# *Genesis: A Silicon Valley Tale*

TECH HISTORY ARTICLE BY DR JEFF DROBMAN

*Highlights*

- **Fairchild founding**
- **Intel founding**
- **AMD history**
- **AMD – Intel rivalry**
- **Search for CMOS**
- **RISC CPU Architecture**
- **Legendary Parties & Conferences**
- **Anecdotes**
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- **Process Technology Evolution**
- **Anniversaries of Technologies**

## Preface

*[This article chronicles the founding and early history of this storied high-tech region of the San Francisco Peninsula – the halcyon days of chip Camelot. I have employed an AMD/Intel emphasis, since that rivalry is perhaps the most legendary and lasting, and all of their founders came from mother chip company Fairchild.*

*This article represents my personal observations, opinions and later reflections – sprinkled with names, dates and facts. I apologize in advance for any inaccuracies, as most of it comes from my quite fallible memory.*

*Moreover, I have a rather unique perspective, being both an outsider and an insider at the same time, starting in 1965. My sister married AMD founder WJ "Jerry" Sanders III when he was a sales manager with Fairchild. I was a junior engineering student at UCLA staying at their beach house in Malibu when plans for AMD were first being considered by the group of 8 from Fairchild. I actually did work for AMD during 1979-82, a period that would change AMD forever, due to the intro of the IBM PC.]*

## The Legend

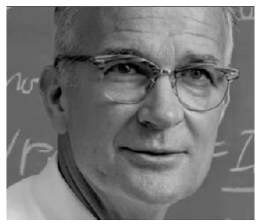
It has long been *legendary* that companies in Silicon Valley got started in garages and beach houses, and I am setting the record straight: *It is true*. **Apple** was started in Steve Wozniak's garage, when friend Steve Jobs came by and saw his hobby computer. **Advanced Micro Devices** (AMD) got its start in founding president Jerry Sanders' rented Malibu beach house, on a chilly December evening in 1968 – though the house was heated considerably by those entrepreneurial fires. AMD was incorporated 5 months later (May 1969).

## Historic Fairchild – the Mother Company

- **In the Beginning … Fairchild**

The archeological origin of Silicon Valley really is Stanford University in Palo Alto. That is where Bell Labs' transistor co-inventor and Nobel Prize winner William Shockley took up residence as an electrical engineering professor. Prof. Shockley immediately founded his own company, Shockley Semiconductor, nearby, ca. 1954. He recruited the brightest PhDs he could find to populate his R&D company, chief among them were Drs. Robert Noyce, Gordon Moore, Jay Last and Jean Hoerni. They all worked together on finding ways to make transistors practical to manufacture in mass quantities, and using more robust silicon instead of the then prevailing germanium.

But over time the bright young (under 30) group of engineers and physicists grew unhappy working for an imperious Shockley and under rigid working conditions. Back then, it was unheard of for professionals to leave their employer for any reason. But, in October 1957, the so-called "Traitorous 8" group of electrical engineers, led by Noyce, left Bill Shockley to create Silicon Valley's first *spin-off*, Fairchild Semiconductor. The group of 8 founders included: Gordon Moore, C. Sheldon Roberts, Eugene Kleiner, Robert Noyce, Victor Grinich, Julius Blank, Jean Hoerni and Jay Last (photo below).



Wm. Shockley


The group of 8 had first contacted East Coast investor (early VC) Arthur Rock to find a company that would hire them intact as a group, but Mr. Rock convinced them to try to form their own company. Rock set out to find funding for a new start-up, and finally succeeded with the founder of Fairchild Camera & Instrument Corp., Sherman Fairchild (whose father was a co-founder of IBM). The new enterprise was formed as *Fairchild Semiconductor* -- a division of Fairchild Camera & Instrument Corp.

### ❖ On a Parallel Track … TI

Meanwhile, back in Austin, Texas, a similar "instrument" company called Texas Instruments ("TI") had become a high volume manufacturer of discrete germanium transistors, and was proceeding on a parallel track to race Fairchild in semiconductor device design, process development and manufacturing.

At TI in 1958, Jack Kilby had become the first to engineer a way to interconnect multiple devices (transistors) on a single semiconductor (later silicon) chip, via external explicit gold wires hand connected. Fairchild's Bob Noyce improved on that by making the interconnects truly *integrated* onto the chip surface via use of an insulator ($SiO_2$) under a layer of metal deposition. Noyce thus truly invented the *integrated circuit* (IC), but TI's Jack Kilby claimed the same based on his earlier design. After years of legal battle, TI and Fairchild agreed to be co-inventors and co-licensors of the basic IC design.

It is also worth noting that TI long since copied Fairchild's university propinquity and synergy model by turning the University of Texas at Austin into its version of Stanford – as a conduit of top electrical engineers. But enough about TI (for now).

### ❖ Motorola's Hogan's Heroes

Meanwhile, back at Fairchild Semi, ca. 1968, a new management team was brought in from fellow pioneering semiconductor company, Motorola. (Yes, Motorola is now known as a cell phone maker, but originally it was one of the three IC pioneers.) This team was called "Hogan's Heroes" – led by Dr. C. Lester Hogan (who remained Fairchild chairman for a few years).

Wilfred J. ("Wilf") Corrigan was a marketing manager in this group. He became one of Jerry Sanders' closest, most respected, lifelong CEO friends ever since those "Heroes" days. (Their wives also were lifelong friends, and their families shared many vacations over the years.)

After a few years at Fairchild, Wilf ousted Dr. Hogan in a corporate boardroom coup, and took over as chairman/CEO of Fairchild Camera & Instrument Corp. – where he remained at the helm during Fairchild's heyday.

At some point, after years of brain drain, it became clear that Fairchild needed to be sold, and Fairchild was being sought as a takeover target. Ca. 1980, Fairchild Camera & Instrument Corp. was sold to French oil drilling conglomerate Schlumberger. *Fairchild Semiconductor* was eventually re-spun out 20+ years later, and trades today under the symbol "FCS".

### ❖ Big Bad Wilf – Goes to LSI

Wilf left Fairchild with a "non-compete" clause, as is typical. Searching for his next thing, Wilf came up with the concept of "semi-custom" ICs -- aka "ASICs" (application specific ICs) -- and launched **LSI Logic** in 1981. Wilf was the founding chairman/CEO of LSI Logic, where he remained for 22 years, until his retirement in 2003.

LSI Logic was unique in that manufactured under license two of the top RISC microprocessors: Sparc and MIPS. LSI became the major supplier to Sony's Playstation due to Wilf's forging a strategic relationship with Sony. Wilf claims LSI shipped over 100,000,000 MIPS microprocessors to Sony.

Today, Wilf is retired from the board of LSI, and several other corps. (including Lucas' ILM, Brooktree, et al.).

*[Ed note: I fondly recall sitting at sartorially impeccable Wilf's elbow (with his cigar in one hand, a drink in the other) in the 1970s, and listening to his stories. Wilf was always generous to me with his time and candor, and he was always dressed as if he were about to meet the Queen. Well, in a way he was: Jerry and wife Linda comported themselves as the King and Queen of Silicon Valley in those days. Linda and Wilf's wife, Sigrun, had also been lifelong friends, even though Linda and Jerry divorced back in 1982. Addendum: Sadly, Sigrun passed away in 2008.*

*Update:* Wilf now travels the world on a 644 foot, 12 deck, condominium/residence cruise ship he owns a share of, called "The World" (Norwegian built; registered in Nassau, The Bahamas; commissioned in 2002). *I traveled (Oct 26-Nov 4, 2010) with Wilf, and my sister Linda, on The World, from Charleston, SC to Savannah, GA to Cape Canaveral, FL for the Space Shuttle launch, which was postponed. I later had a second voyage on The World touring 4 Hawaiian Islands in June 2012.]*

## Intel History

### ❖ Along Came Intel

In early 1968, Intel was founded by legendary semiconductor process engineers Bob Noyce and Gordon Moore. The duo left parent and industry mother company, Fairchild, after being rebuffed on their wants and needs for managing the Semiconductor division. They were suffering a brain drain, with so many new startups luring their engineers away with stock options, which Eastern Fairchild management was not willing to offer. It became clear to the duo that they could only succeed further once again on their own – this time, completely on their own.

By that time, 1968, getting venture capital was common. Intel had raised enough capital to last for 2 years, so they needed to be in production on new products by 1970.

### ❖ Intel's First Products

Intel set out to develop a process capable of the next generation of circuit density, called "LSI" (>1000 transistors). That process needed to be denser in area and lower power than the mainstream process, "bipolar" (using "bipolar" transistors). Noyce and Moore came up with "MOS" (Metal-Oxide-Semiconductor), a so-called "field-effect", rather than "junction", transistor structure to satisfy both goals of density and power. MOS was also a highly *scalable* (shrinkable) process, and thus, has lasted to this day (albeit in an evolved form, called *CMOS*).

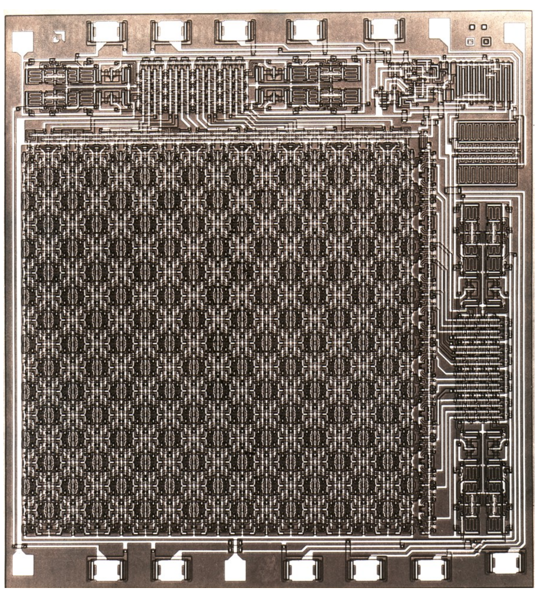
Intel's first product was the IC industry's first ***LSI*** (>=1000 transistors) ***MOS RAM*** chip – the ***i1101A*** 256x1-bit SRAM (Static RAM). Note that each *Static* RAM bit requires 4 transistors (cross-coupled gates), while each *Dynamic* RAM bit only uses a single transistor (plus an intrinsic capacitor).

Intel then succeeded its 256x1-bit SRAM, the *1101A,* with the 1K (1024)x1-bit DRAM (Dynamic RAM) – the *1103*A, and so on. The "A" suffix on these chips signified a first *revision* to the *specifications* of the chip, but not necessarily the first revision of the *die* itself. Chip companies commonly revise a product's die design and/or process, and use a more secretive designation for that. This nomenclature was quickly and quietly adopted by the rest of the chip industry – lasting until this very day.

This basic technology ushered in the LSI era for the IC business. And for any given point in time, the number of transistors dictated the number of bits of RAM, with the 4:1 ratio of Dynamic to Static RAM always preserved.

Each succeeding generation of MOS process shrink resulted in squeezing in *double* the number of memory cells in each of the two chip dimensions (x, y), and hence a *quadrupling* (2x2) of the number of RAM bits on a chip. A very observant and astute Gordon Moore made a prediction early on in 1965 that the number of transistors on a chip would double every 12 months. Moore later revised that in 1975 to a doubling every 24 months. *Moore's Law* (see below) has held up to this day, serving as his greatest legacy.

This all serves to point out Intel's huge and lasting pioneer impact on the entire chip industry. Pictured below is a die photo of AMD's version, the Am1101A, ca. 1972. One can readily see the 16x16 RAM cell array producing 256 bits. Also pictured below are Bob Noyce and Gordon Moore. Sadly, we lost Bob Noyce in 1990 (1927-1990).

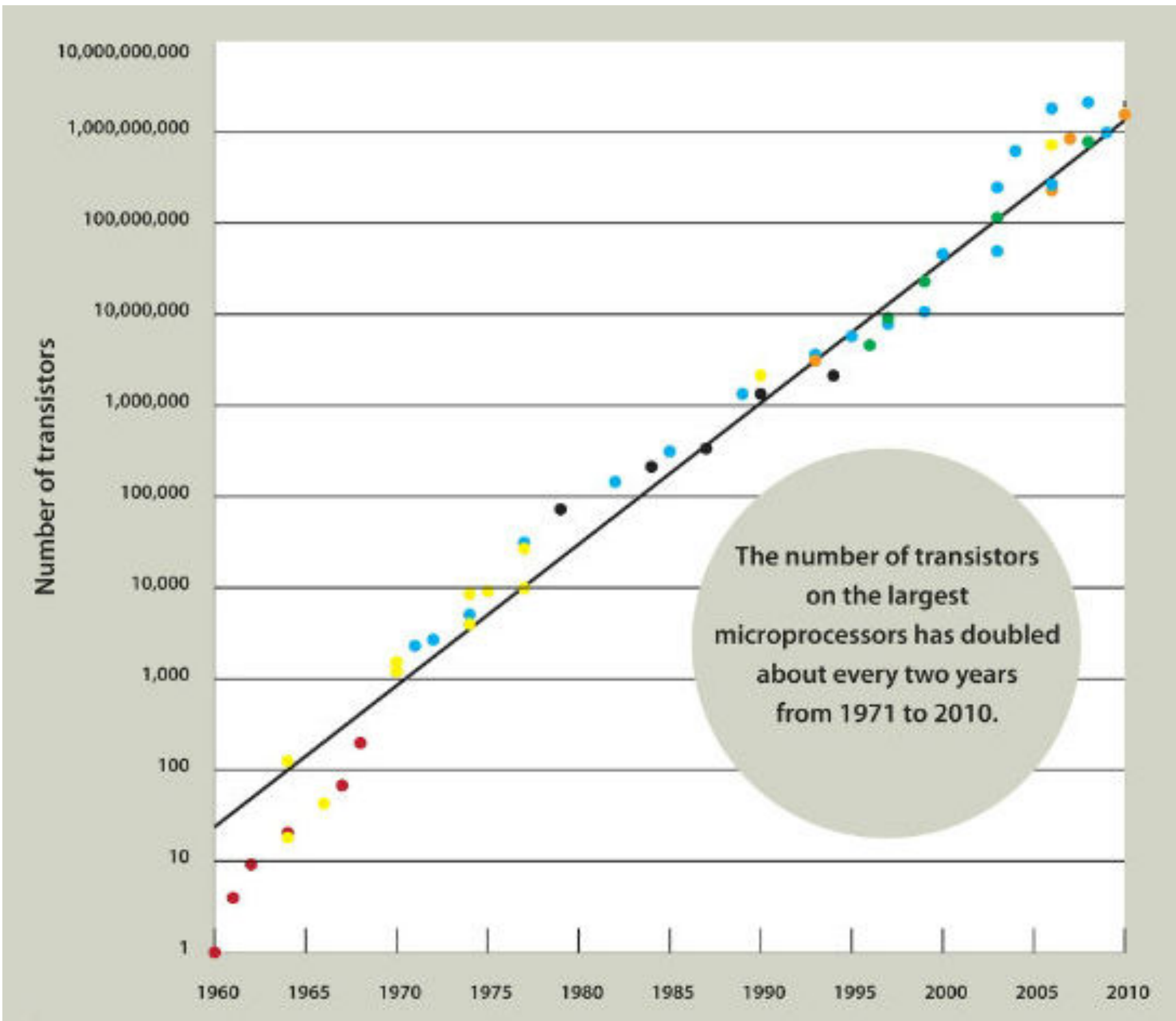


Am1101A (ca. 1972)

Bob Noyce

Gordon Moore




### ❖ Moore's Law

*Moore's Law* is simply this: The number of transistors on a chip *doubles* every 24 months. The extensions of his law are as follows:

- Process shrinks occur every 2 years
- It takes 4 years to *quadruple* the number of transistors, so …
- It takes 4 years to produce the next generation of chip (with 4x RAM)

### ❖ The First Microprocessors

Intel also pioneered the world's first standalone ***microprocessors*** (i.e., a complete *processor* on a single chip). There were other *components* that could be assembled into a *microprocessor*, such as so-called *bit-slice* elements, but these microprocessors were the industry's first to feature a complete fixed instruction set implemented on a single chip.

