Component Quality & Reliability

By Larry Bolton

INTRODUCTION

Each new military computer design comes with a set of functional, electrical, mechanical, environmental, and reliability performance requirements. {Editorial note: MIL-E-5400 (airborne equipment) or MIL-E-16400 (shipboard equipment.)} These requirements are divided into a set of specifications for modules which together will meet the design requirements. These modules are further divided into assemblies which are assigned to specific design engineers. Those engineers select mechanical and electrical components which will allow the assembly to meet its design requirements.

For the purposes of this paper, the term 'components' includes resistors, capacitors, diodes, transistors, integrated circuits (ICs) of small, medium, and large-scale complexities, filters, and coil wound devices. Other devices like switches and relays are loosely included.

In the 1950s, diodes and transistors were a new technology. New manufacturing processes were needed and were unproven. There was lots of room for improvement. Univac was at the beginning of this journey and was a major contributor to their development. The following organizations worked together to make this happen.

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COOPERATING ORGANIZATIONS

Component & Material Engineering

Since each new design pushes the state of the art, it is likely some new and unproven components will be needed. It was the job of Component and Material Engineering to make sure these new components would work reliably in a high stress military environment.

The first task was to create a formal procurement specification for the components. It defined the mechanical, electrical, environmental, and quality requirements any supplier of the item needed to meet. Most parts were required to operate over a -55° C to +125°C temperature range. *Think about it, military equipment must operate in the Arctic & Antarctic cold as well as in Pacific Ocean heat!* Most component procurement specifications required the supplier to subject electronic parts to environmental stresses and burn-in. The specific environmental tests varied depending on the type of component and its construction weaknesses. Final electrical tests exposed the weak parts which were to be removed from the lot.

The other task was to obtain samples of the item from, hopefully, multiple sources and subject them to physical, mechanical, electrical, environmental, and life tests. The component engineer prepared a test request defining the sample sizes and the tests to be performed on each. The tests were in conformance with industry standardized methods tailored to the unique construction details of the items. These tests often included temperature extremes, thermal shock, temperature cycling, mechanical shock, vibration, centrifuge, seal, humidity, and life, among others. All testing was done by the electrical component test lab and environmental test lab. Electrical parameters were measured after the tests. Catastrophic failures were sent to Failure Analysis to determine the cause. At the conclusion of the tests, results were analyzed, and the component engineer prepared a formal report. Unfortunately, although the sample parts passed the qualification tests, that only showed that the supplier could produce reliable parts. It also required a well-controlled manufacturing process to ensure all future product would be reliable.

Early electrical testing was done by hand. There were no automated testers. Therefore, a sister department designed and built custom testers (ACT, ACMET, Complex Array Test System). These testers were used for rapid testing of a variety of parameters on semiconductors. Later, commercial testers became available which could test complex semiconductors.

MSI Test System

February 1970

Testing semiconductors at temperature was difficult. With most systems, a delay from moving the part from a temperature chamber to test socket meant that the part cooled or warmed a bit. An improved Thermal Environmental Test System was designed and built. It allowed semiconductors to be tested electrically at temperature extremes [-55^o C to +125^o C.] It used a jet of gas from liquid Nitrogen which could be kept cold or heated. This jet impinged directly on the device keeping it at the desired test temperature. In cases where suppliers contested our test results, they quickly conceded when shown our testing systems and methodologies.

Some situations required the use of special test fixtures. One was the life test of push button switches. For this test, the environmental test lab developed a tester consisting of a motor driven circular plate which had several casters mounted around the periphery. Switches were mounted on another circular plate which was mounted facing the casters. This allowed thousands of presses to be applied in a few days.

One major problem was the presence of particles in semiconductor package cavities. The environmental test lab developed a diode tap tester. This tester allowed diodes to be tapped while being monitored electrically for momentary shorts. Later, the component test lab acquired a particle impact noise detector (PIND). This was a small variable frequency vibration table with attached microphone. The operator listened for noise from loose particles (some smaller than 1 mil) rattling around inside the package cavity.

When failure modes were defined by Failure Analysis, Component Engineering forwarded this information to the supplier and requested corrective action. We, along with Vendor Surveillance, worked with the supplier to improve his product rather than dump them as an approved source

Screening of components for the Minuteman program was even more intensive than previously described. See the article listed in the reference section at the end of this paper.

Univac Defense Systems Division (DSD) was a member of the Sperry Corporate Semiconductor Coordinating Committee (SCSCC) and the Electronic Industry Association (EIA) G-12 [government contractors and agencies] subcommittee. A component engineer was the designated representative who attended semiannual meetings for over 40 years.

