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LOW COST COMPONENTS: SELECTION AND ACQUISITION OF MICROELECTRON--ETC(U)
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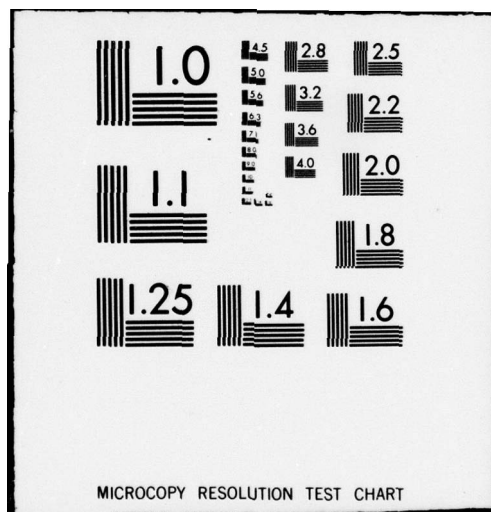
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Technical Document 223

**LOW COST COMPONENTS:
SELECTION AND ACQUISITION OF
MICROELECTRONIC DEVICES**

JH Townsend

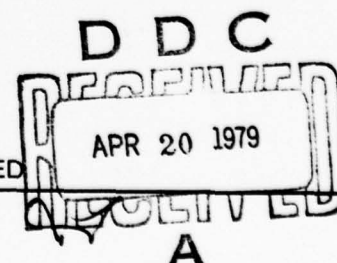
15 February 1979

Final Report: May 1977 through September 1978

Prepared for
Naval Electronic Systems Command
Systems Effectiveness Division

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ADMINISTRATIVE INFORMATION

Work was performed by members of the Design Engineering Division (code 924). It was sponsored by the Naval Electronic Systems Command Systems Effectiveness Division. This document covers work from May 1977 through September 1978.

This work extends and implements prior work accomplished under the TELCAM program (NELC Z269). The author acknowledges the valuable contributions of MC Pritchard of NOSC code 9242, Electronics Design Branch, to the Low Cost Components effort.

Released by
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Under authority of
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Electronics Engineering
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) ➤ Low Cost Components is an acquisition research project addressing microelectronic devices. The goal is to improve reliability and reduce costs associated with components, especially microcircuits. Microcircuits are highlighted because they are subject to common problems with other component types plus the problems associated with a rapidly evolving technology. Guidance is provided for the selection and screening of microelectronic devices. The project implements findings and recommendations from the TELCAM II project, reported in Naval Electronics Laboratory Center (NELC) TR 1957.		

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OBJECTIVE

Develop and implement methods for the low cost acquisition of electronic components, especially microcircuits, meeting the required performance, availability, and reliability criteria for use in military equipments. These methods include tailored screens and rules for their application.

RESULTS

1. A comparative analysis of military and commercial/industrial procurement practices revealed cost drivers which did not contribute to the attributes of the end item. Procedures were developed to minimize these cost impacts.
2. The findings and recommendations of the TELCAM II project were extended, and procedures were developed to implement these recommendations.
3. Screening methods were analyzed and compared; screening effectiveness, cost data, and other screening parameters were combined into a procedural guide.

RECOMMENDATIONS

1. The procedural guide contained in section 2 is recommended for use in the acquisition of microelectronics.
2. Government practice should be modified so that the Government is a better *customer in the open market* and so that the Government plays a more active contributory role in the procurement of component parts for its systems and equipments.
3. "Good design practices" should be documented, consolidated, and published, including derating criteria. Appropriate changes should then be made to MIL-HDBK-217 to reflect microelectronic derating.

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SECTION 1
Low Cost Components
A Cost-Effective Approach to Nonstandard Microelectronics



BACKGROUND

The increasing cost of military hardware is limiting the Navy's ability to adequately equip itself for sustaining its share of the national security effort.

One major source of expense lies in costs due to components of electronic equipment; these expenses include high initial component costs, high support costs resulting from high component failure rates, and high administrative costs due to a proliferation of functionally identical components. Current parts management policies tend to address one of these three facets to the exclusion of the other two.

The current economic inflationary trends and decreasing "real" defense appropriations make it mandatory to establish policies and to implement procedures which lead to minimal life-cycle cost decisions in the selection, procurement, and support of electronic components — while meeting the pressures for increased performance and sophistication generated by technological advances and the military's operational requirements. The Low Cost Component project is directed toward improving parts management techniques to provide more reliable military equipments at lower cost. It is an acquisition research project applied to component parts.

Acquisition research and development is a field devoted to improving the efficiency and effectiveness of the processes which lead to the fulfillment of operational requirements; ie, generation of an operational requirement statement, exploratory development/applied research, advanced development, engineering development, test and evaluation, production/procurement, and logistics support. The Center, as NOSC or a predecessor organization, has been active in electronics acquisition research since 1973. TELCAM II was one of the projects undertaken in acquisition research by the Center during fiscal year 1975. TELCAM II researched industrial integrated circuit specification and procurement practices, especially tailored screening techniques, as an outgrowth of the parent TELCAM program. The TELCAM program as a whole addressed the application of commercial products to military requirements/environments. The TELCAM II results¹ exposed many of the disadvantages of current DoD practices and offered the tailored screen concept as one alternative. However, the scope of TELCAM II was too limited in that it only addressed component procurement problems for production exclusive of administrative and support costs. Therefore, Low Cost Components was initiated in May 1977 to complete the work begun under TELCAM II and to develop practical methods of implementing the recommendations in Navy procurements.

