VIP CLUB

The UNIVAC 7901000-series Integrated Circuits

By Larry D. Bolton [with extracts from a 1965 symposium paper by Ralph J. Kerler[1]]
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Introduction

The U.S. military had a need to utilize the power of computers on ships, aircraft, rockets, and missiles. Commercial machines were much too large and took too much power to be of wide-spread use. Then came the invention of the solid state diode and transistor. These parts could be used in designs of ground-based equipment [e.g., Transtec and Athena computers], but something even smaller was needed for moveable platforms. The first step in this direction was the creation of hybrid integrated circuits which utilized the mounting of individual transistor, diode, and resistor die in a single package. The individual parts were interconnected by 0.001-inch bare gold wires which were attached by manually controlled bonding machines. UNIVAC first used this approach under contract from the U.S. Navy in the CP-667 computer. It used multiple discrete devices within a 10-lead TO-5 cylindrical metal-can measuring about 0.3 inches in diameter and 0.25 inch tall. This technology was limited by the surface area within the package and the number of pins available. The UNIVAC devices contained no more than about 10 elements within the can. Since there were a number of individual component die within the can, there were several gold-to-aluminum wire bonds required. There became a failure mode associated with this gold/aluminum system and, although the failure rate was less than 0.1%, it was still unacceptable for UNIVAC applications. [It was the physical analysis of these failures by UNIVAC that later allowed UNIVAC to come up with a physical cause of the problem. It came to be known as “Purple Plague,” a brittle inter-metallic formation of aluminum and gold. See *When Computers Went To Sea* by David Boslaugh.]

UNIVAC Defense Systems in St. Paul was one of the first systems manufacturers to actively investigate the use of monolithic integrated circuits. The use of a monolithic silicon integrated circuit design allowed the integration of dozens of circuit elements on a single piece of epitaxial silicon [a pure layer of silicon grown on top of a silicon wafer substrate] and would allow several of the gold-aluminum bonds to be eliminated. Work in this area was begun as early as 1960 to 1961 via a development contract with Sperry Semiconductor for work on an early ADD computer. In 1963, an entire department had been created to implement the technology in our Aerospace business arena. The advantage of this approach was demonstrated by the incorporation of several UNIVAC custom devices in the 1824, MBRV, BGRV and later the Titan III aerospace computers. These devices used a gold-doped bipolar diode-transistor-logic (DTL) process and allowed simple logic gate elements to be contained in a single 10-lead metal/ceramic flat pack measuring no more than 1/4x1/4 inch on a side and 1/10 inch thick. The silicon chip (or die) inside was only about 0.050 inches on a side. These circuits were designed for minimal power dissipation, maximum noise margin, maximum reliability, and minimum parts count. An early selection process led to contracts with Westinghouse and Signetics as semiconductor manufacturers for these devices. These aerospace programs were short term with low part volumes. However, with the success of this venture, and given partial funding by the Bureau of Ships, UNIVAC proceeded with the development of the next generation of circuits, with an emphasis on circuit speed.

Development

A cooperative effort between UNIVAC Reliability, Design Engineering, and Purchasing personnel began in 1964. The circuitry required by machines being designed/built in the early 1960s (CP-667) was evaluated. Since development costs for each circuit were high, it was desirable to create as few configurations as possible. It was decided that we could build machines using two and possibly three

[1] Available in pdf format from http://vipclubmn.org on the Links/Docs, Documents page.

basic building blocks. Two were inverting AND (NAND) gates. One had quad 2-input DTL (diode-transistor-logic) gates. The other had dual 4-input DTL gates. The third was a triple DTL gate with 2, 3, and 4 inputs. Based on designing a CP-667 computer with these three functions, a component count was obtained. In order to minimize development costs, the third function was set aside. All functions could be implemented using the first two devices. Specifications for these two devices were developed - see Appendix, Table I. Each semiconductor manufacturer known to have capability in the integrated circuit field was given an opportunity to participate in the early phases of negotiations.

Although UNIVAC provided the initial equivalent circuit design, suppliers were allowed to come up with their own circuit and silicon implementation which would meet the requirements. Five suppliers were selected for continued development based on past performance, long range pricing, supplier interest, and UNIVAC's perception of their capabilities. Development orders were placed in December of 1964 to Westinghouse, Motorola, Signetics, Texas Instruments, and Fairchild. The prime semiconductor process being used at that time was a gold-doped bipolar process on about a 1-1/2 inch diameter wafer [Note: a wafer of this size could yield as many as 490 die.] Samples were built and obtained from each potential supplier in 1965. These samples were technically scrutinized by UNIVAC technology experts and electrically tested. Each supplier had a unique implementation: some had advantages, some had disadvantages. Differences in the package used by each supplier were also noted.