Quality and reliability issues were discussed at these industry/government meetings, then information shared among many users and suppliers.

By the 1990s, product quality and reliability had improved to the point that qualification testing was no longer required, thus the test lab was closed. Military grade components were being discontinued by suppliers. Commercial or industrial grade parts were subsequently procured to the supplier part number without benefit of a detailed procurement specification.

The group had several different names over the years including Material Engineering, Materiel Engineering, and Purchased Material Engineering. It also belonged to Design Engineering or Quality at different times. Design Engineering began to use commercial assemblies (COTS – Commercial-Off-The-Shelf) rather than design custom assemblies [computers, processor cards, video cards, I/O cards, routers, Ethernet switches, media drives, etc.]. The group's function was reassigned, and continuation engineers began monitoring these devices for obsolescence and changes. The department was disbanded in 2012 when Lockheed Martin closed their Eagan facility.

Quality Assurance (QA)

Most computer specifications had Mean Time Between Failure (MTBF) requirements. Quality Assurance collected failure data from module test, final test, and the field. Data was statistically analyzed to look for trends. Failed modules were repaired when possible and any failed components were sent to Failure Analysis. Upon receipt of the failure mode results, QA worked with Component Engineering to contact the supplier and request corrective action.

Univac computers almost always exceeded the MTBF requirement. Credit the combined efforts of Component Engineering, Failure Analysis, Quality Assurance, and Vendor Surveillance.

See the reference listed at the end of this article for more information on the QA organization.

Failure Analysis (F/A)

Failure Analysis used several specialized methods to carefully dissect the failed components to determine the exact physical cause of the failure. It took great care to un-encapsulate the item without destroying the evidence or creating debris which would complicate the analysis. Jewelers grinding wheels were used to section some devices to the point of failure. Analysis tools included X-ray, Electron Microscope, and Auger Spectroscopy.

Most failure modes were well known and easy to identify. But one was defined to the American Society for Quality Control conference in 1962 by George Anderson of the Univac F/A lab. That was purple plague. Semi-conductor die usually have aluminum conductive patterns. The hermetic package they are place in has gold plated “posts”. Typically, a 1 mil gold wire is ball bonded to the die metallization and stitch/wedge bonded to the package post. Under high temperature conditions, the gold-aluminum interface on the die can form an alloy. This purple gold/aluminum alloy is very brittle and is subject to breaking thus causing an open circuit. This discovery led to the industry change to aluminum wire bonding.

Some of the failure modes often encountered include semiconductor diffusion defects, metallization opens and shorts, electro migration, lifted bonds, loose wire pigtails, solder, and eutectic loose particles, lifted die, corrosion, hermetic seal failures, contamination, broken welds, overstress, electrostatic discharge damage, and capacitor dielectric flaws.

Results of the analysis with photos were returned to QA or Component Engineering for possible action.

There was enough work to keep a staff of up to 11 persons busy for 3 decades. Due to the efforts of Component Engineering, Quality, and Vendor Surveillance, reliability continued to improve. By the 1990s, failures were no longer being returned from the field and in-house failures were no longer being analyzed. The Failure Analysis lab was closed.

Vendor Surveillance

The Vendor Surveillance department had representatives stationed at various locations in the US and SE Asia. Some representatives had offices in the supplier’s facility (e. g. Motorola, Texas Instruments, and National). They worked with suppliers to implement corrective actions. They observed our products being made and recommended process improvements. Lot test data was reviewed, and samples of product were inspected prior to shipment. It is via the efforts of Vendor Surveillance that process controls greatly improved (Statistical Process Control) and lead to improvements in product quality, especially in the semiconductor sector.

Receiving & Inspection (R&I)

Besides counting the components as they were received, R&I also pulled samples from each lot and subjected them to mechanical and electrical tests to make sure they met the procurement specification.

They and QA defined additional supplier requirements which were added to purchase orders for the components [e. g. the need for Vendor Surveillance to inspect the parts and test data prior to shipment. Otherwise known as source inspection.]

This continued until the late 1990s when the process changed. Component Engineering and Quality assisted in the review of receiving records. Attention was paid to part and supplier's reject rates. Any products or suppliers that had a history of low or no rejects were "certified" and were allowed to ship directly to inventory without the need for counting or testing.

Procurement Department

Comments from Mike Svendsen: The semiconductor industry was just getting underway, and each vendor had expertise in different processing and assembly technologies. They were investigating and learning what was best and consistently producible. Timely cooperation and communication were essential so that we could both learn from our mistakes and build a better and competitive end product. The technical and quality personnel at Univac and the Suppliers had to have quick and complete channels to exchange info.