APPROACH

Low Cost Components used the findings, extensive files, and information sources of TELCAM II¹ and Low Cost Electronics² as a departure point. (Low Cost Electronics is a comprehensive electronic systems acquisition research and development program.) The sources included 14 of the major device suppliers and most DoD activities with heavy involvement in microelectronics plus several defense contractors and commercial micro-circuit customers. As a baseline, the costs and benefits of the various standard military and

1. NELC TR 1957, Evaluation of Industrial Integrated Circuit Techniques to Military Electronics, August 1975

2. NOSC TD 108, Project Manager's Guide, 1 June 1977; see appendix C

commercial methods were established. Application demands were documented from defense contractors, commercial industry, and the Center's own extensive experience. Problem areas and cost-driving elements were isolated and analyzed, and tentative solutions were proposed. Proposed procedures were validated through application on several projects which were time-coincident and which could be influenced by project personnel. Also, extensive industry data were gathered from microcircuit suppliers, independent test laboratories, and industry consultants.

FINDINGS

The comparison between military and commercial/industrial procurement practices showed strong similarities and distinct differences. The microelectronics industry has a long history of cooperation with the military, and military standards have become the industry standards even though the military market is no longer consequential compared to commercial/industrial markets. The military remains the catalytic force for industry cooperation. The military standards community addressing microcircuits has been highly responsive to the needs of industry. However, practices and procedures within DoD have not been able to keep up with the rapidly evolving microelectronics technology. Also, basic military force changes have subtly altered the military business so that some of the postulates underpinning military procurement practices are no longer valid. This fact, combined with systematic inflexibility, is the source of most of the problems encountered by the Low Cost Components project. Commercial/industrial practices have been subjected to many similar market forces, but industry has been much more flexible in responding to these forces and much more cost conscious. The primary problem with industrial practice has been a lack of quality consciousness, since very high reliability devices have not been in widespread demand outside of military applications until recently.

Microelectronics technology is advancing into more and more applications. Many major advances are into areas requiring high reliability for safety as well as utility (automotive brake systems, for instance) and into applications with extensive custom functionality. This has prodded industry into high reliability consciousness because of the financial impact of failures through warranties or through product liability litigation. The requirements for high reliability have outstripped the natural reliability growth of the microcircuit industry's commercial product; therefore, the popularity of high reliability products and high reliability screens has increased dramatically.

The military has generally specified high reliability despite cost considerations, even though high reliability design practice is not utilized. However, military requirements are only a small part of the microelectronics market now, whereas they were a significant portion of the market through most of the industry's maturation. The rapid growth of the market combined with the trend of the military toward fewer, more complex units brought about a change in the military market position in only a few years. Unfortunately, the military procurement procedures — including specification requirements, source selection criteria, and documentation requirements — assume large quantity purchases of a relatively few standard items. A large military procurement may be a few tens of thousands of pieces whereas a large quantity in the industrial market is millions of pieces. The military buys only 16 of some microcircuits annually using procedures intended for hundreds of thousands. Furthermore, microelectronic technology is advancing in product reliability producing

hundreds of "standard" devices each year while heavily encouraging custom designs and other "nonstandard" devices; and existing military procedures cannot react rapidly enough to avoid creating problems or to take advantage of technological gains. On the other hand, industry does not have to be concerned with long-term support for technically obsolescent/obsolete equipment; the military must support technically obsolescent equipment for a decade or so and obsolete technologies for perhaps an additional decade. This requires that technological trends be considered during the design phases so that advances in technology may be conveniently incorporated in equipment. Current documentation practices do not allow this possibility.

Beyond these purely technical problems are the systematic problems which pervade much of the Government's acquisition process; these include:

- being a very poor customer
- excessive documentation requirements
- lack of flexibility in all phases of part management (design, source selection, procurement, support) with no guidance for exceptions to "standard" practice
- failure to take a comprehensive approach to the acquisition process, from "cradle to grave," resulting in competing, fractioned responsibilities with no long-term accountability
- making design/procurement/support decisions mechanically and in isolation

The systematic problems are not peculiar to parts management but are widespread throughout all types of equipment, systems, and supply acquisitions. In large part, they result from a large number of people establishing procedures which are "best solutions" to many small problems, isolated from each other by time, distance, and charter responsibilities. Table 1 and figure 1 illustrate some of the problems for microelectronics documented by TELCAM II.

Other findings were largely technical. These included data on failure mechanisms, screening effectiveness, cost data, and reliability/quality relationships. Since these data are available in open literature or directly from industry sources and since the conclusions drawn were primarily qualitative rather than quantitative, only the reduced data are presented herein. The purpose of the data was to show trends and milestones, which could be used for guidance purposes, and not to show impeccable research; therefore, the data presented are contained in the tables supporting the text of the guidance document (section 2). All cost data were reduced to "cost multipliers," units of basic device cost, to reduce the impact of inflation and the effects of radical differences in device complexity. The conclusive finding is that the procedures contained in section 2 resulted in an average savings in parts costs and parts documentation costs of 60% on each of five validation projects with no detectable change in end item reliability.