Both Texas Instruments and Fairchild failed to meet the electrical specifications or had an unacceptable design. The initial Signetics and Motorola parts were marginal but Motorola later delivered an acceptable product. The Westinghouse devices were acceptable. The acceptable devices were subsequently electrically evaluated in more detail. Westinghouse was qualified as an initial sole source.

Early in the 1960s, UNIVAC had developed a high speed automatic direct current (DC) electrical parameter tester [Automatic Component Tester] for diodes and transistors. A special handler was created in 1963 to allow this tester to be used for multi-leaded integrated circuits. The development of the 7901000 series circuits required that a new tester be developed in 1965 to also allow Alternating Current (AC) parameters to be tested. The ACMET was completed in 1966. These were the testers used to electrically evaluate these devices. Individual hand testing was also done for specialized tests or parameters.

In addition to meeting all the electrical and mechanical requirements, there were also environmental requirements which had to be met for any military application and to prove reliability. Some of the tests included operation up to 200ºC, storage up to 400ºC, helium leak rate tests, shock up to 1500G, centrifuge beyond 40,000G, and operating life for 2000 hours at 125ºC. Both design and processing deficiencies are brought out by these rigorous tests. Failures in these tests were closely analyzed to define the modes of failure so corrective actions could be implemented, where necessary and appropriate.

Specifications

There were seven procurement specifications created for these new devices:

- The 7901000 specification was for the DTL dual 4-input NAND gate in a 14-lead flat pack. Operation was guaranteed from -45ºC to +135ºC case temperature. Switching parameters are measured at a Vcc of 6.0V. Propagation times are 12ns to 16 ns maximum with output rise and fall times of about 20ns maximum. The equivalent schematic has 12 diodes, six resistors, and two transistors.
- The 7901001 specification was for the DTL quad 2-input NAND gate in a 14-lead flat pack. Operation was guaranteed from -45ºC to +135ºC case temperature. Switching parameters are measured at a Vcc of 6.0V. Propagation times are 12ns to 16 ns maximum with output rise and

fall times of about 20ns maximum. The equivalent schematic has 16 diodes, eight resistors, and four transistors.

- 7901002 specification - This device was never developed. It would have been the third DTL 4-3-2-input gate for use on CP-667. The drawing is now obsolete.
- The 7901003 specification was a +10ºC to +95ºC temperature version of the 7901000 device and was in a 14-lead flat pack or dual-in-line package. It could be used where operating temperature was not as severe.
- The 7901004 specification was a +10ºC to +95ºC temperature version of the 7901001 device and was in a 14-lead flat pack or dual-in-line package. It could be used where operating temperature was not as severe.

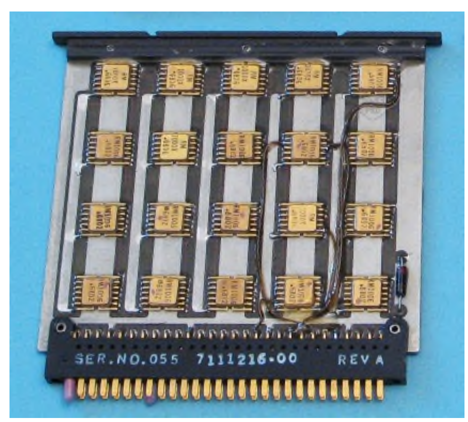
The limited temperature range of the 7901003 and 7901004 devices allowed them to use some of the electrical screen fallout from the 7901000 and 7901001 testing.

The 2801573 specification was a specially screened version of the 7901000 for use on the C-3 program. The 2801574 specification was a specially screened version of the 7901001 for use on the C-3 program.

See Appendix, Table II.

Usage

These new devices were intended to be used in the CP-667 machine to replace the hybrid devices, and a redesign was actually released using these devices. However, only three CP-667 machines were built (before this integrated circuit development). The Navy cancelled the CP-667 program after two units had been delivered. UNIVAC thus put the third unit into their Military Computer Software Development Center, no CP-667 units were built using the 7901000 series devices.



