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15 Product Screening and Burn-In Strategies

Burn-in is a screen performed to precipitate defects by exposing the parts to accelerated stress levels. The goal is to prevent failures from occurring in the field (Pecht et al. 1995).

Burn-in as a requirement was instituted during the time of the Minuteman Missile Program where it was shown to be effective in uncovering defects in low-volume immature parts. By 1968, burn-in was incorporated in a military standard, MIL-STD-883 (1968).

Burn-in processes commonly consist of placing parts in a thermal chamber for a specific amount of time under an electrical bias. During and/or after thermal environmental exposure, functional tests are conducted. Parts that fail to meet the device manufacturer's specifications are discarded; parts that pass are used.

The temperature applied during burn-in is higher than the temperature the part will encounter in the field, as a perceived means of reducing the time to precipitate defects. Other accelerated conditions (stresses), which may be part of the burn-in process, include voltage, humidity, electric field, and current density (Lycoudes et al. 1990). To determine which stress condition and stress magnitudes precipitates defect-related failures, the failure modes and mechanisms must be known. The interested reader can find more information on these methods in the book *Quality Conformance and Qualification of Microelectronic Packages and Interconnects* (Pecht et al. 1994).

Over the last decade, there has been scattered evidence that burn-in is not precipitating many defects. For example, plastic parts were failing at a rate of approximately 800 parts per million in 109 hours and 1 part per million in 1975 and 1991, respectively (Slay 1995). In fact, in 1990, Motorola Reliability Group wrote that "The reliability of integrated circuits has improved considerably over the past five years. As a result, burn-in prior to usage, does not remove many failures. On the contrary it may cause failures due to additional handling" (Slay 1995). In 1994, Mark Gorniak of the U.S. Air Force stated that "these end-of-line screens (reference MIL-STD-883) provide a standard series of reliability tests for the industry. Although manufacturers continue to use these screens today, most of the screens are impractical or need

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Table 15.1 Companies that did not implement burn-in

Company	Product
Hewlett-Packard	PC motherboards
APCD, AHMO, IPO	LAN cards, printer cards, SIMMS
Seagate, Singapore Tech	Disk drive cards
Compaq Asia	Modem cards
TI, NEC Semiconductors	SIMM modules
Exabyte	Tape drive cards
Baxter	Infusion pump PCBAs
Apple	Video tuner cards

modification for new technologies, and add little or no value for mature technologies" (Gorniak 1994). An example of a list of companies that did not implement burn-in is given in Table 15.1.

15.1 Burn-In Data Observations

The first part of our study involved compiling burn-in data from six companies; National Semiconductor, Motorola, Third Party Screening House, Air Transport Systems Division's (ATSD) Third Party Screening House, Honeywell, and Texas Instruments. For confidentiality, the names of the third party screening houses are withheld. The data consist of the total number of parts burned-in along with the number of apparent failures detected via functional tests. Apparent failures are classified as either nonvalid or valid. Valid failures are those that would have occurred in the field if burn-in had not been performed. Nonvalid failures are those that occurred due to handling or other problems that are unique to the burn-in process and thus would not have occurred if burn-in was not performed.

National Semiconductor burn-in data showed that of the 1,119 parts exposed to burn-in conditions, 42 (3.8%) resulted in apparent failures (Plastic Package Availability Program 1995). The apparent failures were due to 35 mechanical rejects and 7 that retested OK. Burn-in did not precipitate any valid failures.

Another study conducted by National Semiconductor showed that the burn-in data, consisting of 169,508 parts, resulted in 6 (0.0035%) apparent failures. Five (83%) of these failures were due to electrical overstress (EOS) and electrostatic discharge (ESD) damage. One (17%) was a valid failure due to AC propagation delay.

Motorola burn-in data showed that parts exposed to burn-in conditions, 186 (0.072%) apparent failures resulted. The apparent failures were due to 182 electrical rejects and four mechanical rejects. Of the apparent failures, none was valid.

A third party burned-in 6105 parts that resulted in 167 (2.7%) apparent failures. The apparent failures were due to 143 mechanical rejects and 24 electrical rejects that were caused by testing errors at the screening facility. Of the apparent failures, none was valid.

Honeywell burned-in a total of 162,940 parts, of which 669 resulted in apparent failures (Scalise 1996). Out of 67 parts that were failure analyzed, five (7%) were valid failures, two (3%) that were process related, and three (4%) that were temperature related. The remaining 62 (93%) were invalid failures, where electrical overstress (EOS) and ESD contributed to 49 (73%) of the failures.