It is a legend that Intel first designed these chips for a Japanese calculator company, and/or as *programmable logic replacement* parts for terminal maker Datapoint Corp. of Texas. The idea was that any chip could be programmed *permanently*, rather than for one clock period, to act as a certain function, such as an *adder*. Or, it could be programmed in the traditional sense to be a more complex function. However, once it was used to implement an entire algorithm, it became a *microprocessor* rather than a *programmable logic* part. (And the world has never been the same since!)

The first part was the 4-bit ***i4004***, introduced in 1971. (That was the date on the *Preliminary Data Sheet* I was given to run ISA simulations on at UCLA as grad student at the time.) It was shortly followed by its 8-bit counterpart, the ***i8008***. I believe the only difference in the two parts was the data bus width being 4 or 8 bits (both internally and externally). They had the same basic instruction set, capable of handling *data* as 4-bit *nibbles* or 8-bit *bytes* (only).

The *addresses* were limited (I think) to 8-bit at first, but extended to 16-bit by the next gen part, the ***i8080***. The i8080 was the first truly widely used (successful) *microprocessor* in the world. Its next gen became the ***i8085*** (ca. 1976), which carried some minor enhancements.

Finally, its next gen resulted from a spinoff – when lead chip architect Bernard Peuto left to startup ***Zilog*** with Manny Fernandez at the helm (ca. 1975). Zilog's first product became the most pervasive, long-lasting 8-bit microprocessor ever – the ***Z80***. The Z80 is the only such chip product still in use today! (See Z80 *Anecdote*.)

### ❖ The Intel 8080 Legacy: Backward Compatibility vs. Computability

Intel has maintained backward compatible processor *ISA* (Instruction Set Architecture) all the way back to the original 8-bit ***i8080***. That is, Intel has guaranteed that all programs written for the i8080, or any of its successors, will also run (or can be configured to run) on any Intel microprocessor – all the way up to the Pentiums.

The entire industry has long recognized the baggage of old architectures/ISAs – new architectures are too constrained with outdated features. Motorola cut ties with its 8-bit ISA way back in 1976 when it introduced its first 16-bit microprocessor, the ***M68000***. Zilog did likewise when it introduced its first 16-bit microprocessor, the ***Z8000*** in 1978. Intel finally gracefully cut its ISA constraints with the Pentiums, but does support the old ISAs in some modes on some models. But for the longest time, the world was handcuffed with a *logic replacement* ISA when it wanted a *computer* ISA.

Notice the part numbering: Motorola and Zilog chose to append a 0 or two to their part numbers – ostensibly to showcase the ISA change as being extensive. Intel kept the basic i8080 number for the i8085, then the 16-bit ***i8086***, and then the 8/16-bit ***i8088***; then going to a longer number starting with the 16-bit i80**1**86 – followed by the 16-bit i80**2**86 and i80**3**86, then the 32-bit i80**4**86; and finally the 32-bit i80**5**86 – which quickly became the ***Pentium*** (as explained elsewhere).

### ❖ The Three Wise Men of the Valley

Legendary AMD area sales manager [my dotted-line boss], Russ ("The Hustle") Almand, once told this fable to a UCLA class of mine: *[I was teaching computer science at UCLA at the time in 1985.]*

There once were *three wise men* at Fairchild: Bob Noyce, Charlie Sporck and Jerry Sanders. Bob was a semiconductor physics and process genius, and led Fairchild's <u>process</u> development. Charlie was great as head of Fairchild's <u>manufacturing</u>/ wafer fab operations. And Jerry could sell sand to an Arab, and thus was VP of <u>sales and marketing</u>. One by one, these three wise men left mother Fairchild.

Bob took fellow process genius colleague Gordon Moore with him to start up Intel in 1968; and Intel has been a world leader in semiconductor process technology ever since. Charlie took his wafer manufacturing skills with him to head up National Semiconductor (ca. 1967); and National has been a leader in chip manufacturing ever since. Jerry took 7 others – with a complete skill set among them – to start up AMD (1969); and AMD, as a second-source IC mass merchant, outsold everyone on similar products. You see, each company retained the mien, or bearing, of its founders to this day!

## AMD History

### ❖ The Founding (May 1969)

Shortly after Hogan's Heroes took over Fairchild, Silicon Valley legend Walter Jeremiah (W. J. "Jerry") Sanders III had been newly appointed VP of Sales and Marketing. The Hogan team, not sure what to do with the notoriously brash and eager Sanders, placed him on sabbatical. In December 1968, Jerry headed to Malibu, renting a beach house on the ritzy and famous "Colony" with his wife Linda [my sister] and their three daughters (actually two at that time). *[Ed. note: I was staying there that fateful day when there was a knock at the door.]*

Knocking on that Malibu door came two separate groups of Fairchild Semi engineers – one headed by Jack Gifford, and the other by Sven Simonsen – looking to startup another spinoff, and asking Jerry to lead them. The astute Sanders convinced both groups to join together into a single company. After receiving $600K in VC funds, and $1M in loans from Bank of America (11th hour, I might add), a group of 8 engineers, headed by Jerry Sanders, founded Advanced Micro Devices in May 1969.

The AMD 8 worked out of their garages for 6 months, until *Building 1* opened (end of 1969) at 901 Thompson Place in Sunnyvale, just off the Bayshore Freeway (US 101) at Lawrence Expressway. *Fab 1* was constructed at *Building 1* a short time later. Wafer fabs in those days were not nearly as complex as today's (using 2-inch wafers). AMD's *Fab 1* cost roughly $1M (the entire B of A investment), while today's fabs cost 1000 times that, or $1B.

The 8 AMD founders boasted that they would be in production on both analog/linear ("LIC") and digital MSI (2$^{nd}$ gen digital) products out of Fab 1 by the end of their first year. (I believe they just made it.) (Pictured below are the 8 AMD founders in group photos: the groundbreaking, and 2 magazine ads.)


mag photo

groundbreaking


❖ **AMD Founders**

The 8 AMD founders, all Fairchild engineers, are listed here:

1. **Jerry Sanders** – *Chairman, President and CEO* (remained in those positions until the twilight; retired in 2002 at age 65)
2. **D. John Carey** – *Dir Digital Operations* (left to be CEO of Integrated Device Technology ca. 1980)
3. **Edwin J. Turney** - *Dir Sales and Admin* (left in 1974, to be replaced by "Z") [b. 1929-- d. 2008]
4. **Sven-Erik Simonsen** – *Dir Engineering, Digital Operations* (remained for many years) *[Ed. note: my direct boss]*
5. **John "Jack" Gifford** *Dir Mktg and Bus Dev* (left to be CEO of Maxim Integrated Products; BS UCLA 1963, MS UC Berkeley [b. 1941--d. 2009]
6**. Jim Giles** *Dir Engineering-Analog Operations*
7. **Frank T. Botte** *Dir Dev-Analog Operations*
8. **Larry Stenger** Managing *Dir-Analog Operations*

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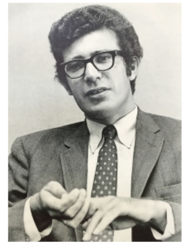
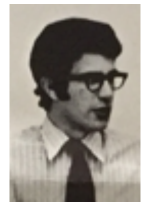
**WJ "Jerry" Sanders III (b. 9-12-1936 )** – *Chairman, President and CEO*   

As stated in the ad, Jerry spent his first 8 years in semiconductor IC sales and marketing, after graduating magna cum laude from the University of Illinois in electrical engineering. Jerry's first job was a brief stint as a design engineer for Douglas Aircraft in Los Angeles. Jerry early on got the "sales" itch, and went to work as a Sales Engineer for Fairchild (ca. 1960) in the Los Angeles area. Jerry got promoted to District Sales Manager and opened an office in Hollywood. There, he worked with Ed Turney, his first Sales Engineer. After the Hogan takeover of Fairchild in early 1968, Jerry was first promoted to Director of World-wide Marketing, and then VP of Sales and Marketing. By Dec 1968, Jerry was placed on "sabbatical", after which he rented that famous beach house in Malibu (Malibu Colony). It was then that Jerry decided to startup a new company – and the rest is history (as documented herein).



John Carey c. 1970.



**John Carey (19xx – 2017)** – *Dir Digital Operations*

I was reunited with John Carey as my CEO at Integrated Device Technology (IDT) in May 1988, coming full circle on being a chipmaker's FAE for microprocessors. John Carey had left AMD to become yet another tech investor, and his pursuit led him to fund three H-P CMOS engineers to start up IDT as a CMOS SRAM fab in 1980. When IDT looked to broaden its offerings from pure memory to logic, John Carey recruited his prized AMD microprocessor and logic manager, John Mick (creator of the Am2900 family), and his lieutenant, Michael Miller (see more on them below).

Mick-Miller first redesigned the 2900 family in CMOS, and then added other logic, memory and data conversion products in prolific fashion (producing 8 product lines). John Mick also recruited some of AMD's best 2900 family FAEs, including my friend Barry Fitzgerald, and their attendant sales managers. It was Barry and SW Area Sales Manager Larry Sebben who hired me, after recruiting several other AMD sales managers – thus reuniting me with Mick-Miller, John Springer and other ex-AMDers from Mick's group. I consider IDT a "spinoff" of AMD based on such a large contingent of top managers taking over IDT at its nexus.

At that time, in 1988, IDT had made a significant decision to become one of three domestic licensees of the MIPS RISC microprocessors. IDT hired me to once again help with the microprocessor tech support. (I remained an IDT Sr. FAE until 1997.)

John Carey remained as Chairman at IDT for many years. Sadly, we lost John Oct 19, 2017.

**Ed Turney (1929 - 2008)** – *Dir Sales and Admin*

Ed Turney had worked for Jerry Sanders in the Los Angeles sales region of Fairchild before AMD was founded, and the two were good friends. So, when AMD was founded, Jerry invited Ed to be head of sales, and one of the original 8 founders. Ed passed away October 15, 2008, at age 79. From his obituary article:

*When Advanced Micro Devices (AMD) was formed in 1969, Turney did not start off using his reputation as Fast Eddie, the super salesman. Although as Director of Sales he had the job of developing a sales organization. Jerry Sanders, Advanced Micro Devices founding CEO, gave him the immediate tasks of buying equipment and constructing the factory including the company's first fabrication area and of building a network of electronic distributors, which was vital to the company's survival against established producers such as Intel, Fairchild, National Semiconductor, Texas Instruments, Motorola and others that no longer exist.*

*Turney "was instrumental in our securing the best distribution network in the United States," said Sanders, now retired. "He built those critical relationships at the distributor level that were key to our business."*

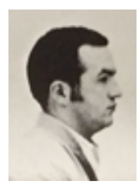
 

*In 1963 Turney met Jerry Sanders who was a regional sales manager in the Los Angeles area for Fairchild Semiconductor, a division of Fairchild Camera and Instrument Corp. Turney joined Sanders and Fairchild, starting a relationship between the two that was to last a dozen years. "Ed was a hot-shot salesman who would get the order through the force of his personality and drive," said Sanders. 'With dogged persistence and great determination and will Ed stood toe-to-toe with guys with more education and made a great a success for himself in the semiconductor industry.*

*Twice Turney would hire Stephen Zelencik, first at Fairchild and later at AMD. Zelencik remembers Turney as "one of the most demanding people I've ever met. If he wanted to talk to you about a customer or a piece of business, he'd hunt you down; call you in the middle of the night, whatever it took to reach you. And then he'd yell." Turney was "honest, hardworking and a very generous person," added Zelencik, a retired AMD Senior Vice President.*

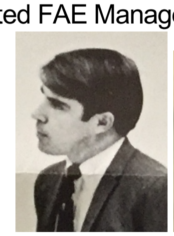
*In late 1974 Turney parted company with Sanders and Advanced Micro Devices. He went on to a succession of small semiconductor manufacturing and distribution companies very often run by people he had worked with at Fairchild. In his later years he was a consultant to firms trying to get started or funded. "But he never again reached the heights that he had attained at Fairchild and AMD," Zelencik said. "He spent the last 30 years of his life looking for the next big one – seven days a week, 24 hours a day. That being said," Zelencik added, "Ed Turney was a great guy."*

*"Ed was first and foremost a sales guy," said Marshall Cox, a semiconductor salesman and executive who knew Turney 45 years. "He was classic Brooklyn; fast talking, high energy, a play-hard-work-hard kind of guy that was on top of every aspect of every piece of business. He knew how to get the business. He made his mark and we'll remember him for it." [ed. Note: I spent a weekend as Ed's guest waterskiing with him at Lake Arrowhead, CA in 1969. RIP, Ed.]*



**Sven-Erik Simonsen** – *Dir Engineering, Digital Operations*

Sven held the secondary position of being in charge of all the "FAEs" (*Field Applications Engineers*, of which I was one, along with legendary AMD FAEs Barry Fitzgerald and KC Murphy). Hence, Sven was my/our direct boss. Each FAE also reported indirectly "dotted line" to an Area Sales Manager (mine was legendary SW Area Mgr, Russ Almand). Sven assigned John Mick to training us FAEs (twice a year conferences at HQ), with help from our Customer Education Dir, Dr. Donnamaie White. Sven eventually abdicated this FAE duty by assigning it to Peter Alfke [now 86 years old, born 11/26/1931, and currently lives in Los Altos, CA], who also was a chief digital design engineer. Peter abdicated by hiring a dedicated FAE Manager, Rick McCarthy.