However, there were applications for these devices. Beginning in 1966, the CP-901, AN/UYK-7, AN/UYK-8, and CP-890 computer designs largely used only the 7901000, 7901001, 2801573, and 2801574 devices. Several peripheral device controllers also used these devices or PC cards from computers. The card type shown here is from the CP-901 arithmetic control section of the CPU. Heat from the components transferred from the chip case bottom to the heat ladder on the card, then from there to the T-bar at the card's top. This T-bar made contact with a metal to forced air heat exchanger. These 56-pin printed circuit cards plugged into a wire-wrap back-panel on 0.2" centers. Two of the pins provided +5v power to the components. Four of the pins provided the ground return while two pins [with plastic covers] were used to code the card when plugged into the back panel.

Computers which were designed using largely only the 7901003 and 7901004 devices include the ARTS, and some UYK-7 applications, etc.

All were very successful programs for many years, i.e. the first CP-901 delivery was in 1967 - the 499th delivery was in the early 90's, a 25 year production run. In 2008, about 50 CP-901 computers were still flying aboard Lockheed P3-C aircraft, still performing ocean surveillance missions.

Alternate Sources

Since we were a part of Sperry Corporation, which had its own semiconductor processing division, we were pressured to include them as a source. Samples were made and tested in late 1967, but the Sperry parts were unable to meet all of the rigorous electrical specifications. It took high level managerial intervention to stop the pressure from corporate headquarters to include Sperry as a device source.

Due to product reliability and production volume issues with sole source Westinghouse, UNIVAC looked to other sources for the devices. We evaluated Sylvania and Raytheon Semiconductor operations. Raytheon became the second source sometime in the late 1960's. Westinghouse was dropped as a source shortly thereafter. By March of 1969, Raytheon was a sole source.

Motorola became a source in July of 1970, and in April of 1971 a new die mask set was qualified. They were also added to the 7901003/7901004 drawings. Quotes in 1970 show run rates of up to 6,000 devices per month for the 7901000, and up to 30,000 devices per month for the 7901001 had been requested. It was noted that Motorola had a run rate of about 60,000 devices per month on the 7901003/7901004 devices in 1971. At this volume, Motorola had capacity issues with the burn-in ovens. Each oven, which contained hundreds of parts, would require 2,000 Amps of supply current. Motorola did not have this capacity in the early 1970's. Capacity was still an issue in 1976. Use of 2" wafers began in 1974 then Motorola changed to a 3" wafer in 1977.

In 1971, samples were obtained from Microsystems International of Canada and they looked good. However, they were never qualified because, politically, it would not have been wise to use a source that was totally outside the U.S.

Fairchild Semiconductor became a source in May of 1974. Files indicate that Fairchild used an 8-mask set to produce these devices. One quote from Fairchild in 1976 shows a run rate of up to 70,000 devices per month had been requested.

Raytheon continued to be a source. One 1968 quote for these devices showed pricing at between $5 and $10 for up to a 100,000 piece order. In May of 1971 their change from a 1-1/2" wafer to a 2-1/4" wafer was qualified.

Over time, numerous changes were tested and qualified in order to sustain production. These included changes in processing, testing, packages, fabrication/packaging/test locations [including moves to Mexico and the Far East.] In addition, most field and system test failures had been analyzed for root cause of failures. Quality, Component Engineering, and Vendor Surveillance worked closely with the suppliers to find and correct the cause of these failures. Problems included metallization micro-cracks, bonding, solder splashes, loose particles, "purple plague," hermetic package leaks, mismarking, and marking permanency. UNIVAC had vendor surveillance personnel in the supplier's plants. These people pointed out laxness in processing and strongly suggested changes to improve product quality. These corrective actions led to improved processes at the suppliers that affected not only UNIVAC products, but all products for all customers.

In addition to the quality issues, there were occasionally parametric test issues where readings between UNIVAC and the supplier did not correlate. These problems were also worked to ensure both were using the same measurement techniques or, at least, to compensate so that we would not be arguing about whether individual units passed or failed our requirements. Some issues also arose when UNIVAC design engineers blamed the parts for causing card electrical failures in final test or in the field. These also required additional testing to determine the failing parameter.

By 1976, Raytheon, Motorola, and Fairchild were sources - the use of Fairchild was becoming prominent.

Phase out

A new Schottky bipolar process had been invented, thus space on fabrication lines was getting tight. The gold-doped process at suppliers was being phased out to make room for the Schottky bipolar process [building a new fabrication line required an investment of millions of dollars.] So, while the UNIVAC demand was dropping, we also began to lose sources for the devices.

A letter was sent to all suppliers in 1977 asking them to define their obsolescence intentions. At that time all stated they had no intention of discontinuing our product, although Motorola stated they would probably do so if volume dropped below 200,000 pieces per year.