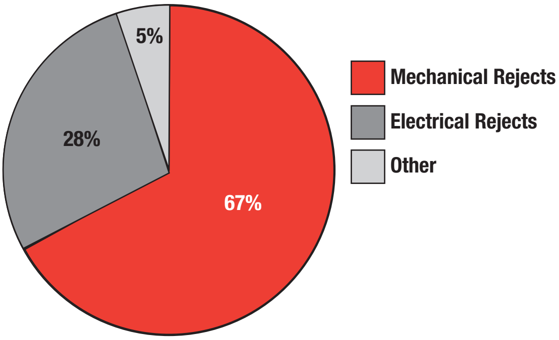

Figure 15.1 Nonvalid failures.

Texas Instruments (TI) burned-in a total of 195,070 different TTL, S, and LS parts (Tang 1996). Of these parts, 25 (0.013%) resulted in apparent failures. Three valid failures (0.0010%) resulted; one due to a die mechanical damage, one from a broken wirebond, and another could not be resolved. The 22 (80%) remaining apparent failures were due to EOS and ESD failures.

Texas Instruments data of HCMOS technology parts showed that out of the 100,165 parts that were burned-in, eight (0.009%) resulted in apparent failures (Scalise 1996). All of the eight (100%) part failures were due to EOS or ESD.

15.2 Discussion of Burn-In Data

Of the total 911,667 parts, the data presented show that burn-in detected 1125 (0.12%) apparent failures, of which 1116 (99.2%) were invalid and nine (0.8%) were valid. The valid failures consisted of: AC propagation delay, a defect in the fabrication process, die mechanical damage, and a broken wirebond.

The breakdown of nonvalid failures is shown in Figure 15.1. Mechanical defects included such things as improper device orientation and bent leads. Electrical rejects include ESD and EOS. ESD is caused by additional handling, whereas EOS occurs due to misapplied power.

The “other” category includes parts that retest OK and parts that are retained by the test lab or lost. Retest OK is defined as parts that do not pass the functional test, initially, but do pass in a subsequent test. These failures are not device related. For example, a contact may have dust and when taken out of its socket and reinserted, the dust particles are removed, creating a better contact that passes the functional test. When these failures are insignificant, the parts are normally discarded. If the failures are believed to be caused by the burn-in process, the burn-in process in reevaluated to aid in preventing such failures from occurring.

Data obtained from Northbrook, in 1991–1992, showed that of 1,017,828 parts burned-in, 70% of the detected defects were due to wafer processing and the remaining were package-related defects. In 1993–1994, 582,480 parts (from the same manufacturers) were burned-in, with 100% of the detected defects due to the wafer process. This suggests that the package quality has improved to the point where burn-in is essentially nonvalue added. In terms of this study, because of the extremely small percentage of valid failures, it is difficult to compare the effectiveness of burn-in to precipitate die-level versus package-level defects. The key point is that 99.2% of the failures could have been avoided if burn-in was not performed.

15.3 Higher Field Reliability without Screening

Honeywell's Air Transport Division had historically screened plastic encapsulated microcircuits (PEMs) for 160 hours at 125°C, followed by a tri-temp screen at −40°C, room temperature and 125°C, believing that this would increase the reliability of the end product due to reduced infant mortality. This has always been a questionable activity because:

- Typically, the integrated circuit (IC) manufacturer does not perform this screen, and doing it at a third-party part screening facility thus becomes suspect and expensive.
- The enormous improvements that semiconductor manufacturers have made in product quality must be addressed with respect to the effect of burn-in. That is, does screening actually decrease field reliability due to part damage occurring during the screening process?

In the previous sections, it was shown that many parts failed during burn-in, the majority being invalid. Two questions to be posed are: were the parts that failed really defective and were the parts that were sent to the field reliable.

It was shown that burn-in caused over 99% of the apparent failures, that is, less than 1% of the parts were really defective. This section attempts to answer the second question.

From previous results, it was believed that the handling required to burn-in parts was causing unacceptable ESD damage. What is particularly unsettling with this conclusion is that it raises the issue of latent ESD damage in fielded equipment that the handling required to burn in parts is causing unacceptable ESD damage. In order to reach a data-driven conclusion as to the necessity of doing part screening, particularly burn-in, data was collected from two sets of data:

- Aircraft field failure data for both military ceramic and commercial plastic parts, where most of the plastic parts were screened, but with a significant and identifiable group that were not screened.
- A ring laser gyro that was built with totally unscreened commercial parts to allow an on-aircraft evaluation of the effects of not screening.

