A letter from Robert H. Norman to his nephew Kevin on his introduction to electronics and subsequent contributions to the development of Micrologic integrated circuits at Fairchild Semiconductor

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Dear Kevin,

Thank you for your letter. There is growing attention to the work we did in developing Micrologic 50 years ago. It has been described as the beginning of Silicon Valley. It surely was an important part of the beginning. I think of it being an effect rather than a cause. In my mind the inspiration and the execution which created Silicon Valley and the huge industry it bore were the inspiration and execution of Bob Noyce. His personal management style which encouraged others of his highly skilled staff to cultivate, grow, harvest and replenish the seeds he planted may have asked too much of some, but the ninth biggest economy in the world is not bad.

Your great grandfather, Leftenant [1] "Red" Norman, who named your grandfather, Russell, flew in World War I for Canada, was shot down, (wore a perforated metal sleeve on his leg for over 10 years), studied engineering at Carnegie Tech while working in a steel mill and invented the push button radio, among other things. So you see, the gods had my future decided early.

By the time I was 11 or 12 I was fooling around with junked radios. About that time I had read the Radio Amateurs Handbook cover to cover. I passed the Eddy test in high school and went to Radio Technician training courses in the Navy. I went to sea on the battleship "Alabama". After the war I finished high school, then studied Electrical Engineering at Oklahoma A&M College. I was a junior when I was recalled by the Navy Air Reserve at the beginning of the Korean War. Education stood me in good stead as an Aviation Technician in a patrol squadron. We flew 19 hour patrols every other day. In between we had to get our aircraft "UP". We would often spend long hours searching for problems with radar, communications, electronic countermeasures and bombing and navigation equipment. I resolved to use my education to develop reliable electronics after I got out. I earned a summer job at Sperry Gyroscope Company in 1953 after my junior year and returned to Sperry after graduation. I was hired as the transistor person in the Digital Section of Advanced Weapons R&D.

I started evaluating the only available transistors, Western Electric type "A", point contact transistors, which were manufactured in a tar filled metal cartridge. The technical literature consisted of the Bell Labs papers in the November 1952 Proceedings of The IRE and a large gray book called *The Transistor*, published by Bell Labs, which was a number of papers written by their engineers.

At the same time I was working on the team developing and programming Sperry's first digital computer, SPEEDAC, for SPErry Electronic Digital Automatic Computer, which featured Plug-In Modules which included vacuum tube flip-flops and gate trees with lumped constant delay lines to avoid race conditions. Memory was a rotating magnetic drum, containing 2000, 18 bit words. The vacuum tube Write Amplifiers for the tracks containing microcode were removed so that those tracks could not be contaminated. We programmed the computer in a form of Assembly Language. I developed and ran the first successful program which did statistical data reduction on the transistors we ultimately used to build reliable military transistorized computers. As part of our job we promulgated the techniques we had developed throughout Sperry with the result that Sperry engineers developed several reliable transistorized computers on military and commercial contracts.

We began to use silicon transistors from the newly formed Fairchild Semiconductor in high-performance, high temperature (aircraft) applications. We were impressed with Fairchild's then unique dedication to on-time delivery and transistor reliability. (Fairchild had been qualified as a supplier for the Minuteman ICBM.)

Fairchild hired one of my top engineers who in turn recommended me for a new enterprise, integrated circuits

Digital computers used thousands of transistors, exacerbating any reliability problems with the individual transistors, their associated diodes, resistors, capacitors, and the interconnections among them. A company called (Ford) Aeronutronics in Orange County, California, developed something called Core-Transistor logic which they described at the 1955 IRE Solid-State Circuits Conference. Logic was performed at the input to a transistor which in turn switched a saturable core the sensed output of which was the input to the next transistors/core pair. Deleting the cores led me to a simpler logic structure using simpler more consistent and robust components, called Transistor Resistor Logic or NOR logic which was patented by Sperry Gyroscope.

The promise of integrated circuits at the time was the use of many fewer functional blocks to fabricate computers. However if you peered into these "integrated circuits" you would find all of the discrete components as before usually in different forms. The popular approaches, RCA Micro Modules and Sippican Welded Cordwood Modules were assemblies of discrete components encapsulated in plastic. Even TI's "integrated circuit" consisted of a silicon bar with a transistor at one end, the rest of the bar constituted a resistor, and a bunch of bonded wires to make a simple circuit.

When Fairchild invited me to Palo Alto to meet with Vic Grinich and Bob Noyce, Fairchild's Jean Hoerni had invented planar transistor technology which Bob described to me as the ability to build silicon transistors underneath an oxide surface which in turn could be used as a substrate for interconnecting components using their metal over oxide technology. I was asked my thoughts on how to use their capability to build digital integrated circuits. I recommended a form of DCTL which emulated the Philco DCTL we were building for high speed (10 MHz) applications at Sperry. We had excluded some circuit configurations which were less reliable, such as series gates.

I was hired to work for Vic Grinich running Device Evaluation Engineering. Our job was two-fold, evaluating new semiconductor devices being developed in R&D and developing the first monolithic (one rock) integrated circuits. My Section's job was to define the circuits, the logic to be implemented, the packaging, the testing and application support. We also conducted the test-to-failure and failure analysis programs which brought the reliability of Fairchild products including integrated circuits from 10,000 hour MTBF up to 10 million hour MTBF. The consequence was recently described in the book, "Digital Apollo" by David A. Mindell. To paraphrase, the Command Module and the Lunar Excursion Module of all manned Apollo flights used a Micrologic/Milliwatt Logic computer. with no failures. The rest, as they say, is history.

The work at that time was performed by a remarkable aggregation of wonderfully talented people under Bob Noyce. I wonder if such circumstances can obtain again. Sometimes I think we might have done more, but, what we did do was pretty good.

Love,

Great-Uncle Bob

[1] Leftenant was the British designation at that time.