Table 1. Some TELCAM II findings.

Devices Available for Design	Procurement Costs for Production	Devices Provisioned
<p>40 000 device types (120 000 device configurations) (growth rate: 80% per year) 2-4% proprietary devices 50 000 industry "standard" configurations in high volume production 1% MIL-M-38510 types 0.5% QPL-38510 listed 0.4% QPL-38510 available 0.1% QPL-38510 available in large quantities</p> <p>NOTE: Only the 0.1% of all devices which are available in quantity on QPL-38510 are readily usable for most applica- tions. The lack of standard devices and the lack of availabil- ity in standard devices force selection and approval of nonstandard parts.</p> <p>In 1973, DoD had 10% of the market share by dollar volume but only 2% by device volume. The trend has been down.</p>	<p>MIL-M-38510 - 20 times Basic Commercial Cost (BCC) MIL-STD-883 - 10 times BCC Industrial High Rel - 6 times BCC Tailored Screen - 4 times BCC</p> <p>for Support</p> <p>MIL-M-38510 - same as production cost (20 BCC) MIL-STD-883 - 2-3 times production costs (20-30 BCC) Industrial High Rel - 3-4 times production costs (18-24 BCC) Tailored Screen - 10-30 times production costs (40-120 BCC)</p> <p>NOTE: These cost comparisons are normalized for devices of equipment configuration, perfor- mance, and failure rate. Basic commercial devices would have significantly higher failure rates, typically. Production procure- ment costs favor nonstandard screens; however, support costs rise due to the much lower quantities required. Current procedures force a decision to be documented at the time of pro- duction without a means of converting to more cost-effective alternatives later.</p>	<p>19 000 part types in National Stock System Only 660 are military standard parts</p> <p>NOTES: Judicious consolidation of requirements could reduce the 19 000 part types to under 5000 part types (est). (A part type includes the device configuration, screening level, temperature range, hermeticity, package material, and lead finish.)</p> <p>Support costs of nonstandard part types are about 20 times as high as for standard types due to higher documentation and administrative costs. Some of these costs could be avoided.</p> <p>Nonstandard parts proliferate, but current procedures do not provide guidance toward the selection of favorable parts for support purposes nor the auto- matic consolidation of pin-for- pin functionally equivalent devices under one or two sup- port part types.</p>



Figure 1. One hundred identical parts were purchased of each of the following screening levels: commercial (no screening), tailored screen, industrial high reliability, and MIL-M-38510/QPL. The actual procurement cost of each device and the documentation produced are shown with each part type. The failure rates of the screened, high reliability, and QPL parts were indistinguishable from each other; the commercial part failure rate was substantially higher.

RECOMMENDATIONS

The recommendations of Low Cost Components are summarized in table 2. Further procedures for implementing these recommendations, at least in part, are contained in section 2, Procedures for the Selection and Screening of Microelectronic Devices. These recommended practices either correct or circumvent the systematic problems noted above. It is also recommended that "good design practices" be documented, consolidated, and published, including derating criteria, and that appropriate changes be made to MIL-HDBK-217 to reflect microelectronic derating.

This project recommends altering support procedures so that upgraded technologies automatically replace superseded technologies on a part-for-part basis in the support system. For example, B-series CMOS should be used to support requirements for both A-series and B-series CMOS. Also, supporting parts requirements should be determined for pin-for-pin functional interchangeability with the maximum standard capabilities (temperature range, hermeticity, etc) to reduce support part proliferation rates.

Table 2. Summary of LCC recommendations.

Area	Commercial Practice	Government Practice	Recommendation
Procurement document	Procure by part number with specification control as necessary	Procure by specification	Emulate commercial practice wherever possible. Specification procurement used for MIL-peculiar and custom devices
Application design	Parts heavily derated in design	Parts heavily stressed by design	Use devices within spec limits, providing protection for them in the end item design Determine derating criteria for the various device technologies
Device packaging	Plastics are used extensively	Plastics are forbidden	Allow use of plastic encapsulated devices when warranted by the end item application
Device outline	DIPs used almost exclusively for most devices	Many "odd ball" outlines specified and used	Use only outlines which are standard for each device
Procurement quantity	Typically large quantity	Small quantity	Use consolidated purchasing (probably by DESC) to obtain large quantity discounts and distribute to users. (Applicable to MIL-type circuits)
Logistics	Short-term warranties and guarantees	Piece-part provisioning	Limited use of guarantees and warranties where economically feasible
Standardization	Technical standardization	Device design standardization	Technical standardization is sufficient for most DoD purposes

Table 2. (Continued).