**Jack Gifford (1941 - 2009)** – *Dir Mktg and Bus Dev*

[excerpted from Jack's memorial biography]

*Jack Gifford attended UCLA on a baseball scholarship and earned a BS degree in EE in 1963. Jack joined Fairchild Semi in 1964, and became its first Director of Analog Products. Jack co-founded AMD in May 1969, and served as VP of Marketing and Planning. He left AMD for Intersil to be SVP, then president/CEO. "Jack is considered to be one of the 'founding fathers' of the analog industry."*

*Jack co-founded Maxim Integrated Products in April 1983, serving as president. Jack became chairman in 1991, and retired in 2007 holding all 3 top positions.*

*Jack loved to play baseball. In 1990, Jack was elected to the UCLA baseball hall of fame. Just before his* *death, Jack donated funds to construct the "Jack and Rhodine Gifford Baseball Training Facility" at UCLA's Jackie Robinson Stadium.*

[ed. Note: I attended the dedication at UCLA on Feb. 6, 2009, shortly after his death on Jan. 11, 2009.]

- ❖ **Significant Others**

The first significant hires, ones that stayed to make great contributions to AMD, were these engineers:

1. **R. Clive Ghest** -- Initial head of digital logic products; designer of AMD's first proprietary logic product of note, the Am2505 (2x4-bit, two's complement *aX+b* multiplier module, ca. 1971). *[Ed. note: I did my master's thesis at UCLA on applications of this chip, with Clive's help; this work was used by the US Navy in signal processing modules.]*

Clive originally joined AMD from Fairchild in 1970. Badge# 65? Worked as applications engineer, test engineer, sales associate, etc. Did product planning on MSI and Microprocessors. Short stint with MMI both here and Europe on product planning and design of Multipliers, Microprocessors and PALS. Rejoined AMD as European FAE Manager. Came back to California to run Product Planning for MOS and Analog. Then Director and VP of Product Planning and Applications, followed by VP of Strategic Marketing and Business Development.

2. **Stephen ("Z") Zelencik** -- Initially *Western US Area Sales Manager*, but soon replaced Ed Turney as *VP of Sales and Marketing*, and remained in that position for over 30 years. The beloved "Z" put his stamp of style and grace on the sales team. "Z" was responsible for putting on the most lavish sales conferences and parties ever held (see separate section below). AMD had the only sales fleet that drove exclusively German luxury sedans. *[For example, in 1981, I was told to buy a Mercedes sedan (all sales cars had to be 4-door), although a BMW would do; so I ditched my Alfa Romeo Spyder and bought my first bimmer, a classic boxy 528i. "Z" was also largely responsible for my hiring, and for that I am grateful; I always considered him my ultimate, and kindest, boss.]*

3. **John Mick** – Joined AMD ca. 1974; worked with Clive Ghest, and then later took over the digital group. John's background in DSP led him to extend Ghest's early work into the most significant proprietary products for AMD, and among the most innovative ever: the Am2900 and Am29000 MPU families. Widely known in the late 1970s as being the chief author of the *Mick and Brick* book (co-authored by colleague Jim Brick) on the Am2900 family. Developed AMD's only proprietary fixed-instruction-set CPU (MPU) product, the RISC architectured Am29000, along with his chief lieutenant for many years, Michael Miller. John Mick also developed AMD's first and only *microprocessor development system* (for the "AMC" div.), and was AMD's chief (and most effective) technical instructor for the FAE team (field applications engineers). . *[Ed. note: I was an FAE supporting all design-in efforts for AMD/AMC for the Western US. I feel that John Mick was never given enough credit outside of AMD for his huge contributions. John was one of the few AMD elite that did not seek the spotlight. John is long retired and lives in NM.]*

4. **George Scalise** – George was brought in as a *VP of Operations* at a time when Jerry was planning major fab and T&A (test and assembly) expansions world-wide. Circa 1980, Malaysia opened the tax incentive floodgates luring nearly all semiconductor companies to build T&A plants all over Malaysia, especially in Kuala Lumpur. George did a "fab" job bringing AMD to Malaysia, and set out on other global expansion plans. However, George was lured to become head of the newly formed (1977) IC cooperative organization, the

Semiconductor Industry Assn. (SIA) – where he remained until 2010. *George will receive the industry's highest honor, the Robert N. Noyce Award, at the SIA annual dinner on November 4, 2010, in San Jose.*

5. **Peter Alfke**

Peter was an early hire as a digital design engineer and researcher, and was highly respected. Peter was assigned to manage the FAEs (as mentioned) ca. 1979-80. He abdicated this role by hiring a dedicated manager, Rick McCarthy ca. 1980. Peter could always be seen with a pipe in his mouth.

### ❖ Cronies

Jerry always ruled AMD with an iron hand. Those that disagreed too much, left (see founders above) -- my way or the highway. (Jerry out-survived all of the other 7 founders at AMD.) So early on, the climate was ripe for the longevity of the *cronies*. The most significant of those ever so loyal to Jerry (after all, Jerry made them very rich, and never mess with the golden goose), were these folks:

1. **Ben ("Benji") Anixter** [d. 2017] – Ben was one of the first product marketing managers at AMD, at first for memories (bipolar and MOS), and later on moved onto corporate marketing. "Benji" was one of Jerry's pals. I was never quite sure what Ben did, or what his title was, as he kept in the corporate background. *[No, Ben and Jerry did not form an ice cream company, but together they made cool chips – and kept AMD "cool."]*

In his own words:

*I joined AMD in 1971 as the digital products product marketing manager after working for Fairchild Semiconductor (the original) for nine years. I had numerous jobs in product marketing until the late 80s when Jerry wanted me to take over corporate communications, Advertising, PR governmental and industry affairs, investor and community relations. Retired now but it was a great ride.*

Sadly, we lost Ben July 30, 2017.

2. **Rich Previte** – Rich was CFO (and I think *Treasurer*) for most of AMD's life. He managed to keep out of the huge spotlight cast by Jerry, and stay in the shadows to some extent. Rich was promoted to *President* and *Chief Operating Officer* much later (ca. 1992), after the AMD board made Jerry give up one of his 3 hats (Jerry kept CEO and Chairman titles).

*[One could consider Steve "Z" a Jerry "crony" for his longevity and closeness. But, "Z" was a highly visible and valuable member of AMD's team. In fact, "Z" should have been named an honorary "founder" of AMD.]*

### ❖ Other Important AMD Contributors Who Have Passed Away

- **Bill Harmon** [d. 2011]

From Paul Chu:

*Bill hired me from Fairchild ( where I worked for Kris and then Kris moved to Marketing) into AMD. Bill was my boss for many years in AMD Product Planning. He was Mr. 2900 - the flagship bit-slice microprocessor family at AMD. He* *designed the 2903, 29116 and several other chips. I learned a lot from him. One of the great visionary things he did was sponsor the Am29000 development for 2 years, under the radar, when he saw the conviction of the team working on the project, and saw the potential of what it could be. So when Sanders finally approved the project, we were almost at the last leg of the development. Bill was always a gentleman and gave you a lot of flexibility to do your job.*

- **Leo Dwork** [d. 2011]

[Obit] *Leo was born in New York on a summer day in 1920. He married his school sweetheart Beatrice, served in the US Navy and embarked on a career path that helped create and transform the semiconductor industry.*

*With a B.E.E. and M.E.E at hand, Leo started his career teaching electrical engineering in NY. He was very active in the IEEE societies and even worked for the RCA institute of electrical technology. His path to semiconductors started in 1953 when he joined Sylvania in Ipswich, MA. After a few years he went to CBS-Hytron and then to Motorola in 1958 where he was part of the group that pioneered the development of planar epitaxial transistors. He later became group Vice President and Director of Product and Operations Groups. In the late 60's the semiconductor industry was still relatively new and growing; aggressive and restless young men formed new companies that focused on integrated circuits instead of transistors. Leo and other Motorola executives followed Dr C Lester Hogan and became "Fairchildren". It was quite a change moving to a startup in Mountain View, working long days and playing hard at night. This is where he met Jerry Sanders who was then WW Director of Marketing and Sales. In 69 Jerry left Fairchild to found AMD, while Leo stayed for several years before joining Jerry. At AMD Leo negotiated the 5-year patent cross-license agreement with Intel and the rest is more recent history …*

And this fond memory of Leo from Wilf Corrigan:

*I went to work for Leo directly in 1962, when I was given the job running Silicon Transistors. Leo was essentially the #2 man at Motorola at that time. He was responsible for all Transistors, Germanium, small signal, Power,and Silicon, also Integrated Circuits. He was very much a mentor to me professionally, and Bea and Leo were mentors to us as a couple socially…. They introduced us to Football games (ASU), and essentially gave us basic training in how to be members of the top management hierarchy. When Les Hogan became CEO of Fairchild, Leo and I, and several other Motorola people moved with him. I remember him as a very warm, very wise friend, who made a big difference in my life.*

### ❖ AMD History – The First Decade (1969-1979)

AMD was founded with the mission of being a "second-source" company (to Fairchild initially), to make "pin compatible" replicas of popular chip products. Its first products were indeed functional, electrical, pinout and package copies of Fairchild's Linear (analog) ICs, such as operational amplifiers. AMD also formed a digital logic group (see below).

AMD, being a second source company, needed to assemble a top-notch sales team to be able to compete with Fairchild, and later, Intel. That task was initially Jerry's and Ed Turney's. After Ed Turney left AMD, he was replaced by Terry Jones, VP of Marketing; and in 1977, Steve Zelencik ("Z") was promoted to National Sales Mgr. A year or two later, "Z" replaced Terry as VP of Sales and Marketing -- where he ruled the AMD sales world until his retirement a few years ago.

Early on, AMD had organized US sales fIirst into 3 "areas" (East, Mid, West) and 6 "regions" (East N/S and Mid-Atlantic, Mid-Am, West N/S) and appointed 3 Area Sales Mgrs: Steve Marks (East), Chuck Keough (Mid-Am), Steve "Z" Zelencik (West), with these 5 regional sales mgrs.: Paul Macdonald (NE), Bill Seifert (Mid-Atlantic), Ken Smyth (SE), Shel Shumacher (NW & HQ), Russ Almand (SW). By the end of the first decade, AMD organized North American sales into 6 "areas", with these managers: Dave Chavoustie (SE), Dan McCranie (N Central), Jim Miller (S Central), Glen Balzer (NW), Russ Almand (SW); along with "regional" managers in each area, including mine in the West: Brian Curry (So Cal-LA), Bill Caparelli (So Cal-OC/SD).

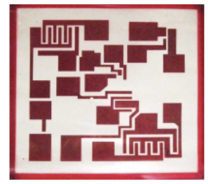
A photo of the early AMD sales team, featuring Ed Turney, Terry Jones, "Z" and Russ Almand appears here (L) and the 1972 corp team at Bldg 1 (Rt):

AMD promoted itself as a "high-reliability" mass merchant of ICs by touting it offered military reliability for no extra charge (*Mil Std 883B for free* ran their ads) -- as a means of gaining the trust of new customers, and stealing business away from their imitated rivals. AMD was able to achieve success on this unique business model by hiring and pampering the world's best sales team. *[I can say that because I was part of it, 1979-1982.]*

No company would want to be *exclusively* a second source, and so AMD set out to design some proprietary ICs. As there has generally been more room for innovation in the *digital* domain, as opposed to the *linear* or analog domain that was AMD's birthright (3 founders were linear designers), AMD pressed ahead with a new digital effort. First, Clive Ghest was hired to head the effort. His initial success was the **Am2505**, in a 24-pin ceramic DIP package to be suitable for *military* applications – the primary early target market.


Mid-decade, John Mick's background in DSP led him to extend Ghest's multiplier concept into a 4-bit DSP microprogrammable microprocessor "slice" and chip family that won over the entire industry, the **Am2900** family. The huge success of the 2900 gave AMD its first credibility as an innovator. The 2900 was designed into many DSP-based products (especially military ones) such as radars in the decade of the 1970's and early 1980's. *[Hughes Aircraft was one of AMD's biggest customers in those days. Coincidentally, I had left Hughes, where I was a Doctoral Fellow, to join AMD in 1979. I spent a lot of time at Hughes designing in the 2900.]*


Rubylith
Drobman (1968)


Cutting rubylith

## ❖ Early Chip Design – Mask Making with Rubylith

From the beginning of IC design, the entire industry used a red plastic material called "rubylith" onto which each mask was laid out by hand cutting by specialists (usually women). Here are photographs of the process, along with a top-level, metal mask.

