High-Reliability Microcircuit Procurement in the DSN

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The implementation of microelectronic circuits in the DSN is discussed together with utilization of an equivalent MIL-STD-883 Class B device, screening tests to be used and screening philosophy relative to failure mechanism patterns. The costs to be expected and the advantages of standardization of device types to increase quantity buys are also discussed.

I. Introduction

For the past several years, the JPL DSIF Digital Systems Development Section has utilized a standardized line of digital logic elements in system development and implementation. These modules were manufactured with discrete components which were screened by being subjected to voltage/temperature stresses and specified visual and electrical tests. The component screening process coupled with workmanship controls during module assembly produced a digital module at a reliability level suitable for ground telemetering and control systems.

As systems have become more complex, increased speed requirements and space limitations have necessitated the use of microcircuits in DSIF digital systems. This article discusses the philosophy being used in the procurement of these microcircuits.

II. The Reliability Level

MIL-STD-883, "Test Methods and Procedures for Microelectronics," contains industry-accepted methods and conditions of test that might be selected to achieve a desired level of quality and reliability. Three reliability classes have been defined by this standard as follows:

Class A. Devices intended for use where maintenance and replacement are extremely difficult or impossible and reliability is imperative.

Class B. Devices intended to be used where maintenance and replacement can be performed but are difficult and expensive and where reliability is imperative.

Class C. Devices intended to be used where maintenance and replacement can readily be accomplished and where downtime is not a critical factor.

Various levels of screening tests can be selected from MIL-STD-883 to verify that the device can be properly classified for an intended use as indicated above. The highest levels of screening tests are more restrictive and therefore more costly to perform. To be cost effective, a careful study of screening levels must be made to select only those which contribute significantly to the assurance that the device meets the classification desired.

Class B is considered adequate for DSN systems. Screening test levels have been selected from those recommended in MIL-STD-883 for this device classification.

III. Failure Mechanisms

Experience data which will identify the most frequent failure mechanisms for similar device types are extremely valuable in selecting screening tests. Rome Air Development Center (RADC) Reliability Notebook Vol. II lists the most common failures of microelectronics as:

(1) Lead bond failures.

(2) Leakage (nonhermetic).

(3) Changes in transfer characteristics.

The following are listed by RADC as failure mechanisms which are representative of the industry average:

Failure mechanism	Percent of total failures
1. Wire bond failures	33
2. Metalization failures	26
3. Contact and photolithographic failures	18
4. Others	23

In another survey, less than 50% of total defects can be traced to device complexity while more than 50% of defects are due to lead bonds, photolithography, and contamination.

The Digital Systems Development Section has accumulated failure data on the high-reliability modules referred to in Section I by utilization of a program which requires each failed component to be reported and the failure mechanism determined. The transistor is the only discrete component which is sufficiently similar to the microcircuit to be of interest. The results on some 275,000 transistors are:

Failure mechanism	Percent of total failures
Contamination due to nonhermeticity	79
Lead bond failures	14
All other	7

A special set of circumstances existed which contributed to the very high contamination failure rate. Since this has been corrected, the leading defects are lead bond failures, with metalization defects next in frequency of occurrence.

IV. Screening and Test Philosophy

The Digital Systems Development Section has published a general specification for integrated microelectronic circuits (ES 506145) which is being used to procure devices for DSN digital systems. This specification has incorporated screening tests which are expected to minimize the probability of that devices with potential defects will be installed in system hardware. Special emphasis is placed in those areas of high failure incidence as shown below:

Failure mechanism	Screening test
Lead bond failures	Pre-cap visual Temperature cycle Centrifuge Burn-in Bond strength
Contamination defects	Pre-cap visual Temperature cycle Hermeticity Burn-in
Metalization defects	Pre-cap visual Temperature cycle Burn-in

It will be noted from the table above that pre-cap visual, burn-in, and hermeticity play prominent roles in detecting potential failures. Electrical tests which are designed to identify changes in parameter and functional characteristics are contained in a detail specification because of the unique nature of each device type. The detail specification also specifies limits on certain critical parameters and requires that measured values be provided. A lot percent defective allowable (PDA) is defined in the detail specification. This requires the supplier to collect certain test failures for each device in a given screening lot. If the percentage of fails exceeds the allowable limit, the entire lot is rejected. This prevents the acceptance of any lot which encountered a higher than normal rejection rate, with the likely possibility that the remainder passed the test with marginally acceptable characteristics.

The general specification requires that JPL be permitted to monitor any of the manufacturing or screening operations. Failure mechanisms may not be in the same ratio for a particular supplier when compared to the industry average. As this becomes known, it permits a shift in monitoring effort into the area of greatest concern. It has been found that suppliers of this product devote attention to process details in direct proportion to the interest and concern shown by the user. Inherent reliability is a function of process controls, while screens aid in identifying devices where process variations occur.

V. Costs of Screening

Screening costs can be reduced to a practical level by pooling orders to increase quantities and providing a controllable specification to facilitate a competitive bidding environment. Pooling of orders is readily accomplished when devices are standardized for use in multiple systems. In addition to the cost benefit resulting from large-quantity orders, the customer also benefits because the supplier can assign a manager to the program and still make a profit. The supplier can also accommodate process monitoring and benefit from the usual upgrading of his system. Larger quantities attract more suppliers, thus increasing competition. The supplier is willing to furnish meaningful data which can be used effectively on follow-up procurements, including histograms of population distributions by parameter, which enables the user to adjust his specification limits, increasing the yield and further reducing costs.

An example of unit price reductions resulting from quantity buys is shown below:

Device	Catalog price for 100 units at equivalent Class B, $	Recent procurement to JPL Class B, $
Device A (SSI)[a]	6.30 ea.	4.20
Device B (SSI)[a]	11.44 ea	5.90
Device A (MSI)[b]	18.45 ea.	7.90
Device B (MSI)[b]	29.91 ea.	11.45

[a]Small-scale integrated circuit.

[b]Medium-scale integrated circuit.

While the unit price reductions are impressive, the real benefit comes from a better managed program which gives added confidence to the user.

VI. Follow-up and Analysis

Persistent follow-up is required in order to continue to realize maximum benefit from procurement dollars. Devices which fail must be analyzed to properly evaluate the screens. Proper data analysis permits the elimination of money spent on screens which detect very few or no failures. Increased processing is of no value if it delays deliveries without producing a more reliable lot. Only by follow-up and analysis can an assessment be made as to whether the objectives are being met.