The supplier sales force and our Procurement staff worked together to document and follow up on changes made to the process flow. The semiconductor industry was eager to get input from our technical evaluations which allowed them to improve their products. This ultimately made our computers more reliable and producible. We all benefited from the incredibly open and positive communications. http://vipclubmn.org/People9.html#Svendsen

EPILOGUE

Most of this activity occurred from the 1950s thru the 1980s and describes the UNIVAC/Sperry Defense Systems Division activity. Early in this period, the military was a major user of new electronics. Early computers used thousands of diodes and transistors. Suppliers competed to make products meeting military demands. Today, that is no longer the case. Except for automotive and other ruggedized applications, products are made for only a 0^{o} C to 70^{o} C home environment or industrial environment. It is up to defense contractors to find ways to protect commercial devices from harsh environments. Fortunately, quality and reliability of commercial devices has improved to help in this effort.

Comment from Jack Metzger: Lowell, Larry Bolton did a fine job on this article. It covers a high level of activity that covered component approval from Athena to the integrated circuits phase of design. I held a role in the germanium to silicon phase of semiconductor phase. I toured vendors to come up with small signal components that would package onto printed circuit cards. But that is another story.

Wrap up:

The Twin Cities presence of what was UNIVAC/Sperry defense systems has been closed. There are Air Traffic Control and fiber optic transceiver design offices which remain, but some are no longer part of Lockheed Martin. The manufacturing facility in Clearwater, Florida still exists as part of Lockheed Martin and does contract assembly work. The former Twin Cities employees have moved on, retired, or transferred to other Lockheed Martin facilities.

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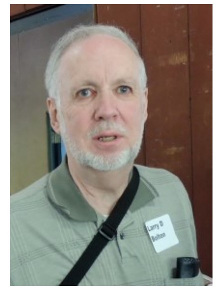
Larry D. Bolton - U of Minnesota, BEE, 1965

Senior Staff Engineer retired from Lockheed Martin in 2006 after 41 years as a component engineer with UNIVAC, Sperry, Unisys, and Lockheed Martin. http://vipclubmn.org/People1.html#Bolton.



References

The following related articles can be found on the vipclubmn.org web site.

- Chapter 40, Engineering: 4. Maintenance Panels (switches) - http://vipclubmn.org/Engineering.html#Maintenance
- Chapter 42, Engineering/Components: 1. Component Engineering - Engineering Components Chapter (vipclubmn.org)
- Chapter 42, Engineering/Components: 2.1 Component Analysis (thermal test) - http://vipclubmn.org/Components.html#Analysis
- Chapter 42, Engineering/Components: 2.2 Minuteman Pulse Transformers - http://vipclubmn.org/Components.html#Pulse%20Transformers
- Chapter 42, Engineering/Components: 2.3 The Motley Crew and Complex Array Tester - http://vipclubmn.org/Components.html#Motley
- Chapter 42, Engineering/Components: 3. Procurement - http://vipclubmn.org/Components.html#Procurement
- Chapter 42, Engineering/Components: 4. Product Assurance - http://vipclubmn.org/Components.html#Product%20Assurance
- Chapter 42, Engineering/Components: 6. PC Card Development by Jack Metzger - http://vipclubmn.org/Components.html#Metzger
- Article 107, Larry Bolton's Vendor Surveillance Notebook - http://vipclubmn.org/Articles/BoltonNotebook.pdf
- Article 117, Environmental Test Lab Development - http://vipclubmn.org/Articles/TestLabRev3.pdf
- Article 118, SNERT Custom Integrated Circuit Development - http://vipclubmn.org/Articles/SNERTDevelopment6.pdf
- Article 120, 4th UNIVAC Engineering Symposium paper BY Ralph Kerler - http://vipclubmn.org/Articles/7901000.pdf Integrated Circuit Development Paper
- Article 121, The Univac 7901000 Series IC Development - http://vipclubmn.org/Articles/The_Univac_7901000RevC.pdf
- Article 129, Minuteman Program Parts Control - http://vipclubmn.org/Articles/MinutemanPartsControl2.pdf
- Article 182, Semiconductors at Univac by Mike Svendsen - http://vipclubmn.org/Articles/UnivacSemiconductorPaper.pdf
- Article 197, Semiconductor Chronology at DSD - http://vipclubmn.org/Articles/SemiconductorAtUnivacDSD.pdf

See also the book "Digital State: The Story of Minnesota's Computing Industry" by Thomas J. Misa of the U of Minnesota - http://vipclubmn.org/Articles/BookReviewDigitalState.pdf

Editing by Lowell A. Benson – BEE, U of MN, 1966, http://vipclubmn.org/People1.html#Benson