Ex-AMD Bob Likins recently offered this observation of the mystery ruby mask:
*That would be a metal mask ruby for different sized bipolar test transistors. These were placed in various locations across a wafer so they could be manually probed with test needles attached through cables to a curve tracer for characterizing electrical performance.*

Plus this interesting story:
*Back in the day black and clear check films were shot from those ruby layers. The product engineer would then overlay these films to make sure there were no errors. It was difficult to tell the emulsion side of those films from the plain film side. This engineer OK'd the films to make masks. Everything looked OK until wafer probe when he discovered the die was a mirror image of what was designed. He realized he had checked the films wrong side up. The device was destined to be assembled in a flatpak. Realizing he could recover the error by assembling the die "up", he rebuilt the probe card, tested the wafers, assembled the die as is then had the package trimmed and formed upside down (compared to all previous products). Perfect! He later became an AMD VP.*

## ❖ AMD History – The "SIA" (1977-present)

The Semiconductor Industry Association ("SIA") was founded way back in 1977 to aid the entire industry. AMD supplied one of its key execs, George Scalise, to head it. Below is a recollection from long-time AMD counsel John Greenagel:

*August 31 [2010] will be a major milestone for the Semiconductor Industry Association (SIA) as the organization closes the doors on the Silicon Valley office and relocates its headquarters to Washington, D.C.*

*Jerry Sanders was one of five co-founders of the SIA back in 1977. This was a time when Japan's "VLSI Project" was making a serious bid for world leadership in semiconductors through a combination of focused efforts on advancing technology, developing extremely efficient manufacturing, and limiting access to the huge Japanese chip market. The lack of accurate and comprehensive data on the total size of the global chip market and the size of the major country and regional markets was a major barrier to understanding precisely what was going on, especially regarding the market access issues in Japan.*

*The original philosophy in keeping the SIA headquarters in Silicon Valley rather than inside the Washington "beltway" where most industry and trade associations are based was that industry leaders – including the pioneers and founders of the microchip industry – would be more effective spokespersons for the industry than hired lawyers and professional lobbyists based in Washington.*

*The relocation of SIA headquarters reflects the rapid expansion of government influence over an ever-broader range of public policy issues that affect our industry's ability to compete in a global market (in which roughly 80 percent of all chips are sold outside the US). It remains to be seen whether the top leaders of the industry will continue to be personally involved in lobbying activities in the years ahead. There is no question – at least in my mind – that SIA was able to "punch above its weight" (to use one of Jerry's favorite expressions) because it relied so heavily on top leaders of the industry to articulate their concerns to Washington policymakers.*

*When the San Jose office closes next week, it will mark the end of my employment at SIA. It's been a great privilege and pleasure to work with George Scalise and the rest of the SIA staff for the past seven years. Working at SIA also provided a great opportunity to work on the same side with some great people at Intel and other companies that* *competed with AMD. I will miss all of this and hope to find some way to stay involved with the industry.*

*In case you missed, George will receive the industry's highest honor, the Robert N. Noyce Award, at the SIA annual dinner on November 4 in San Jose. No one deserves it more!*

Finally, from the SIA itself:

*The SIA is the voice of the U.S. semiconductor industry, America's number-one export industry over the past five years. SIA seeks to continue U.S. leadership in this critical sector that employs 185,000 people in the U.S., and provides the enabling technology for America's $1.1-trillion high-tech industries with a U.S. workforce of nearly 6 million people. More information about the SIA can be found at* www.sia-online.org

### ❖ The Z8000 (1978)

In 1978, Intel was the industry leader in microprocessors, with their 8-bit (i8085) and 16-bit (i8086) CISC MPUs -- though there was stiff competition from the likes of Motorola (M6800/68000) and even Intel spinoff Zilog (Z80/8000). Apple had designed the M6800 (actually a derivative, the 6502) into its flagship Apple II PC, while the Z80 became ubiquitous in a rich segment of the market known as *embedded control*.

AMD, meanwhile, led with its proprietary Am2900 4-bit slice family into the embedded control market, but covered its bases by licensing all of Intel's other MPUs, including the 8-bit i8080, i8085, i8048, i8051.

At the beginning of 1979, AMD decided to license as its 16-bit microprocessor the **Z8000** from Zilog, rather than the industry leading i8086 and M68000. The decision was supposedly based on the superior architecture of the Zilog part, but was more likely based on political considerations (see "Intel-AMD Rivalry").

AMD, realizing the significance of entering this new market space (16-bit MPU), decided to make a big commitment to providing top notch development systems for it, along with boards stuffed with AMD MPUs and complementary products – just like big brother Intel had been doing for several years. The result of the decision was the formation of its ***AMC*** subsidiary (see below).

*[KC Murphy and I were quickly hired to provide technical support for the Z8000 – KC in February and I in April, 1979.]*

### ❖ Development Systems and CP/M

All microprocessors, of any architecture, need to have both hardware and software developed around them. Part of this *development* includes the inevitable test, debug and integration. Intel and later AMD were among the industry's first to provide complete computer-based ***development systems*** for this purpose – each costing up to $20,000 fully configured (reasonable at the time). Both used the industry standard floppy disk-based (no hard disks yet) operating system (OS) from Digital Research, ***CP/M*** (*Control Program/Microcomputer*). Intel called their OS ***ISIS***; and AMD called theirs ***AMD/OS*** (see below).

Both company's boxes were architected with the then industry standard backplane bus called ***Multibus***. Their boxes were stuffed with an assortment of CPU, memory and I/O cards called *Multibus* cards – and were thus easily configurable.

Moreover, a very important component was provided as an add-on in a separate box: an *In-circuit Emulator*, or ***ICE***. Each ICE unit offered an assortment of pods – one for each microprocessor supported. The primary utility of an ICE unit was to support incremental build and test of the basic hardware of any design, by providing an *actual* microprocessor outfitted with added instrumentation (such as clock control, single-step, etc.and a *trace buffer*). Each microprocessor *pod* plugged into the real microprocessor socket on a prototype board.

Software development was supported even before any hardware was built via the *emulation* capability of each microprocessor pod. Each ICE unit additionally provided so-called *emulation memory* – RAM with the capability to emulate any type or speed of memory (RAM, ROM with any number of wait states assigned to each block).

ICE units were critical components of any *microprocessor development system.*

Additionally, third-party ***logic analyzers*** were used for hardware debug -- which were independent of the microprocessor employed. Over time, the logic analyzers evolved to blur the distinction with ICE – thus eventually eliminating the need for microprocessor IC vendors to supply their own ICE units.

Finally, the full complement of software *development tools* included these (one set for each supported microprocessor): compiler, assembler, disassembler, linker/builder (*make*), source code editor, and debugger. (The need for a *simulator* was obviated by the ICE, which was an *emulator* – stronger than a simulator.)

### ❖ H-P

Hewlett-Packard was always the biggest test equipment supplier in general, and the number one *logic analyzer* vendor as well. H-P has also been one of *the Valley's* biggest tech companies, and is often lumped into the *Silicon Valley* story. Moreover, H-P was one of the pioneers of the CMOS process (initially, CMOS/SOS), spinning off IDT (see *CMOS* below).

### ❖ AMC (1978-1985) and Siemens

AMD, having made the commitment to provide boards, boxes, systems and software for all of its micro-processors, made a strategic move. They partnered with Germany's top semi company, **Siemens**. The arrangement was this: Siemens bought an immediate 17% stake in AMD (getting a board seat), and each company set up their own, nearly identical, wholly-owned (actually, 80-20% split on each) subsidiary. AMD launched its subsidiary as ***Advanced Micro Computers*** (AMC) in late 1978/early 1979 in rented space on Scott Blvd. in nearby Santa Clara. Siemens built a similar subsidiary in Munich. The two subsidiaries remained separate but equal until the AMD-Siemens split that occurred a few years later (giving back each other's 20% stakes).

AMD CEO Jerry Sanders assembled a team from outside the chip industry to lead its ***AMC*** subsidiary. *[Ed. Opinion: This was probably a mistake. For instance, Frank and Jerry decided to pursue the development of AMC's own OS, to compete with CP/M and Unix – over my strenuous objections (way outside AMD's core competency). And so I quit. And eventually the entire AMC enterprise folded.]*

The key AMC executives, engineering managers and FAEs are listed here:

1. **Frank Zurcher** - *President*
2. **Bob Sumbs** - *VP of Sales*
3. **John Drakeford** – *Director of Marketing*
4. **Tenny Doone** – *Director of Engineering*

5. **Jim Ready** – *Manger of Software Engineering* (Ambitious Jim left early to found Hunter-Ready, later Ready Systems, with his *VRTX* real-time OS – an extension of what he had been working on at AMC.)

6. **KC Murphy** – *Field Applications Engineer (East)* (Ambitious KC eventually coerced an AMD VP title, then left to become VP at Cadence; much later a brief stint as president at Pivotal until it was bought by Broadcom, becoming a director there; he has since left, to parts unknown.) *[I lost track of KC after he joined Broadcom. After all, KC originally was my East Coast counterpart at AMC, and we shared a lot back then.]*

7. **Jeff Drobman** [the author] – *Field Applications Engineer (West) [I left AMD when the IBM PC came out, but I was rebuffed on my idea that the PC should become the focus at AMD – which it did much later, after AMC was dissolved.]*

Given this team, I would still opine that the most significant contributions came from the ubiquitous John Mick. John designed the first development system. He was smart enough to license the popular *CP/M* as its operating system, and design a modular box that employed the then industry standard *Multibus* board format for easy change/upgrade. John also continued to train all the FAEs.


### ❖ CP/M and MS-DOS

When I was AMC/D FAE, all of our customers asked if our *AMD/OS* was compatible with *CP/M*, since they were very familiar with ***CP/M*** as the industry standard disk OS at the time. In fact, Intel called their OS *ISIS* even though it too was really CP/M – developed somewhat magnanimously by legend Gary Kildall (whose company was Digital Research).

CP/M went on to become ***MS-DOS*** after Bill Gates bought another company's version for $50,000 to offer to IBM for its new PC in 1981. It was always a shame that Bill Gates became so wealthy off of Gary Kildall, who did not make much money off it. *[Maybe Bill should donate a nice stipend to Gary's heirs, or create a scholarship in his name.}*

### ❖ RTE/RTOS

One additional software component was needed to be supplied to microprocessor systems customers: a real-time operating system (kernel), or *executive* – a so-called ***RTE*** or ***RTOS***. Intel and AMD/AMC both supplied these as third-party products. AMC briefly hired Jim Ready to develop its own version, but abandoned the project when Jim left to start his own company, ***Hunter-Ready***. Hunter-Ready called their product, ***VRTX*** (Virtual Real-Time Executive). Hunter-Ready changed into ***Ready Systems*** after Hunter left.

### ❖ The Big Board (NYSE in 1979)

AMD became a publicly traded company, listed on NASDAQ, in 1972 – creating the usual complement of instant millionaires among the founders. AMD's Sanders, being ever so status conscious, wanted to have AMD listed on the most prestigious stock exchange, the New York Stock Exchange (NYSE). Jerry succeeded in getting AMD's stock listing as simply "**AMD**" on the NYSE in October 1979. (Note: neither tech stalwart Intel nor Microsoft ever made the jump to the *big board*.)


### ❖ The Asparagus Campaign (1980)

AMD CEO Jerry Sanders officially launched his *Asparagus* campaign at the August 1980 International Sales Conference. This program was explicitly an effort to boost innovation through the design of *proprietary* products. Such original designs command higher prices, due to the monopoly position – until a second source offers competition. Thus, Jerry urged AMD to design more *proprietary* products – by making an agrarian analogy to growing asparagus.

Jerry introduced his *Asparagus* campaign by relating this story: When he was in France (where he vacationed every summer to bask among the worldly wealthy), he once ordered asparagus. He was told that asparagus takes <u>two years to grow</u>, and that is why it was so expensive. Hmmm, thought the nouveau riche CEO … sounds like our proprietary products! It takes chip companies like AMD about two years to design and produce a brand new product.

So Jerry made the analogy an official AMD campaign by stamping the image of a cluster of green asparagus all over AMD's promotional material (even *embroidered* asparagus for our clothes) – turning AMD into the first *green* company. That is, AMD even adopted ***green*** as its new corporate color (abandoning the original orange/olive, and the Beatles' white). AMD has been *green* ever since.

*[Even today, AMD'ers like me cannot eat asparagus without thinking of the AMD campaign, and Jerry's farming story.]*

A couple years later, Jerry extended this with a ***Liberty Chip*** campaign: AMD was to introduce a new product or revision thereof each week – 52 in all -- for the first year. I believe they made it, but it was more a marketing gimmick than real innovation.

### ❖ INT-STD-123 (1980)

AMD had very early on decided to promote its *high quality* standards as a sales edge. First, there was the "MIL-STD-883B for Free" campaign. A decade later, AMD introduced a follow-on campaign called the "INT-STD-123" program, whereby AMD proposed their own "international standard of quality" using defect ppm ordinals.

AMD's John Corbitt recently wrote for our AMD alumni website the following:

*In the late 70s and early 80s there were many US companies that manufactured DRAMs, including AMD and Intel. However, it became known that the US suppliers had much lower quality (reliability) levels than their Asian competitors (Japan). I think there was a landmark publication by HP at the time supporting that finding.*

*AMD introduced quality metrics that were defined and guaranteed, unheard of for commercial products at that time, and all products were guaranteed to 0.1%, 0.2%, or 0.3%. Another powerful ingredient was the adherence to MIL-STD-105D, which was a United States defense standard that provided procedures and tables for sampling. AMD also provided the sales and marketing team with a double-sided card for their wallet to help explain the concept to customers. The wallet-size card is a example of the Quick Reference Table that was in the MIL-STD-105D spec.*

*Customers liked it and I spent a lot of time with QA folks explaining the relationship between AQL and LTPD, but it raised the bar for our competitors. In those days the 0.1-0.3% corresponded to 1,000-3,000 PPM, which was typical for components at that time. Current PPM levels are at least an order of magnitude less and many components have reliability levels (FIT) in the single-digit range now.*

### ❖ The IBM PC (Aug 1981)

The intro of the **IBM PC** in August 1981 was a seminal event in AMD's corporate history. Just before that time, AMD had made a commitment to second-source Zilog's Z8000 16-bit microprocessor, and compete with Intel and Motorola head on. With IBM forcing Intel to license a second-source for its complete and future line of i86 microprocessors, and Intel selecting AMD, AMD abruptly switched allegiances and product focus. Bye-bye Zilog, hello Intel and IBM.