Area	Commercial Practice	Government Practice	Recommendation
User-supplier dialog	Extensive	None	Establish procedures for technical cooperation between designer and supplier
Quality specs	Minimal	MIL-M-38510 Class B	Tailor quality level to reliability requirements and program risks
Screening	Tailored screens used when supplier standard screens are not adequate	MIL-M-38510 screening	Use supplier standard screens when possible and tailored screens when both necessary and economically practical
Quality control	Supplier QC reviewed by knowledgeable buyer representatives. QC specifications very limited	Process line certification	Process line certification severely limits flexibility of supplier; use commercial practice where possible. Limit process line certification to MIL devices
Documentation	Very limited	Extensive quality documentation and device design documentation	Require minimal quality documentation. Provide better end item design documentation; avoid device design documentation except for custom devices
Process line	Off-shore facilities used extensively	Only certified lines allowed (inherently CONUS)	Allow use of off-shore facilities only when part number guarantees are adequate. Stateside manufacture in all other cases. (Buy-American Act implication)
Procurement	Commercial distributors often used	Commercial distributors sometimes used, direct supplier procurement more common	Direct supplier procurement or procurement through qualified ITL sources
Screening source	Varies. ITLs used extensively	Supplier screening exclusively	Supplier screen for standard screens. ITLs for tailored screens and incoming inspections when in-house facilities are not available

SECTION 2
**Procedures for the Selection
and Screening of Microelectronic Devices**

1.0 SCOPE

1.1 APPLICATION

This document establishes procedures for the selection, screening, and source control of microelectronic devices. The selection procedures are intended to guide the specification of microelectronic devices for specific design requirements, especially when nonstandard devices are justified. The screening procedures are intended to allow tradeoffs between costs, schedule, and reliability performance in order to achieve acceptable levels of performance, risk, and expense. Documentation requirements are established to enable cost-effective logistics management of the end item in which the microelectronic device is used.

1.2 CLASSIFICATION

For the purpose of this document, the following classifications apply.

1.2.1 Device Grade

Grade M: Standard microcircuits for which MIL-M-38510 detailed specifications exist, selected in accordance with MIL-STD-1562

Grade P: Nonstandard microcircuits which can be substituted for standard microcircuits (Grade M) in the given device requirement

Grade T: Nonstandard microcircuits for which a functionally similar standard microcircuit (Grade M) exists but which has different technical characteristics from the Grade M microcircuit

Grade Z: Nonstandard microelectronic devices which have no standard microcircuit (Grade M) functional equivalent

1.2.2 Screening Types

Type I: Screening and processing in accordance with MIL-M-38510

Type II: Screening in accordance with MIL-STD-883

Type III: Screening in accordance with vendor's high reliability program standards

Type IV: Special screening

Type V: No screening (other than the supplier's normal QA/QC procedures)

1.2.3 Nonstandard Device Classes

Class 1: Industry standard – available from multiple sources

Class 2: Proprietary – available from a single source, in volume production

Class 3: Developmental – proprietary devices in limited production

Class 4: Custom packaged devices

Class 5: Hybrids containing standard or Class 1 and Class 2 nonstandard devices which are not standard or Class 1 or 2 nonstandard devices themselves

Class 6: Custom designed devices (including custom LSI and hybrids containing custom designed devices)

3.0 DEFINITIONS

3.1 GENERAL

The definitions of MIL-M-38510, MIL-STD-883, and MIL-STD-1313 apply.

3.2 SCREEN

The composite of procedures and test methods with the purpose of determining the suitability of a specific device, as manufactured, for a given application.

3.3 SUPPLIER

A provider of devices and/or services.

4.0 GENERAL REQUIREMENTS

4.1 SELECTION CRITERIA

Grade M devices shall be used to the fullest extent possible. Other grade devices shall be selected only in accordance with the detailed selection requirements which follow. Grade P devices may be substituted for Grade M devices in accordance with the terms of the contract.

4.1.1 Approval

4.1.1.1 Grade M Devices. All Grade M devices are approved for use. The general requirements of MIL-STD-1562 shall govern.

4.1.1.2 All Other Grade Devices. Approval for any device other than Grade M shall be requested from the procuring activity or its agent acting as the approval authority in accordance with the procedures of MIL-STD-965 unless otherwise specified by the terms of the contract. Unless otherwise required by the procuring activity in accordance with the terms of the contract, Procedure I of MIL-STD-965 shall be used. Contract terms automatically granting approval require no further authority.

4.1.2 Device Packages

The following precedence shall govern the selection of device package outline:

<u>Order of Precedence</u>	<u>Package Type</u>
1	Dual in-line packages
2	Flat packages
3	Cans and special packages

Specially packaged devices shall all be considered Class 4 nonstandard.

4.1.2.1 Grade M and Grade P Devices. The package type (outline and material) shall be one of those designated in the applicable MIL-M-38510 detailed specification. Grade M

1.2.4 Procurement Methods

Method A: Procurement by part number

Method AA: Procurement by part number with warranty control

Method B: Procurement by part number with specification control

Method C: Procurement by specification

2.0 REFERENCED DOCUMENTS

2.1

The following documents form a part of this document to the extent specified herein:

SPECIFICATIONS MILITARY

MIL-M-38510 Microcircuits, General Specifications for

STANDARDS MILITARY

MIL-STD-883 Test Methods and Procedures for Microcircuits

MIL-STD-965 Parts Control Program

MIL-STD-976 Certification Requirements for JAN Microcircuits

MIL-STD-1313 Microelectronics Terms and Definitions

MIL-STD-1331 Parameters to be Controlled for the Specification of
Microcircuits

MIL-STD-1562 Lists of Standard Microcircuits

HANDBOOKS MILITARY

MIL-HDBK-217 Reliability Prediction

PUBLICATIONS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

NHB 5300.4(3D) Test Methods and Procedures for Microcircuit Line
Certification

devices must be procured from suppliers specifically qualified to deliver devices in the specified package (listed in QPL-38510). Grade P devices must be procured from suppliers who normally offer the device in the required package; package material may be any material suitable to the application and available as a standard option from the supplier.

