vol. 9 (1963) p. 66) with three other guys that collaborated on it. That was the first official paper published. It was the first time such tight technologies (probably about 4 or 5 microns) had been used as well such tiny devices. A single transistor was maybe about 100 square mils. I didn't use any resistors. I used transistors instead of resistors because they took up too much space. No diodes, just 7 transistors in a gate. It was an immediate sensation. At that time most purchasers were in the military and it got designed into all the military systems.

I left Sylvania to go to Transitron in January of 1964 where I did TTL and a lot of other things. I had to start all over again in technology. In Spring of '64 I was down again at the electronic show in New York and I ran into Howard Moss who at that time was running R&D for Texas Instruments. When I was in graduate school I had given some seminars at TI. I was an expert on radiation damage in semiconductors. He said, "I'll show you something." He took me into this room where some guys were making presentations. And there on the screen was my TTL. That became Series 54.

He said, "See we're not that far behind you." They made the mistake of copying my exact circuit as I published it. After publication I had moved a level-shifting diode from the output of the device to an input of the inverter. That made it a little better. I also changed to using a buried collector in an epitaxial technology. They did a nice trick though; they changed the pin-out. SUHL was cleaning its clock in the military market. But then came the master stroke from TI. By about '66 or '67 they put it in plastic and started selling them for one dollar a gate. 7400 at that price was unstoppable. It wasn't that fast. SUHL was about 7 or 8 nanoseconds, their stuff was around 14 or 15 nanoseconds. But it was good enough for the people who were buying plastic. Sylvania was not able to compete with that. Hermetic packages were selling for a couple of bucks a piece.

At Transitron I put the SUHL product line in, but I was focused on other things, including a custom TTL family for Honeywell in the Boston area, which included a RAM that came out in 1966. It came out of our collaboration with them. They described what they wanted. We had to figure out how to do it. It was not exclusive to Honeywell. They wanted it to be but I insisted that if I was to complete the project that I be allowed to sell it to everybody. It got us into a lot of other places. Everybody and his brother started using it for scratchpads; I sold it to National Cash Register, Univac. That was the hottest selling product at Transitron.

D.L. - What were the chalenges in fabricating the circuit?

T.L. - I had to advance the technology to make it to about 3 or 4 microns. It had 4 transistors in each cell; 100 transistors in a chip. If I remember correctly, the chip was less than 90 mils on a side, which for that time was pretty small for a 100 transistor chip. It was a very good project. I would say it took us about 18 months. I don't remember how many engineers worked on it directly. I never had more than about half a dozen engineers all together.

I left Transitron at the end of 1969 and joined Fairchild in 1970.

Tom went on to talk about his experience at Fairchild and at Performance Semiconductor (after he left Fairchild at the beginning of 1984). I have not transcribed this part of the interview.

D. Laws 8.12.06

Excerpt from “Monolithic Milestones”

Electronic News, Monday, January 3, 1972, Section 1, page 1.

Meanwhile, although some work had been done in TTL at Pacific Semiconductors, Fairchild and Signetics, the man who was pursuing it most aggressively was Dr. Thomas A. Longo, then in the dual role of director of research and engineering, and manager of IC production, at Sylvania Semiconductor division, Woburn, Mass.

Starting work in 1961, he showed his first low-level TTL circuit at 1962 Wescon in Los Angeles. Dr. Longo, now vice-president and general manager of Fairchild Digital Products division, admits that the biggest thing the circuit had going for it was speed, for otherwise it has “poor noise margin, no fanout, and no capacitive drive capability. But it did demonstrate speed. Unfortunately, I had no encouragement concerning the high speed, but people did want TTL flexibility.”

So it was back to the drawing board, to come up with what emerged as SUHL in late 1962. In January of the next year, he showed it to engineers at the Guidance & Control division of Litton Industries, Woodland Hills, Calif. Litton was skeptical, but thought there might be a place for Dr. Longo’s toy in the Phoenix missile, then being built by Hughes Aircraft. This application ultimately became known as the Phoenix gate, the first practical application of TTL.

“The guys at Litton didn’t believe that the circuit would do all I claimed for it, and they demanded to see the circuit diagram,” Dr. Longo recalls. “I refused until they gave me a purchase order at $300 a part. Then they turned around and put the circuit out for bids to the whole industry. They got 7 bids and made 4 awards. So now Fairchild, TI and Transitron had it as well as Sylvania.”

The Phoenix Gate (no relation to Motorola in Phoenix) and its promotional value, however, and “the SUHL family was on the road by the fall of 1963.” A few months later, in February of 1964, Dr. Longo hit the road himself, moving over to Transitron, first as director of ICs and transistors, and later as general manager.

Sylvania and Transitron had a cross-licensing deal, plus mutual shares of the Longo reputation, which gave them a big head start in the TTL market. Even today, Dr. Longo is proud to note that SUHL is the only standard TTL to get designed into a computer mainframe (GE- 600 Series) in the United States, at Honeywell Information Systems, Phoenix (Formerly General Electric). Although the competing TI 7400 Series is in a couple of European systems, it has yet to make a U.S. mainframe.

[Found in Stanford University Library, Terman Archives SC 160 Series XI Folder-semiconductors]

For more information visit:
http://www.computerhistory.org/semiconductor/timeline/1963-TTL.html