Strict control kept out semiconductor flaws

With billions of dollars and the hopes of the world at stake, NASA could hardly risk failure of the Apollo 11 mission because of some obscure transistor or IC defect. Semiconductor manufacturers made sure the risk wasn't taken.

In their quality-control efforts for the space program, the manufacturers have learned that pre-cap internal visual inspection, burn-in on all parts, separate high-reliability facilities and employe motivation are important steps to reliability.

Joseph Flood, director of reliability and quality assurance at Motorola Semiconductor Products, Inc., Phoenix, Ariz., says that all parts, at NASA's insistence, were inspected visually for workmanship faults before final packaging. These checks uncovered potential problems—bits of wire or foreign particles in the package, for instance—that would probably not have been detected in electrical or burn-in tests. The effect was to minimize the number of latent failures—and the manufacturers ecstatically point to the success of Apollo as proof of their high reliability.

Motorola's Bert Stelzer, manager of administrative services in the Reliability and Quality Assurance Dept., says the department even considered extending its visual inspection to include X-ray of the packages. X-ray techniques are especially useful in spotting die-bond voids —the cause of hot spots in operating ICs—and in checking lead bonds. But aluminum metallization and bonding wires are transparent to X-rays, and Motorola was using aluminum bond wires (a monometallic aluminum system is widely accepted as the most economical and reliable interconnection choice); so visual inspection was performed before final packaging.

Stelzer points out that no major process innovation was involved in gettting high-reliability components for Apollo. "The problem has been to assure ourselves of the reliability levels that we already have," he says. "We don't lose much product in our burn-in tests. Average losses were about 1 to 2 per cent, and many of them were not outright failures but just borderline on some specification or other."

Stelzer is convinced that a smoothly running process is the key to reliability. "You must have constant production," he says "under good controls, and at a rate sufficient that you can monitor the process. If you run a start-stop operation, you can't monitor the process reliably."

Gordon Russell, national sales manager for aerospace and defense marketing at Fairchild Semiconductor, Mountain View, Calif., reports: "Apollo really taught us a lot about reliability. We implemented internal visual inspections and designed traceability procedures that had never been done before. Our quality-control people can trace lots all the way back to wafer processing."

But Russell found some of the procurement arrangements uncomfortable. In supplying transistors to Raytheon, he says, Fairchild agreed that it would supply the devices and Raytheon would perform visual and environmental tests—leak test, shake, centrifuge, etc.—plus 100 per cent screen and burn-in.

"If more than an acceptable percentage of a lot failed this critical inspection, we got the whole lot back," Russell notes. "And we could not give back to them any part of rejected lots."

The result, of course, was a happy customer, but Russell doesn't consider it a suitable arrangement for a vendor. "We need control of screen and burn-in in our own house," he says. "If we don't have that control, we don't have a good monitor on our process. And we can't control what a customer does to our circuits if he tests them at his facility."

Russell found also that to build to the extreme Apollo reliability criteria,Fairchild needed separate production lines. "Asking girls on a standard line to build to Apollo standards is like asking a guy to study in a room where three other guys are having a bull session," he says. "The girls must have a separate facility where they can concentrate and maintain their high standards."

Segregation alone is not enough, of course; the staff must be motivated to do high quality work. And semiconductor manufacturers in Apollo have recognized this. Astronaut Frank Borman, for instance, visited the Motorola plant to tour the production areas and to speak to the staff working on Apollo parts. "The visit," says Stelzer, "had a very significant effect on the girls on the line. Each girl became very conscientious about doing her job and doing it right. She identified personally with the end result—a safe flight to the moon."

The girls working in high-reliability areas were given special smocks to wear that identified them with their work, and all containers holding Apollo parts were boldly marked as such. The object of all of this was to fix the attention of the production staff on the end use of the products and the need for quality. It worked admirably.

All in all, Russell found Apollo a fascinating project. He notes that the guidance computer was one of the first projects to be committed to the use of ICs, and finds the design a unique example of the use of repetitive elements in circuitry.

The computer was built of RTL 3-input NAND gates throughout. Flip flops were formed of cross-coupled NAND gates, and buffers were built by masking out a collector resistor.

There were two advantages to this approach. By using identical parts in large quantities, the designers at the MIT Instrumentation Laboratory, in Cambridge, Mass., benefited from the efficiencies of volume production. And because of the repetitive nature of the circuitry it was much easier to predict reliability. "The prime consideration of the whole program," says Russell, "was reliability. This thing had to work." The reliability, of course, has proven out; there have been no failures to date.

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