The main reason Intel selected AMD was that at the time, they already had cross-licensed products: the Intel i8080/8085 and i8048 were licensed to AMD, in exchange for AMD's designs of the Am9511/12 math co-processors, plus an error-correction (EDC) chip (Am9517?). In exchange for the i8088, i8086 and future gens, AMD was to design more such *peripheral* chips and cross-license them to Intel. (See *The $B Lawsuit*, below.)

This new partnership with Intel affected all of AMD's microprocessor product direction, especially the AMC systems division – and changed AMD forever. AMD then and there decided to try to beat Intel at their own PC game, and did so for a brief while. (See *The AMD-Intel Rivalry*, and *Anecdotes/Jerry & the PC*, below.)

### ❖ The Middle Ages (1982-1998)

AMD's 4-bit 2900 family was extended by Mick's team (which included Michael Miller) into a 16-bit microprogrammable microprocessor "slice," the Am29116 (ca. 1981). At some point later, Mick's team realized that the advent of "RISC" computer architecture in the 1980s eliminated the need for microprogrammable microprocessors. And so, the famous **Am29000** ("29K") "RISC" CPU was designed to take its place (ca. 1987) as a complete, 32-bit fixed-ISA (not microprogrammable) fully pipelined processor.

From 1987 until ca. 1998 (when AMD pulled the plug), the **29K** was one of the premier RISC microprocessors for high-end "embedded control" applications such as graphics workstations and laser printers. During that period, the 29K competed with these other RISC CPUs: MIPS R2000/3000/4000 derivatives -- manufactured and supplied by 5 vendors (IDT, LSI, Performance, Fujitsu and Siemens); SPARC (by LSI and Cypress), and PowerPC (by Motorola and IBM*). [Ed. observation: How ironic that AMD, born as a 2nd-source company, had its greatest innovation be the only single-source RISC CPU!]*

### ❖ My PAL MMI

The collision of two forces resulted in AMD's acquisition merger of nearly as large ***Monolithic Memories (MMI)*** ca. 1984. First, ***PALs*** (Programmable *Array* Logic) were introduced as a proprietary *PLA* (Programmable Logic Array) implementation by MMI (a misnomer for a *memory* company). MMI turned the industry generic PLA into its proprietary PAL with a simple twist and trademark – and a fabulous track record for this IC niche.

AMD also had a successful proprietary programmable logic group. AMD's niche was a larger programmable device than a PAL, and they called it the ***MACH*** family.

Second, AMD's Sanders desperately wanted to become a ***$1B*** company – organically or not. So, Jerry introduced a ***Gigabuck*** campaign to spur his sales force to the $1B sales goal, at a time in 1981 when AMD's revenue was only half that. Failing to advance revenues fast enough to suit the ever so ambitious Sanders, Jerry approached MMI's CEO (over dinner I believe) about combining their companies – but really combining just AMD's *programmable logic* division with the entire MMI (whose PAL was most of the company).

So it was said, so it was written. The accretive deal was consummated – and just 2-3 years later, AMD became a $1B company with the combined revenues.

However, the good times lasted only so long, and then it was so long, MMI. AMD divested its entire *programmable logic* division, including the original MMI group, ca. 1995. AMD exec David Laws was assigned to head the new spinoff. (I am sure the MMI founders did well with their AMD stock, though, so no tears for them.)

### ❖ Remember the Alamo: AMD Moves into Texas

During those Middle Ages, AMD first expanded to the state of Texas by building its first wafer fab outside of California in the Alamo City – **San Antonio**. This early fab (Fab 3 or 4) was dedicated to *bipolar* products (only), since AMD was not yet so effective with their MOS process.

AMD further expanded to the Lone Star state a few years later, when they moved their microprocessor design group to Austin, Texas, to take advantage of the UT grads who would otherwise end up at TI. And the rest is significant history for AMD in Austin.

### ❖ The Real McCoy

AMD General Counsel of 17 years (1993-2010) Tom McCoy wrote a fabulous farewell letter chronicling some of AMD's richest history, which is excerpted (with Tom's permission) here:

*In early July 1993, I was in my office of my law firm in Los Angeles when an old friend, a founding member of the AMD Board of Directors, called. AMD was in a complex and multifaceted contract and intellectual property litigation battle with Intel, a battle that was not going well. He asked me if I would meet with Jerry Sanders, the Founder, Chairman and CEO of AMD, and Rich Previte, the President and Chief Operating Officer of the company, about taking over lead outside counsel responsibility. My conversations with Jerry and Rich led to a 17 year AMD adventure that ends today.*

*I dove into the crisis in mid-1993 with an army of lawyers from my firm, and we were fortunately successful in turning back the tide. Along the way, I forged a close counselor relationship with Jerry and his team, and with the Board of*

*Directors. In early 1995, I left my firm and joined AMD as General Counsel. I vowed I would stay no longer than four years before returning to my firm, long enough to build a world-class law department and IP portfolio for a great little company. Obviously, I found more to do and I stayed a bit longer than I had planned.*

*The chapters of my professional life at AMD have been rich indeed: The birthing of the AMD K5 microprocessor. (Yes, it was a big die, and it was late, but it worked and it proved we could design great proprietary x86 microprocessors from the ground up.) The acquisition of NexGen, and the creation of the AMD K6 MMX microprocessor, later infused with dynamic power management and 3D instructions. The building of Fab 25 in Austin, and the astounding success of the Submicron Development Center (SDC) in Sunnyvale. The pioneering of flash memory technology, and a very successful joint venture with Fujitsu, later unified and spun out as Spansion when flash memory devolved into a commodity business. The ever-shaping of the company to be centered as an innovator and scrappy competitor to Intel in advanced x86 technologies, resulting in the creation of Vantis out of our PLD business (then sold to Lattice Semiconductor) and the creation of Legerity out of our telecommunications business (then sold to Francisco Partners). And most near and dear to me, the bold strategic move into Dresden to build our advanced technology fabs. I remember walking the field we ultimately bought in Wilschdorf, assuring myself that it would be big enough for three clean rooms, a dream we had that is now coming into reality.*

*In more recent years, I am particularly proud of the transformational moves we made beginning with leading the world into a seamless transition to x86-64bit computing, the acquisition of ATI and the creation of a Fusion processor powerhouse, the investment from Mubadala followed by the partnership with ATIC in the game-changing creation of GLOBALFOUNDRIES, and, yes, of course, my little Project Slingshot and the fight for a fair and open marketplace for our technology.*

*Along the way, I have had the privilege of counseling the only three CEOs in the history of the company, Jerry Sanders, Hector Ruiz and Dirk Meyer.*

### ❖ Nex-Gen (1996)

It is not well known (or at least remembered, outside of the usual cognoscenti circles) that AMD struggled mightily with their internal design of their first *Pentium-class* CPU, the **K5**. This was a critical juncture in their history: If AMD fails to develop their Pentium-class CPU, the entire company might have failed. So, Sanders and his AMD board acted: They bought stalwart Pentium-class CPU design startup ***Nex-Gen***, who was well on their way to success. It is really Nex-Gen, not AMD, who designs their Pentium-class CPUs – and in Austin, not Sunnyvale.

### ❖ The Latter Years (1998-present)

During AMD's final era, it refocused itself to a sole purpose of taking on Intel once and for all, with its Pentium-class CPU. To that end, AMD first dropped the **29K**, after deciding it was too expensive to continue with a roadmap for 2 independent CPU architectures (29K and Pentium) – even though the 29K was honed for *embedded control*, while its version of the Pentium was a Windows desktop/notebook CPU (different markets entirely). AMD thus ceded the embedded control market to MIPS, SPARC, ARM et al. (Motorola likewise discontinued the PowerPC it co-developed with IBM, forcing devotee Steve Jobs' Apple to shift to the Pentium.)

### ❖ Backin' a Flash – Spansion

AMD had long been a player in another programmable niche with their ***PROM*** (Programmable Read-Only Memory) group. AMD's first decade process technology was all ***bipolar***, and they made a full complement of *bipolar* memories: SRAM, mask ROM and PROM. Only after AMD successfully transitioned to MOS were they able to offer the hottest of these programmable memories: the ***E****PROM* (*Erasable* PROM).

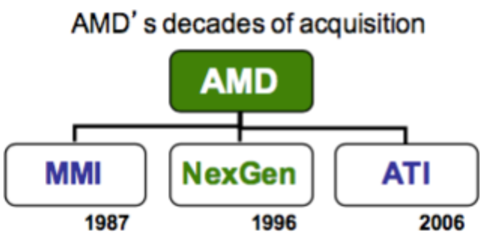
What made this technology distinct for the entire industry was the use of a glass window over the chip, on the package lid, for *ultraviolet (UV) light* to be used to erase the *entire* ROM contents. The ***E****PROM* could then be re-programmed with new data, *ad nauseum*. This was a huge cost and inventory benefit for the electronics systems industry, since these memories did not need to be distinguished, and were completely reusable – just like a RAM.

The next gen of this technology eliminated the need to *remove* the chip from the board (socket or solder) in order to re-program it. This meant affording a PROM to be re-programmed *in situ*, while still on the board. This new technology has been called, *Electrically Erasable* PROM, or ***EE****PROM* – or in the hopelessly propeller-head vernacular, ***E²****PROM* (or even just *E-squareds*).

The final enhancement to the ***EE****PROM* was affording the memory to be erased in blocks, and much *faster* than before – in fact, nearly instantaneously, or in a *flash*. And so the current gen of *PROM* was born as the ***Flash*** memory – a fast-erasable ***EE****PROM.* How ubiquitous this has become! **SanDisk** is now the big systems vendor of Flash memories, buying ICs from the likes of AMD.

However, the entire chip memory business has always been a fiercely competitive marketplace. This accrues from *memory* arrays being the simplest design of any IC, and hence fertile ground for all the Japanese, and then Korean, IC vendors to step in and take market share (through all manner of predatory pricing). It quickly became a very tough business. Many IC vendors dropped out of the memory business over the years.

AMD's decision was to partner with the enemy – an *if you can't beat them, join them* solution. So, AMD formed a joint venture with Japan's *Fujitsu* to produce Flash ***EE****PROM* memories. AMD then spun off the venture as ***Spansion*** (publicly traded under SPSN) ca. 2003.




- **Post Sanders: Hector Ruiz (2001)**

Hector Ruiz was Jerry Sanders hand-picked successor. Jerry retired (at the direction of the AMD board) after turning 65 in 2001.


Hector held the AMD reins until he was succeeded several years ago by Dirk Meyer. In Jan. 2011, the AMD board decided to relieve Dirk Meyer of his CEO duties.

- **Post Hector Ruiz: Lisa Su (present)**

Lisa Su was his replacement, and she serves currently as CEO. Su pushed AMD in the direction of making "APU" SoC chips: a combo CPU + GPU multii-core chip. The GPU architecture/design came from AMD's acquisition of graphics chip maker ATI (Advanced Tech Inc.) long ago. AMD called this the "Zen" family, leading up to the current "Ryzen" and its "Threadripper" variant.

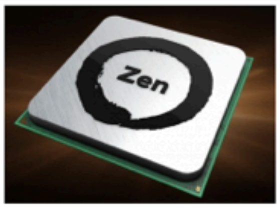
AMD's biggest design win for its "Ryzen" APU family was the latest Microsoft Xbox One.

# AMD's Zen

*AMD News*

**AMD's new Zen Processor**




AMD Zen

*stock news usa (2016)*

(Click image to view full size)

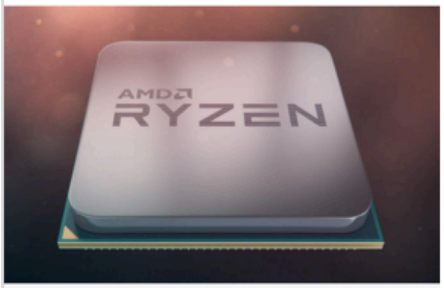
AMD made radical alterations to its Zen design while keeping itself distant from an ugly past. The company knew it had to make the changes to become a force to reckon with in the server and PC markets. So when the designers of the chip sat down to map the Zen design, they had two priorities: To boost CPU performance to maximum and to stabilize power efficiency.

According to a company spokesperson, the chips will come with 8 to 32 cores. The 32-core chips may come in the quad-CPU configurations although those details haven't been finalized yet.

- ❖ CPU performance
- ❖ Power efficiency

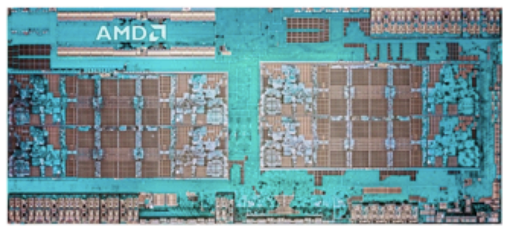
*Source: stocknewsusa (2016-08-26)* Inside AMD's Production Of The Zen CPU

8-32 cores




Ryzen 7 will have three CPUs to start, all having eight cores and supporting simultaneous multi-threading:

- *Ryzen 7 1800X: 8C/16T, 3.6 GHz base, 4.0 GHz turbo, 95W, $499*
- *Ryzen 7 1700X: 8C/16T, 3.4 GHz base, 3.8 GHz turbo, 95W, $399*
- *Ryzen 7 1700: 8C/16T, 3.0 GHz base, 3.7 GHz turbo, $329*




**Ryzen**

4.8 billion transistors and more than 2,000m of signal wire


## Intel-AMD Rivalry

### ❖ In the Beginning … Sibling Rivalry

The storied rivalry began when Jerry Sanders first met Intel co-founders Noyce and Moore (and later Intel pres. Andy Grove). Jerry idolized them like big brothers, and so he imitated them, and thus irritated them -- a typical sibling rivalry.

Recall that AMD was founded as a second-source IC supplier. After developing many Fairchild Linear products, AMD branched out by becoming a licensed second-source of Intel's early microprocessors, the 8-bit i8080 and its successor i8085; also its "embedded controller" versions, the i8048 (with small on-chip memory). In return, AMD cross-licensed its proprietary "math co-processor," the Am9511/12 (which were forerunners of later Intel "floating-point co-processors," the i80287/387).