4.1.2.2 Grade T Devices. The package outline shall be one of those designed in the applicable MIL-M-38510 detailed specification, unless mechanical requirements justify a non-specified case outline. Package types normally offered by the supplier shall be used in preference to special packages. Any package material suitable for the application may be used.

4.1.2.3 Grade Z Devices. Package types (outline and material) normally offered by the supplier for the device type shall be used in preference to special packages.

4.1.3 Lead Finishes

The following precedence shall govern the selection of lead finish in accordance with MIL-M-38510:

<u>Order of Precedence</u>	<u>Finish Designator</u>
1	X
2	A or B
3	C

Only lead types and finishes in conformance with MIL-M-38510 shall be used.

4.1.4 Design Considerations

4.1.4.1 Application Design. The design of the end item should incorporate characteristics which reduce the stresses on devices to the lowest possible level. Characteristics to be considered include (but are not limited to) device derating, good thermal design, conformal coatings for hermeticity, vibration and shock isolation, electromagnetic shielding and filtering, transient protection, and open/short circuit protection. The "good design practices" recommended by the supplier shall be followed to the greatest extent possible. When good design practice must be violated or when the application requires characteristics which have no established recommended practice, the supplier shall be consulted and appropriate tests conducted to determine the adequacy of the device design; this provision is mandatory for all Grade T devices.

4.1.4.2 Device Design. The design of standard devices and Classes 1, 2, 3, and 4 nonstandard devices may be evaluated by use of supplier data and guaranteed specifications. Class 5 nonstandard device design should be evaluated by use of supplier data and guaranteed specifications and should be verified by sample screening. Class 6 nonstandard device design shall be evaluated by appropriate testing. Detailed designs should be evaluated against the design and construction criteria of MIL-M-38510 for Classes 5 and 6.

4.1.4.3 Reliability/Quality Level. The reliability requirements for the application shall be allocated to the device level, and the average failure rate per device shall be compared to the appropriate generic failure rate contained in part 3 of MIL-HDBK-217. The required quality level (RQL) shall be determined in accordance with table 1. The design reliability level shall be at least the minimum tolerable reliability. The design quality level shall be equal to or greater than the required quality level as determined in table 1; the maximum design quality level should be determined through economic analysis.

4.1.4.4 Design-Procurement Considerations. The design of the end item should incorporate devices which qualify for procurement by method A or B to the greatest extent possible.

Table 1. Computation of required quality level.

1. Computation of Allocated Failure Rate (AFR):

$$AFR = \frac{\text{Failure rate attributable (allowed for microcircuits)}}{\text{Number of devices expected}}$$

NOTE: If estimating the input quantities, estimate allowable failure rate low and number of devices high within the reasonable estimating limits.

2. Listing of Generic Failure Rate (GFR):

Look up GFR in part 3 of MIL-HDBK-217 table 3-1 or 3-2, for the appropriate application environment.

3. Computation of Reliability Ratio (RR):

$$RR = \frac{AFR}{GFR} \quad \text{for all devices except nonstandard Classes 3, 5, and 6.}$$

$$RR = \frac{AFR}{1.1 GFR} \quad \text{for Class 5 nonstandard devices}$$

$$RR = \frac{AFR}{10 GFR} \quad \text{for Class 3 and Class 6 nonstandard devices}$$

4. Determination of Required Quality Level (RQL):

RR	TOTAL RELATIVE QUALITY FACTOR	
	Normal Criterion	Tightened Criterion
> 100	< 20	< 40
50-100	20-85	40-105
25-25	85-140	105-160
10-25	140-185	160-205
5-10	185-220	205-405
2-5	220-245	240-265
1-2	245-260	265-280
< 1	> 260	> 280

The RQL is the minimum total relative quality factor corresponding to the RR range of the device. The total relative quality factor is the sum of the quality factors for each of the screen requirements. Screening requirements should be determined in accordance with appendix A.

4.2 SCREENING REQUIREMENTS

Screening requirements are specified by specification control requirements in the purchasing documentation or by supplier quality control documentation. The specified screening requirements shall utilize supplier specifications to the greatest extent possible, subject to the restrictions of the device grade and class and of the device application risks.

4.2.1 Grade M Screening

All Grade M screening requirements shall be as specified by MIL-M-38510 (Type 1 screens).