In July of 1982, Motorola announced they were discontinuing all gold-doped processes including the DTL and TTL processes.

In August of 1987, Motorola no-bid an order for a new build but did indicate they had a reserve die bank of 800,000 die which could have been packaged and tested. Raytheon had been mostly inactive due to their higher cost but did indicate they could still make the devices. Fairchild had last made the devices on a 3" wafer and could still build a few from their existing die bank but would need funding to switch to the newer 4" wafer size in order to continue making the devices.

The status at Unisys at that time showed 75,000 of the 7901000-01 in stock with an additional 50,000 on order. Delivery rates were 5,000 per month. For the 7901001-01, there were 65,000 in inventory with 425,000 on order. Delivery rates were 40,000 per month. Prices ranged from $2.80 to $5.50 each depending on order quantity and supplier.

We continued to procure these devices until National Semiconductor, who had acquired Fairchild Semiconductor, shut down their line in 1994. We made a last time buy of devices to support spares and repair of existing equipment. The UYK-7 computer had been replaced by the new UYK-43 computer. However, we know that last time buys never cover enough material to last a lifetime. Lansdale Semiconductor obtained the rights to continue building the Fairchild devices if the need arose.

These two devices were in production for almost 30 years, and over that time it is estimated 10s of millions of the devices were produced, procured, and shipped to customers in the aforementioned computers. Many of these are still being used reliably today.

Author's Biography

Larry D. Bolton
University of Minnesota - BEE, 1965: Component Engineer with UNIVAC/Sperry/UNISYS/Lockheed Martin for 41 years from 1965 to 2006. During this career, he was responsible for all types of electrical components. His responsibilities were to generated procurement specifications, test/evaluate samples, qualify sources, and work with suppliers to resolve component technical, quality, and reliability issues.

Appendix

Thanks especially to Ralph Kerler for contributing his paper "Integrated Circuit Standardization within Defense Systems Division" which was presented at the 1965 Transactions of the Fourth UNIVAC Engineering Symposium. This paper was the source for most of the events up to 1965 which are discussed in this article. A *.pdf version of the entire paper with more technical details is available elsewhere in our legacy project archives.

The Lockheed Martin MS2-Eagan Material Engineering department has several files of history after 1969 (test data, communications, etc) which were also used to prepare this article. Other artifacts include photos of various die, failure mechanisms, and even wafer fabrication process masks.

Table I – Comparison of the Aerospace 1824 component and 7901000 series characteristics

Characteristic	"1824"	"7901000"
Package	10 Lead Flat Pack	14 Lead Flat Pack
Fanout	5	6
Collector Logic Capability	No	Yes
Operating Temperature	0ºC to +125ºC	-55ºC to +125ºC
Power Per Inverter (Avg.)	5 mW	30 mW
Noise Margin (Minimum)	0.5 V	0.35 V
Supply Voltages	4 V	6 V and 3 V
Propagation Speed (Typ.)	50 ns	10 ns

Table II - Part numbers of the devices which may be found marked on various hardware artifacts.

			Supplier Part Number				
UNIVAC PN	**BI**	**Pkg**	**Westinghouse**	**Raytheon**	**Motorola**	**Fairchild**	**Lansdale**
7901000-00	NR	Flat	WS282Q	RM1000	SC900FH	HL51223	LC70041A
7901000-01	Yes	Flat		RM1000X RM1005	SC900FH-1	HL51224	
7901001-00	NR	Flat	WS283Q	RM1001	SC901FH	HL51225	
7901001-01	Yes	Flat		RM1001X RM1006	SC901FH-1	HL51226	LC70042A1
7901002 *							
7901003-00	Yes	Flat	WS286	RM1003	SC1856FH	HL56988	LC70043A
7901003-02	Yes	DIP			SC1856LH	HL57196	
7901004-00	Yes	Flat	WS287	RM1004	SC1857FH	HL56989	LC70044A
7901004-02	Yes	DIP			SC1857LH	HL57197	
2801573-00	Yes	Flat		RM1035	SC61075FH	HL70709	
2801574-00	Yes	Flat		RM1045	SC61076FH	HL70710	

BI=Burn-in required NR=not required *=Obsolete device
Pkg=Package Flat=Flat Pack DIP=Dual-In-Line Package

There was a third device, a 16-bit memory cell, which was also developed and was used in many of these same computers. It is specified on UNIVAC specifications 7902897 and 2801575, but that could be the subject of a separate story.