### ❖ The IBM PC (Aug 1981)

Arguably the single biggest event in tech history, the intro of the **IBM PC** (with MS-DOS) in August 1981, also was a seminal event in the AMD-Intel relationship. IBM decided to use the Intel **i8088** as its initial PC's CPU if and only if Intel licensed a legitimate second-source for it. IBM refused to commit to a single-source for its most important component. To ensure this, IBM bought a 17% initial stake in Intel, getting a board seat, and a say in the CPU licensing. AMD was the obvious choice, since it was already a viable cross-licensee on CPU products. So it was viewed, so it was done.

Peaceful co-existence ensued for many a year, while the PC flourished -- with 2 CPU suppliers. The 8/16-bit i8088 was followed by the full 16-bit **i8086**, then the 16-bit **i80286** (with separate **i80287** math co-processor), next the **i80386** (with separate **i80387** math co-processor, plus off-chip L1 cache memory); next the first 32-bit CPU, with integrated math co-processor and on-chip L1 cache, the **i80486**.

Finally, the next generation CPU, the **i80586** came out -- but Intel changed the name from "586" to "**Pentium**" to be able to trademark its name. A court had ruled at that time that a basic "part number" could not be trademarked.

The next-gen "586/Pentium" architecture was a large departure from the 8080/8086 roots. All Intel CPUs to that point were so-called "CISC" (complex instruction-set computer); the 586 was Intel's first catch-up attempt at the much more advanced "**RISC**" (reduced instruction-set computer) architecture. The 586 also added on-chip L2 cache, as was common at that time. (This was simply supported by the increase in the next-gen process's level of integration, ever following *Moore's Law*.)

- **The $2B Lawsuit (1991)**

# AMD lawsuit slams Intel

*Charges chip giant with monopoly, coercion*

BY JIM NASH and SALLY CUSACK
CW STAFF

Advanced Micro Devices, Inc. filed a $2 billion lawsuit last week against its semiconductor rival and market leader Intel Corp. AMD charged Intel with deliberately trying to create a monopoly with its 80386 and I486 microprocessors.

Reaction to the suit from industry observers and users was muted. Analysts speculated that it could help dissipate fear in the market that Intel might harass or zero-allocate personal computer vendors who decide to use AMD chips.

Intel's reaction was swift and caustic. Andy Grove, president and chief executive officer of the Santa Clara, Calif.-based company, called the suit "ridiculous" in a prepared statement, referring to AMD as "the Milli Vanilli of semiconductors."

The suit, filed in the U.S. District Court of San Jose, charges Intel with violating the Sherman and Clayton antitrust acts. AMD claims Intel tried to monopolize the chip and chip-peripheral markets for IBM-compatible

Continued on page 8

## AMD slams

FROM PAGE 1

desktop computers. According to Sunnyvale, Calif.-based AMD, Intel did so in two ways. AMD alleges Intel sabotaged a contract between the two firms, allowing AMD to license Intel 80386 technology in its own AM386 product.

Intel also coerced PC OEMs into rejecting AMD chips in favor of Intel goods, AMD charged.

The Federal Trade Commission began investigating anonymous allegations of this kind in July.

**Scare tactics**

An AMD spokesman said Intel also uses the courts to intimidate competitors — an accusation thrown back at AMD by Grove. "Since they can't win in the marketplace, they try to defeat us in the courts and press," Grove said.

"AMD certainly is making every possible effort to draw attention to its position in its arbitration case with Intel," said Bill Tai, an analyst at Alex. Brown & Sons, Inc. in San Francisco. Tai was referring to the binding arbitration AMD forced on Intel to settle complaints about the AM386 contract.

In the arbitration, Intel was found to have breached the contract by deliberately seeking to hold up technology transfers required by the agreement.

The arbiter is now deciding how AMD should be compensated.

"There are those who argue that Intel's influence in the marketplace is so powerful that it could be construed or misconstrued as [monopolistic] intentions," Tai said. "Intel is in a position to make or break its customers' market share."

Tai said he is unaware of any incidents like this happening but said he is "sure there have been incidents of some loose-cannon salesmen." Tai added that he doubts there ever was a management policy to financially harm vendors using AMD chips.

At least one component distributor has stated publicly that Intel cut off his supply of the company's products when he refused to stop pushing Cyrix Corp. math coprocessors [CW, July 1]. Two PC components vendors that asked to remain anonymous also said they have been pressured by Intel to use its products.

**Sitting on the fence**

At Northgate Computer Systems, Inc. in Eden Prairie, Minn., Chairman Arthur Lazere did not take sides in the AMD/Intel conflict.

"At this point, I haven't heard anything that would cause me concern. Interesting squabble, but nothing alarms me," Lazere said.

A spokesman for IBM noted, "I think it will have no effect on us. Through a technology exchange agreement, Intel gave us a license to actually process these chips. We do this in relatively small quantities for internal products. We will continue to buy the bulk of our 80386 chips from Intel. It is not appropriate for us to comment on the potential outcome of the case."

COMPUTERWORLD SEPTEMBER 2, 1991

The Intel-AMD processor cross-licensing arrangement included Intel handing over to AMD computer tapes (*tapeout*) of the complete "mask set" (>20 masks) for each CPU model, thus making each vendor's products completely "mask" compatible. Feeling safe with their long-standing 10-year contract, AMD began turning up the heat on Intel with strong selling pressure. But it was when AMD (particularly CEO Sanders) began to brag about out-selling Intel's **i80286**, that Intel CEO Andy Grove said, "Enough!"

Coincidentally at that point, IBM released Intel from having to license any more microprocessors. IBM cemented this when it sold back its stake in Intel.

So, when the **i80386** was released by Intel, the stage was set -- and Intel abruptly refused to hand over to AMD the mask set. "But, we have a contract!" cried AMD executives. "Sue me!" replied Intel. And sue AMD did, followed by Intel counter suits, to the tune of a dramatic **$2B** lawsuit between the two CPU IC giants (in 1991). (Granted, Intel has always been the much bigger brother/giant, much to AMD and Sanders' chagrin.)

AMD asked for and got a jury trial, which was probably a mistake. The issues involved, both technical and business, were far too complex for any lay person. But the jury ruled a mixed decision: finding that Intel did have cause for withholding future mask sets (AMD failed to provide adequate designs in return) and terminating the cross-licensing contract, but that AMD was entitled to some Intel IP in exchange for the designs AMD had provided to Intel.

According to AMD's chief legal counsel, John Greenagel:
*The litigation that was tried in front of a jury related to the original 1976 license agreement regarding*

*microcode. AMD triggered the suit by introducing a 287 math co-processor that incorporated the Intel microcode. Clearly, this case was a proxy for the more important -- and more risky -- issue of whether AMD could incorporate Intel microcode in subsequent versions of the x86 processors. We lost the first trial but the judge overturned the verdict when it was revealed that Intel had not turned over a critical document that undermined its assertion that the "microcode" referred to in the 1976 agreement did not cover the instruction set in Intel "microcomputers and related peripherals." Clearly, a critical issue was the definition of "microcomputers," which Intel attempted to claim did not include microprocessors. AMD won in the retrial -- I attended many of the court sessions and set up a communications "war room" in the Saint Claire Hotel in advance of the verdict. Jerry attended every day of the trial.*

The court ruling has paved today's roadmap: Intel did not have to give AMD any more mask sets, but did have to give AMD the micro-code for the **i80486's** math co-processor. But that ended the deal. No **586** for AMD. AMD was on its own for the "5th" generation CPU. AMD's internal design, the ***K5*** floundered, as described. So, AMD carried on under the Nex-Gen tent. And the "586" became the ***Pentium*** -- a name only Intel could use. AMD had to come up with its own model names. We are now on the Pentium **III**, or 3rd gen Pentium-class architecture.

Electronic News

The Business Newspaper For Industry Management

'OL. 37 NO. 1876 MONDAY, SEPTEMBER 2, 1991 TWO DOLLARS

**PC Board Vendors Buffeted by Complexity, Costs**

By BERNARD LEVINE

The printed circuit board industry is undergoing a shrinkage reminiscent of the compression in the discrete TTL business which once was its mainstay.

The availability of single-chip versions of board-sized computers, the emergence of multichip modules, and system-level ASICs are taking an inexorable toll on rigid board real estate with the result that auction rooms in recent months are overflowing with solder flow equipment, water jet cutting systems, eyelet machines, conveyorized cleaners, and similar artifacts of the trade.

The high level of integration of semiconductor circuits made possible by revolutionary design tools is only one of the woes afflicting the bare board business. Surface mounting has added to board complexity and the cost to upgrade opera-

SPECIAL REPORT

tions for the technology has forced many captive houses to seek refuge with contract manufacturers, and independents to scramble for cash to upgrade; meanwhile, rigid board competition from the Far East, where fewer environmental restrictions have given offshore suppliers greater pricing leverage, has added to the general overcapacity in the U.S.

AT&T, Xerox, Hewlett-Packard, Data General, Control Data and General Dynamics are among major OEMs which have unloaded bare PC board manufacturing equipment recently, either dropping out of the business entirely or consolidating operations. While most continue to do board assembly, they are often obliged to buy bare boards from outside vendors. But the benefit to independent U.S. suppliers has been negligible and a number have been forced to close up shop.

The total value of rigid printed wiring boards in the U.S. has declined steadily since 1988, when it peaked at $5.548 billion, according to a study

See PCB, Page 4

**'ujitsu Ltd. Videns U.S. Jnix Thrust**

By GERRY KHERMOUCH

'CAMPBELL, Calif. — For e second time in as many eeks, Fujitsu Ltd. expanded s thrust into the Unix mar- et in the U.S. last week by king a $40.2 million equity ake in a workstation startup

**AMD Charges Intel Conspires to Shut It Out of 386 Market**

By ROBERT RISTELHUEBER

SUNNYVALE, Calif. — Advanced Micro Devices last week charged Intel with conspiring with certain computer makers and parts distributors to shut AMD out of the 386 "ridiculous," Intel chief executive Andrew Grove last week remarked "What we have here is the Milli Vanilli of semiconductors. Their last original idea was to copy Intel.

## ❖ Other Lawsuits

AMD continually sued Intel over the past 20 years or so over Intel allegedly coercing Dell and other major customers not to use AMD processors, via various predatory and illegal practices. Intel finally relented, after years and many millions of dollars of legal fees, in Nov. 2009 -- agreeing to pay AMD a whopping $1.25B for dropping all lawsuits.

# Search for CMOS

## ❖ The Survivor Process: CMOS

IC process technologies evolved over the past 50+ years from early bipolar and TTL to MOS, which in turn had its three distinct sub-era based on using P-channel (P-MOS) or N-channel (N-MOS) transistors – or both (CMOS). After all these 50+ years, CMOS has survived to be the mainstream IC process of choice. This is due to CMOS having achieved early on the process technology holy grail of a combination of high speed, low power, high density and scalability. The latter attribute, *scalability*, especially was responsible for the longevity of CMOS. Over the 30+ years of its existence, CMOS has been successfully scaled down from 2u to 1u to sub-micron to nanometers.

By 1980, every IC vendor wanted to have CMOS. But, back then, it was not an easy upgrade from the then prevailing N-MOS. The story of how each IC company found their way to CMOS is a truly interesting one. It all sprang from the labs at HP.

## ❖ HP & IDT

I personally credit HP (Hewlett-Packard) with having started the whole CMOS process success. In the late 1970s, HP process engineers developed one of the first CMOS processes that used a *sapphire* substrate, and it was dubbed *CMOS on SOS*, or simply *CMOS/SOS*. "SOS" stands for "silicon on sapphire", whereby a standard silicon wafer is grown with a sapphire substrate. While the unusual substrate gave marvelous performance (lowering parasitic capacitances for one), it was very costly.

By concentrating on improving the electrical characteristics of the planar structures of intrinsic CMOS, process engineers were able to achieve high enough performance without the sapphire substrates – making CMOS affordable.

By 1980, HP had perfected CMOS but did not know what to do with it. HP was a *systems* company, not a chip company. So, in 1980 HP spun off it CMOS technology by transferring 3 of its CMOS engineers into a new IC company that HP and others financed and owned: *Integrated Device Technology* ("IDT").

HP and IDT early on enticed former AMD founder and operations director John Carey to invest and then take over IDT as Chairman. As stated, John Carey then began a trail of hiring AMD marketing and sales engineers to build an effective organization, and product lines.

The first product line came directly from HP: *SRAMs* (Static RAMs). This was natural, since SRAMs used 4 CMOS transistors per memory cell (4T), and both speed and power were important. A little later, dual-port SRAMs were developed using 4T or 6T cells. FIFOs came next, as an obvious extension to dual-port SRAMs. [Ed. Note: I worked for IDT as an FAE 1988-1997, and was known as "Captain FIFO", among other things.]

## ❖ Intel & AMD, TI & TJ, IDT & Cypress

Intel was the obvious choice to be first in CMOS, since Intel invented P-MOS and was first to switch to N-MOS. However, for some reason, Intel struggled to get CMOS right. But, by 1981 Intel did indeed have a CMOS process, though not considered very good. After time, Intel finally did improve their CMOS process.

AMD, wanting to compete with Intel (always), became desperate to achieve their own CMOS process. First, AMD hired TI's CMOS exec, TJ Rodgers, to run AMD's CMOS development program. Then the unthinkable happened: TJ was lured away from AMD by venture (vultures?) LJ Sevin and Ben Rosen to create *Cypress Semi* as an all- CMOS house to compete directly with the HP sponsored IDT. Cypress and IDT thence and forevermore commenced on a trail of direct competition across all product lines.

AMD was in a bad way, having spent a lot of money on their CMOS development program but with no leader to run it. Then, in August 1981, IBM came to the rescue (or so AMD thought) by forcing Intel to license AMD for mask-level designs of the entire Intel x86 product line. AMD thought this was the way to CMOS, via Intel's own masks. [Ed. Note: Jerry Sanders told me he did not care so much about getting the x86, thinking the PC was "just a fad," but was more interested in acquiring Intel's CMOS process.