4.2.2 Production Process Screens

Production process screens include the sampling inspections of MIL-STD-883 method 5005 (for Class B devices) plus any supplier-specified tests to assure the quality conformance of each process step. Purchasing documentation shall not specify production process screens for Grade P devices except for specific device characteristics which are important to the functioning of the device in the application. Purchasing documentation for Grade T devices shall specify tests of all device-peculiar requirements which are not part of the production acceptance screens. Specification control requirements should conform to MIL-STD-883 method 5005 for all Grade Z devices except when supplier controlled specifications are deemed adequate or when the risk of nonconformance is deemed to be acceptable. Purchase orders shall cite the titles and dates of supplier documentation accepted in lieu of specification control requirements.

4.2.2.1 Hybrid (Class 5 Nonstandard) Devices. Production process screens for hybrid devices shall conform to the requirements of method 5008 or method 5005 of MIL-STD-883 as appropriate.

4.2.2.2 Custom (Class 6 Nonstandard) Devices. The combined specification control requirements and supplier specifications for production process screens shall conform to method 5005 (for Class B devices) of MIL-STD-883 as a minimum. Additional requirements shall be considered to evaluate design suitability and production process integrity in excess of standard requirements.

4.2.3 Production Acceptance Screens

Production acceptance screens are used to reject faulty or weak devices through 100% testing. Method 5004 of MIL-STD-883, Class B (or method 5008 for hybrids), shall be considered the standard baseline; however, the production acceptance screening requirements shall be tailored to the device application and cost/risk criteria. Requirements tailoring shall be accomplished in accordance with appendix A of this document. Grade T peculiar characteristics which are not functional/electrical parameters may be tested through production process screening. Purchase orders shall cite the titles and dates of supplier documentation used in lieu of specification control requirements.

4.2.4 Incoming Acceptance Screens

Incoming acceptance screens are used to supplement production process and production acceptance screens and to ensure the integrity of the previously conducted screen. Incoming acceptance screening requirements shall be determined in accordance with appendix A of this document. The screening requirements document shall contain the test methods, test levels, test sequences, and acceptance criteria for the incoming acceptance screens. The purchase order shall cite the screening requirements document whenever a quality guarantee is implemented.

4.2.5 Test Methods and Test Levels

Test methods shall be selected in the following precedence: (1) MIL-STD-883 methods, (2) NHB 5300.4(3D) methods referenced by MIL-STD-883 or MIL-STD-976, (3) other NHB 5300.4(3D) methods, (4) supplier-approved methods, (5) other proven industrial methods. Experimental test methods shall not be applied unless they are essential to test a critical device characteristic and have been reviewed by supplier design and test personnel. The standard test levels and number of test cycles shall be as specified in the test method unless otherwise specified in the specification control requirements of the purchasing documentation.

4.2.6 Test Sequences

Test sequences which are standard to the screening facility shall be used unless they clearly violate recognized test principles.

4.2.7 Screening Type Precedence

The following precedence shall be considered in selecting screening type:

- Type I
- Type II
- Type III
- Type IV
- Type V

Costs and reliability risks shall be utilized in establishing tradeoffs between screening types in accordance with appendix A.

4.3 DOCUMENTATION REQUIREMENTS

4.3.1 Design Documentation

4.3.1.1 Specification Control Requirements. The specification control requirements shall characterize the device and the application. The device characterization shall include, as a minimum, the following:

- case outline (may be case outline designation from MIL-M-38510, appendix C, or industry designations)
- functional description, including truth tables, transfer characteristics, and pin assignments

- maximum electrical parameters
- static parameters with tolerances (may be stated as MIN, MAX, TYP, or NOM \pm TOL)
- switching and dynamic parameters with tolerances
- limiting characteristics such as case material or lead finish
- operating temperature range
- any special parameters or characteristics

The device characteristics shall be prepared in accordance with MIL-STD-1331 as a minimum. Supplier specifications and actual test data shall be fully incorporated into the device characterization. Supplier notes on device limitations shall be referenced or incorporated as appropriate. When a MIL-M-38510 detailed specification exists, the device characterization may reference the detailed specification and cite exceptions. The application characterization shall contain the same information elements with the following exceptions and additions:

- actual maximum, static, and dynamic parameters, with tolerances, shall be used. (Thus, the device characterization may show an input as being less than 0.8 V for a given condition, whereas the application characterization may specify an actual signal less than 0.25 V.)

- actual expected normal maximum and minimum operating and storage temperatures shall be cited.

- other environmental conditions shall be cited (vibration, shock, humidity, electrical transients, radiation, thermal shock, etc). However, these environmental conditions shall be stated at the device level, not at the assembled equipment level.

- all characteristics which are known to be critical to circuit operation shall be noted. Any second-order parameters which can affect circuit operation shall be specified and included as "special parameters" in the device characterization.

The application characterization may simply cite exceptions to the device characterization. In addition, the specification control requirements shall specify the requirements for packaging and handling for shipment and storage (such as antistatic tubes).