From the first set of data, an examination of the field failures that occurred with the burned-in PEMs is shown in Table 15.2. The results show of the total failures, 6.6% were valid, 31.7% were invalid, 4% could not be determined, and the remaining 57.7% were not failure analyzed. The failures that resulted could be due to the part, sub-system, or system level. For example, the invalid failures do not pertain to those caused by burn-in, as discussed earlier. These invalid failures may be due to a lead that was not soldered to the printed circuit board. A process related failure, which is

Table 15.2 Field failure results: Ring laser gyro with screening

Part type Failure type	Digital SSM/MSI	Digital LSI/Mem	Linear	Total parts failed	Percent of total failures
Valid					
Fabrication	0	2	2	4	1.8
Temperature	0	0	11	11	4.8
Invalid					
EOS/ESD	8	1	5	14	6.2
Other	7	18	33	58	25.5
Undetermined	2	1	6	9	4.0
No failure analysis	16	70	45	131	57.7
Total parts failed	33	92	102	227	

considered to be a valid failure, could be a solder joint that did not wet properly during the soldering stage.

Of the invalid failures, 6.2% were due to ESD damage. This is far higher than expected based on historical in-service failure data. From this, the conclusion is that burn-in not only adds no value, but it may even increase the field failure rate of the devices built with these burned-in parts. It was also hypothesized that latent ESD effects could be introduced somewhere in the build process of the equipment.

To assess this hypothesis, a decision was made to include in the Honeywell product mix, a ring laser gyro that was built with totally unscreened, commercial parts (second data set). The part types and manufacturers used in this assembly were the same as those used in the devices that had the higher ESD related failure rate, that is, the first data set. This is because the design engineers are required to work from a relatively small list of approved parts and manufacturers. The build facility was also common to all the devices. What this means is that a comparison can be made between devices built with screened parts and devices built with unscreened parts, where the only difference is the part screening. These devices are installed in the same aircraft and in the same equipment bays.

The devices built using the unscreened commercial parts have accrued well over 200 million piece part hours without a failure. The devices that were screened resulted in 669 (0.4%) failures out of the total 162,940 parts. The only difference between these devices is that screening was not done on the devices that had no failures.

What has been shown in this comparison study is that a high percentage of latent ESD failures resulted when the parts were screened, and no failures resulted when the parts were unscreened. Therefore, the parts sent to the field were not as good as originally thought, since burn-in degraded part reliability. That is, burn-in precipitated many invalid failures and degraded part reliability, resulting in field failures. For these reasons, many field failures can be avoided if burn-in is not performed.

15.4 Best Practices

Many companies involved with “critical systems” require burn-in because they believe that the risk to do otherwise is too high. Our findings not only question this so-called safety net viewpoint, but show that this net has become a trap that should be avoided. Burning-in parts from a quality manufacturer will increase the number of field failures. The failures due to the burn-in process can be significant relative to those due to inherent defects and, therefore, an alternate approach to burn-in is necessary.

Since burn-in has shown to be ineffective, many companies have begun implementing a burn-in elimination program. This program is based on burn-in data, which implies that burn-in is being performed. However, our recommendations is that, instead of conducting burn-in and then implementing a burn-in elimination program, manufacturer part family assessment and qualification data should be used to assess the need for burn-in. This approach is based on existing data, where burn-in has not been performed, thereby avoiding part degradation.

Manufacturer part family assessment is dependent on the supplier. Parts must come from a supplier that is periodically certified, implements statistical process control (SPC) or an acceptable documented process, has acceptable qualification testing results, abides by procedures to prevent damage or deterioration (e.g., handling procedures, such as ESD bags), and provides change notifications should not require burn-in. Once a quality part is obtained, results from the qualification tests can be used to determine whether or not burn-in needs to be conducted. If no failures occur in qualification tests and the manufacturing processes are in control, then confidence can be gained to assess the part quality without performing burn-in.

15.5 Summary

Burn-in is a screen performed to precipitate defects by exposing the parts to accelerated stress levels. The goal is to prevent failures from occurring in the field. Burn-in processes commonly consist of placing parts in a thermal chamber for a specific amount of time under an electrical bias. During and/or after thermal environmental exposure, functional tests are conducted. Parts that fail to meet the device manufacturer's specifications are discarded; parts that pass are used.

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Problems

15.1 What is screening? What are the steps in conducting screening? What are the benefits of screening?

15.2 Present an example of how to lower the hazard rate during the useful life of a product.

15.3 What is error seeding and why is it used?

15.4 Give examples of defects in electronics that can be detected by screening.

15.5 Explain how screening can be used to validate product reliability during the product development. Provide some examples.

15.6 Define “burn-in” and list some of its pros and cons.