It turned out that Intel's CMOS process at the time was not that good. And then a few years later, Intel cancelled the license anyway. So, after all that, AMD was stuck developing CMOS on their own anyway.

## RISC CPU Architecture

- **UC Berkeley, David Patterson and SPARC**
- **Stanford and MIPS**
- **AMD 29K**
- **PowerPC**
- **ARM**

## Legendary Parties & Conferences

- **Hawaii**

I recall attending those great International Sales Conferences in August of 1979 - 1981 at the Hilton Hawaiian Village on Waikiki Beach. We had a great, spirited time competing in events like beach volleyball and outrigger canoeing, by sales area. Sales areas competed in other ways too: my SW Area brought embroidered beach chairs in 1979, and each area had custom designed shirts. There also was some legendary drinking of Tropical Itches at the Hau Tree Bar, led by the Japanese (who sometimes had to be carted away). The weeklong conferences always concluded with a great luau.

- **AMD's 10th Anniversary Party at the SF Civic**

(Ah, I recall attending that great 10th anniversary party at the Moscone Center in April 1979, but that is another legend.)

- **Cocktail Parties**


## Fab Tours

## Anecdotes

### ❖ CAD vs. Rubylith

When I was a PhD student at UCLA ca. 1978, I was working on essentially a hardware description simulation language for ICs (a forerunner of Verilog and VHDL). Jerry asked me what good was it. When I told him that computer and IC complexity would soon become too great for humans to handle, and thus my CAD tools would become necessary, Jerry told me matter of factly that the then current method of hand drafting each mask and cutting masks into red plastic "rubylith" with an Exacto knife would always be used. He could not see the future coming so soon.

### ❖ Jerry & the PC

Right after AMD inked the deal with Intel (August 1981), Jerry Sanders told me, "We think the IBM PC is just a fad – it won't last. The real reason I wanted the deal with Intel was to get access to their CMOS process!" Unbelievable how wrong AMD's vision was, yet they still succeeded in spite of it – driven by competition and jealousy, not vision.

Turned out Jerry was vastly wrong on both accounts: The PC has been huge and everlasting, and AMD never was able to convert the mask sets into a viable CMOS process. Jerry later hired TJ Rodgers to try to get CMOS from TI. AMD eventually got their CMOS going. And ironically, the ex-AMD team founder John Carey brought with him to IDT got an industry-leading CMOS process (from H-P) to work with long before AMD ever did.

*[I quit AMD shortly after that disagreement on the significance of the PC, followed by more rebuffs on my plans to have AMC use the PC as a development system, and make PC-based cards instead of Multibus cards. I left AMD, bought one of the first IBM PCs, and started my own PC business in March 1982.]*

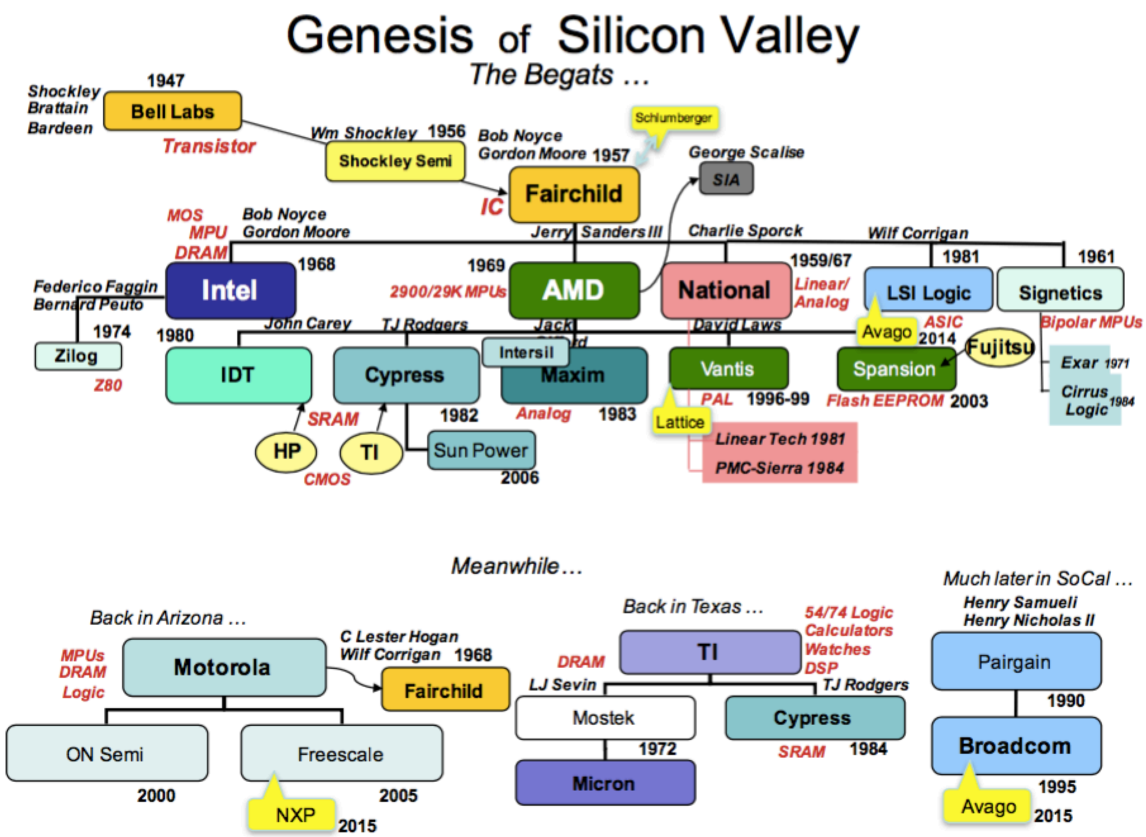
- **AMC'S AMDOS**

I urged AMC's management to simply call our OS ***CP/M*** – the recognized standard – but I was rebuffed out of hubris. "We paid a lot of *&!* money for it, so we are going to call it 'AMD/OS'!" Ouch!

## Valley Significant Others

- **Don Valentine & VCs**
- **Ben Rosen**

## Genesis Org-chart




## Process Technology Evolution

- **IC Processes – The First Era: Bipolar**

The underlying transistor technology that was integrated in an "IC" evolved in an orderly and predictable fashion. The first transistor ever – invented by Bell Labs' trio of Shockley, Bardeen and Brattain in 1947 – was a large (not microscopic) crude bipolar junction transistor (likely PNP). The first "integrated circuits" (ICs) were developed nearly simultaneously at Fairchild by Bob Noyce and at Texas Instruments by Jack Kilby (granted co-patents later) in 1959.

From the Computer History Museum in Mountain View, CA:

*In the spring [of 1959], Kilby along with Jean Hoerni and Robert Noyce of Fairchild Semiconductor, Kurt Lehovec of Sprague Electric, and others, filed patent applications that held keys to the development of the monolithic integrated* *circuit. Jay Last's team at Fairchild, which would create the first planar integrated circuits, also began their efforts in the fall [of 1959]. Kilby demonstrated his first circuit at Texas Instruments in 1958, and Fairchild introduced Micrologic in 1961.*

The "planar" IC technology was a hugely significant advance at the time – being the prime enabler of the *integration* of a microelectronic circuit, or "IC". This technology was about building 3D transistor structures into the top layers of semiconductor wafers – layer by layer (hence *planar*) – while also producing as small a 2D topology on the top of the wafer as possible, where the individual transistors are interconnected, making the circuit *integrated*.

The early digital ICs integrated 1 or 2 bipolar transistors per gate, along with silicon resistors, forming "RTL" transistor structures. Each IC product was a small collection of gates (e.g., quad AND, hex Inverter), and became known as "small scale integration" (SSI). The next major innovation was the formation of the ubiquitous dual-transistor inverter/gate structure, known as "TTL" (transistor-transistor logic). Here, a linear transistor replaced a resistor in the pull-up structure of the switching transistor. That allowed a single circuit element, the *transistor*, to build all gate elements. IC chip size was then forever determined by the transistor area times the number of transistors.

The need for *digital* rather than *analog* IC technology continued to drive IC engineers to seek transistor structures and their attendant process technologies that could be continuously *shrunk*, i.e. scaled smaller. Shrinking IC geometries (dimensions) allowed increasing the number of transistors per chip area (cf. *Moore's Law*), which in turn gave rise to similar gains in size and complexity of processors, memory and logic. Additional benefits accruing from process shrinks include gains in transistor *switching frequencies* ($f_T$) – hence *clock speeds* – and lower *power consumption* per transistor and per interconnect (by lowering parasitic capacitances). Lower *power consumption* is necessary to enable increased transistor density by maintaining power density at thermally manageable levels.

The single biggest shift in the evolution of process technologies was the break from *bipolar* to *MOS*. One could easily characterize the whole evolution of process technologies as having <u>two distinct eras</u>: bipolar and MOS.

The *bipolar* era had its own evolution: RTL -> DTL -> TTL and ECL

*ECL* (Emitter Coupled Logic), which vanished ca. 1985, had a very useful life as the highest speed bipolar transistor structure. ECL was a *current-switching* technology, whereby the emitters of two transistors were interconnected such that a constant current was switched between the two transistors. *Current* switching is much faster than *voltage* switching as TTL performed (eliminating parasitic capacitance as the speed bottleneck). ECL however produced monstruously high power consumption. Only the most speed demanding applications then used ECL, but paid a power premium. For example, applications such as IC testers needed to be faster than the ICs they tested. Also, the fastest large-scale computers of the era would utilize ECL for logic and SRAMs. [Ed. Note: Burroughs was one of AMD's ECL SRAM customers in 1979.]

As for TTL, so-called Schottky diodes were later added into the bipolar switching transistors to make them faster, and then a lower power version was created, to produce "LS" (Low-power Schottky) TTL. TTL logic parts added "LS" into their part numbers to indicate the presence of this technology. TI had their "SN54/7400LS" logic family; Fairchild had their "9300LS" family; and National Semi had their "DM54/7400LS" family – all dominant technology for logic in the latter 1970s and the 1980s.

The last attempt at achieving lower power with high speed using bipolar transistors was ca. 1978 with $I^2L$ (Integrated Injection Logic). This technology never left the lab. [Ed. Note: I used this process at Hughes Aircraft in 1978.]

"Biploar" TTL IC technology used only bipolar transistors – which are inherently high power consuming and had a large footprint. So, after a search for a more power and silicon economical transistor structure, there was next a move to a whole new transistor structure: *MOS* (metal-oxide-semiconductor), which was a "field effect transistor" (FET) – in the whole called "MOSFET".

### ❖ IC Processes – The 2nd Era: MOS

The *MOS* era also has had its own evolution: P-MOS (1968) -> N-MOS (1970) -> CMOS (1980), where

CMOS = P-MOS + N-MOS

CMOS delivers the desirable combination of high-speed and low-power, with high density – while being *scalable*. CMOS began as a viable process ca. 1980, and remains today the dominant and mainstream process. CMOS has proven to be highly *scalable* – it has been shrunk continuously since 1980 from 2u to 1u to sub-micron to today's nanometers.

### ❖ MOS Beginnings

Fairchild's prodigies Bob Noyce (developer of the "planar" IC technology that made ICs possible) and Gordon Moore (known now mostly for his "law") left Fairchild in 1968 to found Intel as the world's first "MOS LSI" semiconductor IC product company. Their technology was a planar structure of "P-channel MOSFETs".

Intel's first successful product was the world's first LSI product, and the first DRAM chip (part number 1101A) – a 256x1-bit DRAM constructed as a regular array of 16x16 DRAM cells (one transistor and one capacitor per memory cell, i.e., bit). Here is a die photo of AMD's later developed copy of the Am1101A from 1972 (from which one can clearly view the 16x16 cell array):

The next innovation was to achieve a faster and lower-power transistor: the "*N-channel* MOSFET". This was quickly followed by another innovation: the change from "enhancement mode" to "depletion mode" transistors, to convert the power supply from negative (-12V, then -5V) to positive (+5V and less later). Using a +5V power supply for MOS parts was a big improvement, since it allowed a *single power supply* for an entire board and system when bipolar TTL chips were also used (almost always), and it made *interfacing* MOS logic to TTL logic much easier (same 5V logic levels). "*N-channel* " MOS (+5V) quickly became the defacto standard for all MOS ICs.

### ❖ CMOS

The next major innovation in IC technology via transistor structure was the use of "complementary" P and N MOS transistor structures to simultaneously achieve higher speeds, lower power and higher density – the holy grail of digital logic and memory ICs. This technology was dubbed "CMOS". Its transistor structure interconnects a *P-channel* pull-up transistor with an *N-channel* pull-down transistor – in a "push-pull" totem pole between the power supply rails (Vcc and ground). This allowed having only one of the pair of transistors (P or N) to be "on" at any time, with the other completely "off" – and maintain minimal power loss through the single "on" MOS transistor. The transistor *totem-pole* structure implements a single inverter, or half of a two-input gate or SRAM cell.

The hard part of developing CMOS initially was configuring the complementary P and N-MOS transistors into a planar IC structure while still using a single +5V power supply. (Until then, P-MOS used -12V or -5V.) The initial problem utilizing a CMOS part in a system was interfacing it to TTL logic and TTL I/O parts. That was due to CMOS needing its inputs pulled up or down all the way to the power/ground rails (+5V or 0V); voltage levels in between drove both the P and N transistors "on", consuming twice the power and causing noise margin problems. The first work-around was to use "pull-up" resistors on the circuit board (PCB) on each CMOS input – but this was costly in power and board area. Additionally, having outputs swing from 5V to ground added a fair amount of "ground bounce" (and some "supply bounce") to complicate noise margins.

So, the next innovation was find a circuit structure for CMOS *input* pins that was TTL voltage level compatible, and *output* pins that were "low-swing" (3V swing).

The final innovation in CMOS was to take the supply voltage down to 3.3V – to lower power consumption, reduce ground bounce and other internal noise, and allow use of batteries (2x 1.5V works). This is the basic technology in use today -- for mainstream ICs.

### ❖ Other Exotic IC Processes

CMOS is still able to satisfy the needs for DRAMs and CPUs alike. However, for special needs, especially in the analog domain, other exotic processes have been developed over time. Most have simply used other, more expensive wafer materials, but there are a few that use different transistor structures.