4.3.1.2 Screening Control Requirements. The screening control requirements include all requirements for production process and acceptance screens and for incoming acceptance screens and inspections, including test reporting requirements. The screening control requirements shall specify the test methods, test levels, number of cycles or test time, accept/reject criteria, and the test sequence(s). Tailored screening requirements shall be considered acceptable as long as combined test method effects are preserved. Substitute test methods shall be considered acceptable if data are available to substantiate that induced stress levels will be maintained. The screening control requirements shall completely specify critical tests in accordance with appendix A of this document. Acceptance screen electricals shall include, as a minimum, all critical static and functional parameters. Process screen electricals shall include all critical dynamic and switching parameters at ambient temperatures and critical static parameters at ambient, minimum, and maximum operating temperatures. Separate specifications may be established for interim and final electricals and for ambient and high/low/delta limits tests.

4.3.1.3 Substitution List. When Grade P devices are specified, a substitution list shall be established listing the Grade M device equivalent to the Grade P device, the Grade P device type, and the part number of each possible source of supply

4.3.1.4 Detailed Design Documentation. Design documentation per MIL-M-38510 shall not be ordered except for Classes 4, 5, and 6 nonstandard devices. Documentation for Class 4 devices shall include only die to terminal documentation. Die-related documentation may be excluded for Class 5 devices.

4.3.2 Procurement Documentation

4.3.2.1 Procurement by Part Number. Method A procurements shall use a purchase description which references the design documentation for information only. The purchase description shall contain a list of satisfactory complete vendor part numbers and shall cite the appropriate supplier specification sheets or catalogs. The purchase description shall specify any special requirements such as marking, workmanship, packaging for shipment, and other necessary characteristics which are not controlled by the part number. The purchase description may specify a maximum acceptable reject number for incoming acceptance. Exhibit A illustrates a Method A purchase description.

4.3.2.2 Procurement by Part Number With Warranty Control. Method AA procurements shall use a Method A purchase description plus contractual guarantees specifying the supplier obligations if the supplied parts do not meet the required standards as determined by the incoming acceptance screen. The incoming acceptance screen must be available for review by prospective suppliers. Suppliers shall not be responsible for parts damaged by faulty handling, faulty test equipment, or improper test procedures by the receiving activity. Exhibit B illustrates various types of guarantees and warranties. It is usually necessary to specify an allowable number of rejects in the purchase description before the warranty becomes of force.

4.3.2.3 Procurement by Part Number With Specification Control. Method B procurements shall use a specification control drawing. Only the detailed specification and screening requirements which are considered critical to the device application shall be specified, including deviations to normal device characteristics for Grade T devices. Device characteristics which are noncritical shall be listed separately for reference purposes; in the event of conflict between cited noncritical characteristics and supplier specifications, the supplier specifications shall govern. Supplier-specified screens which meet or exceed the screening controlled requirements shall be acceptable. The drawing shall list the known acceptable sources of supply, supplier part numbers, and supplier-specified screens (including the effective dates of supplier data). The drawing shall reference the design documentation as source data. The drawing overrides supplier-controlled requirements only on the specified critical characteristics and tests.

4.3.2.4 Procurement by Specification. Method C procurements shall use a specification control drawing. The drawing shall completely specify the device characteristics in accordance with the design documentation. Suggested sources of supply shall be listed including part number and screening level as applicable; however, supplier part numbers and/or specifications shall not take precedence over the drawing specified requirements.

4.3.2.5 Letter of Inquiry. Information for making source decisions is frequently deficient. Additional information may be obtained formally via letter of inquiry. The inquiry may simply verify supplier published specifications, screening criteria, and QA procedures. Critical applications may also desire clarifying information on the supplier's QC, such as AQL and LTPD standards, and information on part maturity such as device volume, QC success rate, and production yield rates. The information obtained cannot be used to exclude potential sources; however, it can be useful in the specification of the incoming acceptance screen. Occasionally, suppliers may be reluctant to release detailed information, especially on QC success rates, because of prevailing market competition. However, the supplier should, on these occasions, be willing to agree to guarantee that the devices and services will meet certain minimum standards.

PURCHASE DESCRIPTION

1. Item: Integrated Circuit
2. Function: 16-Channel Analog Multiplexer/Demultiplexer
3. Package Description: 24-Pin Dual-in-Line
4. Package Type: Ceramic
5. General Requirements: The integrated circuit shall meet the requirements of MIL-STD-883, Class B, Method 5004, and shall be capable of meeting the requirements of Method 5005.

As a minimum, the integrated circuit shall be tested in accordance with the manufacturer's high reliability test program as shown in the manufacturer's listed catalog for MIL-STD-883, Class B devices.

6. Detailed Electrical Characteristics, Maximum Ratings, Terminal Functions, and Package Dimensions shall be in accordance with the manufacturer's listed catalog.
7. Marking: The integrated circuit shall be permanently and legibly marked with the manufacturer's identification and part number and date code. Pin 1 shall be identified.
8. Workmanship: The integrated circuit shall be manufactured in such a manner as to be uniform in quality, and shall be free from defects that may adversely affect the function of the item in its intended application.
9. Approved Source of Supply(s) [must be reviewed for each procurement]

RCA Corporation
Solid State Division
Findlay, OH

Code Ident No: 18717

Part No: CD4067BF/3

Catalog Reference: RCA Integrated Circuit Book, Dated July 1977 [update for each procurement to current issue]

Fairchild Semiconductor
Mountainview, CA 94041

Code Ident No: 07263

Part No: F4067BDMQB

Catalog Reference: Fairchild CMOS Data Book, Dated December 1977

10. Devices shall be supplied in metal tubes or antistatic plastic tubes. Containers for devices shall bear caution warnings relative to handling.