The first forays into exotic wafer materials used germanium (Ge) instead of silicon (Si) for the bulk wafer. While Ge is faster than Si, it is much more expensive and brittle. A good balanced solution to both problems exists today: SiGe – a combination of the semi materials.

Another method to achieve higher speeds is to employ so called "III-V" materials like *gallium arsenide* or *GaAs*. *Vitesse Semi* was founded in the 1980s (in Camarillo, CA) expressly to make and sell GaAs standard IC products. Unfortunately, GaAs ultimately proved too expensive to compete with the speedier CMOS that later eventuated. Vitesse disbanded their GaAs fabs ca. 2004, and they now use only CMOS themselves – as a *fabless* chip vendor.

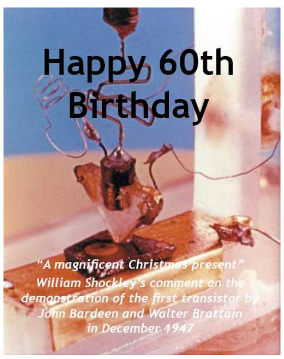
Similar "III-V" materials are still being used for very high-speed, costly applications. Those are now more complex than GaAs, and include GaInP and the like.

Finally, another way to achieve high speed instead of via *materials* is via transistor *structures*. *HBT* (hetero-junction bipolar transistors) is one such process.

## Anniversaries of Technologies

- **Transistor (1947-2007: 60th)**

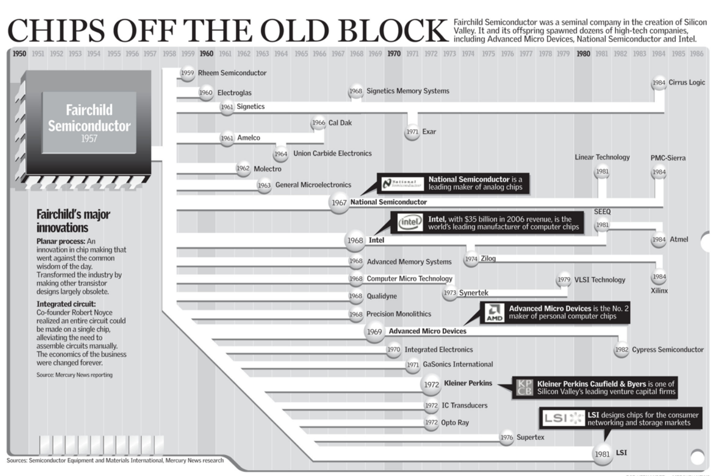
The invention of the transistor in December 1947 at Bell Labs by the trio Shockley, Brattain and Bardeen saw its most recent anniversary celebrated in 2007. Picture below is the commemoration.




Wm. Shockley

- **Fairchild Semi (IC 1957-2007: 50th)**

The invention of the transistor in 1947 at Bell Labs by the trio Shockley, Brattain and Bardeen saw its most recent anniversary celebrated in 2007. Picture below is the commemoration spinoff chart (courtesy of the San Jose Mercury News).



### ❖ Integrated Circuit (IC 1959-2009: 50th)

The integrated circuit (IC) is now widely considered to have been invented jointly by Jack Kilby at TI and Bob Noyce at Fairchild in 1959. They were eventually awarded a joint patent. Kilby had claimed he invented it as early as 1957, but his use of externally mounted (soldered) wires was not "integrated" enough in that it was not "monolithic". One could easily argue that the *monolithic* integrated circuit was the Fairchild invention (Noyce, Last, et al.), especially since they introduced the seminal concept of *planar* structures.

The Computer History Museum in Mountain View, CA celebrated the event with their "IC at 50" program May 6-8, 2009. The May 6 session was titled "From "Tinkertoys to Solid Circuits: Microcircuitry in the Late 1950s" covered the period up to and including Jack Kilby's work and included speakers Michael Riordan (Historian), Charles Phipps (TI), Jay W. Lathrop (TI), L. Arthur D'Asaro (Bell Labs). The May 8 session was on "The Planar Integrated Circuit: Building the Future at Fairchild Semiconductor" with speakers Christophe Lécuyer (Historian), Leslie Berlin (Historian), Gordon Moore (Fairchild), Jay T. Last (Fairchild).

From the CHM: ""Why this year? Didn't Kilby demonstrate his first circuit at Texas Instruments in 1958? And didn't Fairchild introduce Micrologic in 1961?" We chose 2009 for this event because the year 1959 saw an extraordinary burst of intellectual activity across the semiconductor industry aimed at solutions to the challenge of integrating multiple devices on a single chip. That spring, Kilby along with Jean Hoerni and Robert Noyce of Fairchild Semiconductor, Kurt Lehovec of Sprague Electric, and others, filed patent applications that held keys to the development of the monolithic integrated circuit. Jay Last's team at Fairchild, which would create the first planar integrated circuits, also began their efforts in the fall."

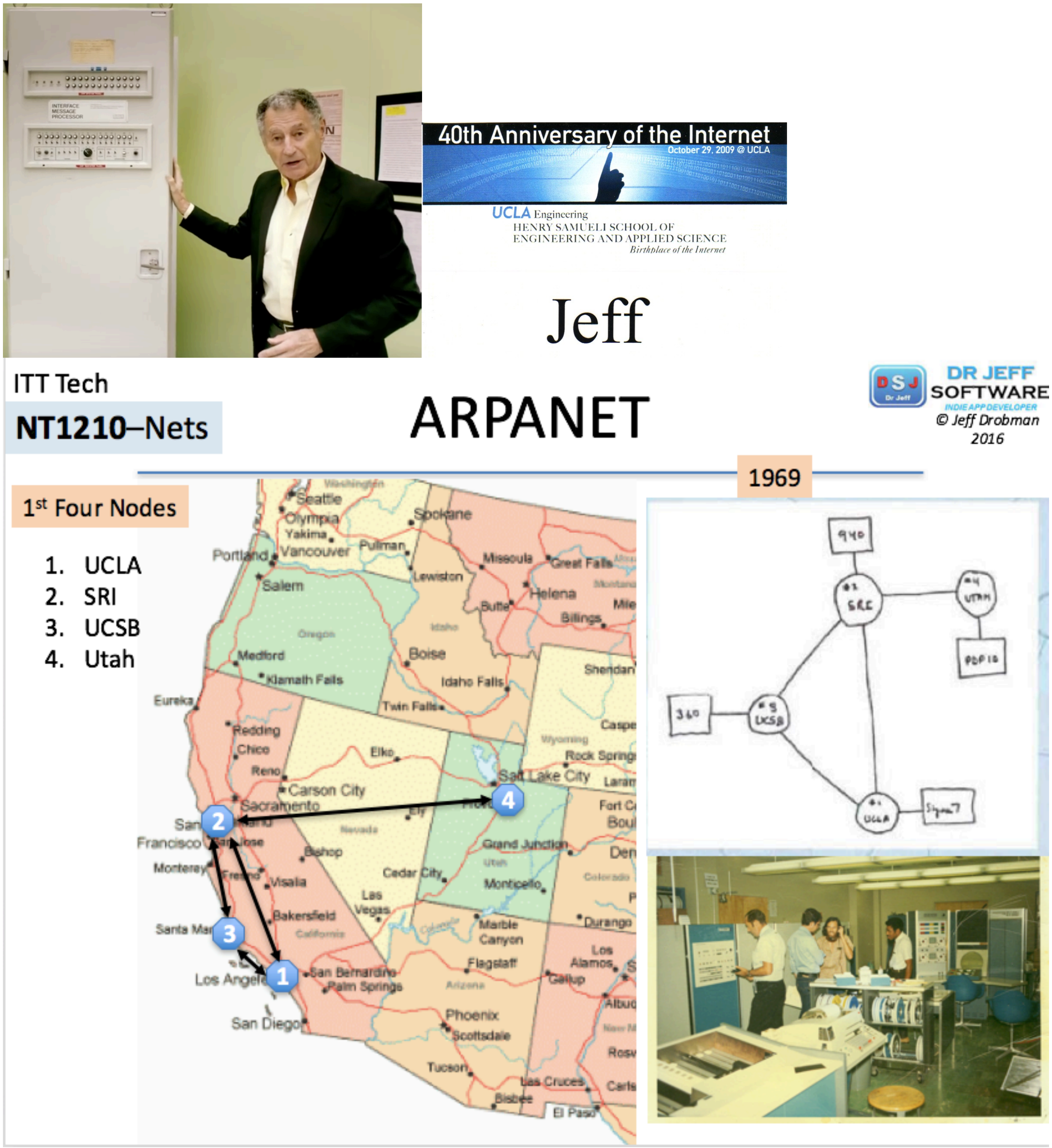
For more information go to the CHM website at: http://www.computerhistory.org/events/listing/ic-at-50/

### ❖ Internet (1969-2009: 40th)

A completely unrelated , yet oddly coincident, event that most people consider the "birth of the Internet" occurred in a lab in Boelter Hall at UCLA's School of Engineering on Oct. 29, 1969, when student RA Charley Kline sent a message over the brand new ARPANET from UCLA's "Node 1" to SRI's "Node 2". That message was merely the first ever attempt to login to a remote computer via sending a data packet over a leased telephone line (DS0 – 56 kbps) via use of the first "packet switch routers" that has just been designed and delivered to UCLA and SRI under ARPA contract by BBN, called "IMPs" (Interface Message Processors). Charley Kline typed "L" and received an "L" echoed back; then he typed "O" and got an "O" back; then he typed "G", but the telephone link crashed! So, it is said that the very first Internet message was "LO" – as in "Lo and behold!" or merely "hello".

A celebration commemorating this seminal event has been held at UCLA every 5 years, starting with the 25th anniversary in 1994; the last, the 40th anniversary was held in 2009. On Oct. 29, 2011, a special celebration was held in that very same lab (BH3428), co-sponsored by the Computer History Museum, dedicating that lab as an Internet historic site and museum. The original IMP router and its Xerox Sigma 7 host computer were restored and ensconced therein.

[Ed. Note: I was a UCLA undergrad working in the lab next door when the first IMP was installed at UCLA in Sep. 1969, and the first message was sent in Oct. 1969. I vividly recall all the excitement and buzz around UCLA Prof. Len Kleinrock (PI in charge), Charley Kline, Jon Postel (ICANN and DNS founder), Vint Cerf (TCP/IP co-inventor), et al. I continued to work in the lab next door where terminals were installed to access the "B" machine (a PDP11-45) connected to the IMP in the 1970s), whereby I used the ARPANET to access a GE/Multics computer at MIT, and an IBM 360/91 at UCLA (3rd host) to edit and print my PhD dissertation. I attended all of the UCLA Internet anniversaries. Shown below is my badge from the 40th in 2009. Also shown below is the "Internet Timeline" I put together with assistance from 2 of the 4 "fathers of the Internet", Len Kleinrock and Vint Cerf. For much more info on the Internet founding, go to my Dr Jeff website page on "Tech History", here: http://www.drjeffsoftware.com/history.html ]


40th Anniversary of the Internet
October 29, 2009 @ UCLA
UCLA Engineering
HENRY SAMUELI SCHOOL OF ENGINEERING AND APPLIED SCIENCE
Birthplace of the Internet
Jeff
ITT Tech
NT1210–Nets
ARPANET
DR JEFF SOFTWARE
INDIE APP DEVELOPER
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1969
1st Four Nodes
1. UCLA
2. SRI
3. UCSB
4. Utah
Seattle
Olympia
Yakima
Spokane
Portland
Vancouver
Pullman
Salem
Lewiston
Missoula
Great Falls
Helena
Butte
Billings
Medford
Klamath Falls
Boise
Idaho Falls
Twin Falls
Eureka
Redding
Chico
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#3 UCSB
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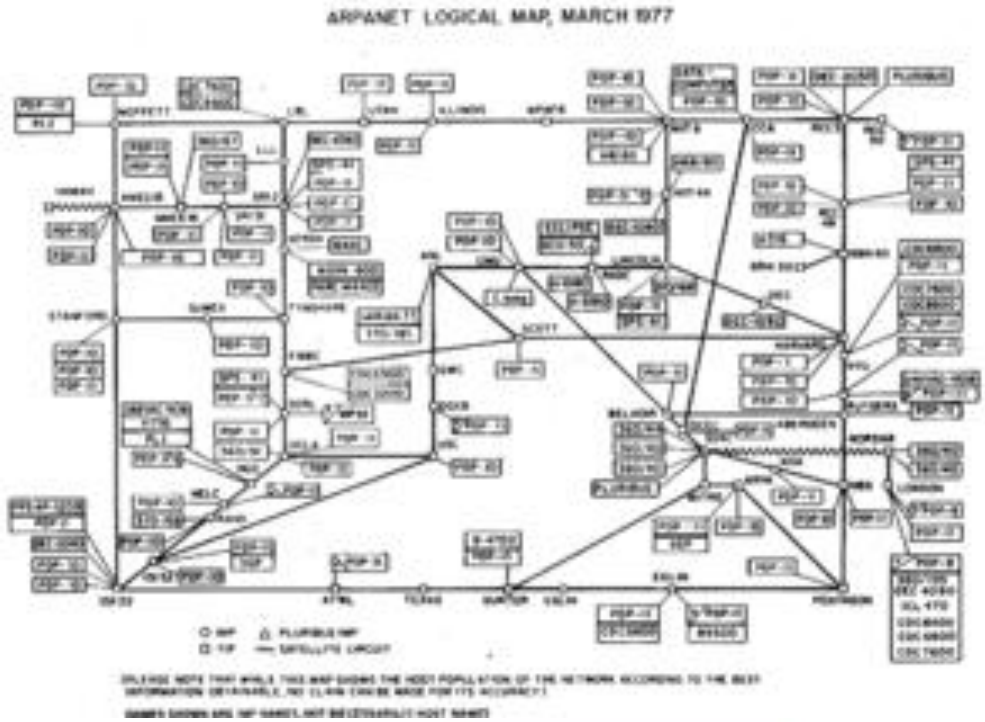


## INTERNET TIMELINE