NOTES:

(1) This device satisfies the specification requirements of 12345-05-7723 rev O dated 30 September 1978 and the screening requirements 12345-05-7724 rev O dated 30 September 1978

(2) This device is a functional replacement for military part M38510-XYZ01BQX for this procurement only. (This note applies to all Class P devices.)

Exhibit A: Sample
Purchase Description

SIMPLE GUARANTEE

The supplier agrees to replace, at no cost to the customer, any device which does not meet the specifications, expressed or implied, of the attached purchase description.

REIMBURSEMENT WARRANTY

The supplier agrees to reimburse the customer for costs incurred due to any device which fails to meet the specifications, expressed or implied, of the attached purchase description. (Other negotiated terms may include the term of the warranty, allowed costs, and the maximum cost per failure.)

Exhibit B: Sample
Guarantee and warranty

APPENDIX A: TAILORING SCREENING REQUIREMENTS

GENERAL

Screens are applied with the two-fold purpose of testing the integrity of the manufacturing process and of testing the suitability of a device for a given application. Each screen is a composite of test methods in specified sequences which apply known stresses to the devices-under-test. In theory, the stresses are such as to fail faulty or weak devices and pass good devices. In practice, some weak devices will normally be passed, and good devices will be failed if the screening stresses are sufficiently high. The most effective screen is one which eliminates the greatest number of weak devices at the least total cost. However, the potential weakness of a device must be referenced to the stresses it will encounter in a given application. Also, the total cost includes the cost of the devices, the cost of the screen, and the cost of any subsequent failures of devices not caught by the screen; this latter cost may vary considerably from program to program. The process of determining the most effective screen has come to be called "tailoring."

It is important to realize that any given screen involves some risk. However, a number of techniques may be applied to reduce total project risk without modifying the screen. Furthermore, screens which have low inherent risk may require so many project resources (time and money) that they will induce undesirable consequences on the project. The techniques which reduce risk are those which improve device yield and which reduce failure mechanisms; they may be economic (such as device guarantees) or processing specifications. Properly employed, these risk-reduction techniques can greatly reduce the screening requirements at very little cost.

TAILORING STEPS

The following steps are recommended in tailoring screening requirements:

Definition phase

1. Define the design/application requirements.
2. Compare the design/application requirements to the device characteristics to determine special and application-critical characteristics.
3. Review MIL-STD-883 test methods, test purpose, and test effectiveness (table A-3 is provided for qualitative assessments of test effectiveness).
4. Determine special project risks, using supplier data and comparing the expected performance of standard quality devices with the project requirements.

Design phase

5. Tailor the electrical test requirements.
6. Determine visual examination requirements.
7. Determine the mechanical test requirements.
8. Seal testing (yes or no).
9. Tailor burn-in and bake requirements.

Procurement phase

10. Determine what standard screens meet or exceed the project requirements, if any.
11. Specify the incoming acceptance screen.
12. Write the source control document.

DEFINITION PHASE

The definition of the design/application requirements and the comparison of these requirements to device characteristics are considered design practice. These requirements fully incorporate appropriate derating criteria. Parameters which cannot be derated fully should be classified as application-critical. The application requirements should stay within the device specifications and generic application guidance. Characteristics which are essential to the design should be classified as application-critical. Requirements which exceed device specifications or which are not covered by device specifications should be categorized as special characteristics. Prospective suppliers should be consulted to ascertain whether the required special characteristics can be supplied. Risks may be determined qualitatively by categorizing them as follows:

Technical risks	Application-critical parameters Special characteristics
Processing risks	Required Quality Level (RQL) Technical susceptibilities of the device Technology limitations Supplier limitations
Testing risks	Test method effectiveness Test resource requirements

Processing risks and testing risks are discussed under Design Phase. Each significant risk identified should be controlled through production process, production acceptance, or incoming acceptance screens or a combination of these screens.

DESIGN PHASE

GENERAL

A screen must be designed with both risks and costs in mind. The screen must be designed to cover, as a minimum, all critical risks; tradeoffs may then be established between risks, costs, and schedule. All technical risks—application-critical parameters and special characteristics—are classified as critical risks. The table of typical stresses (table A-1) includes high risks which may be reduced through design techniques; these stress conditions should be considered for incorporating tests to reduce processing risks; however, testing risks tend to limit the practicality of highly efficient screens because costs rise so much more rapidly than test effectiveness.

Processing risks include the required quality level (RQL), device and technology factors, and supplier limitations. The RQL is really a measure of the margin between the allocated failure rate and the nominal failure rate achievable with standard (Product

Table A-1. Typical stresses.

Military Application Environments [†]		
Environment	Symbol	Above-Normal Stress Conditions*
Ground, Benign	GB	None
Ground, Fixed	GF	High Temperature
Ground, Mobile and Portable	GM	Temperature, Vibration, and Shock
Naval, Sheltered	NS	Temperature, Vibration, Severe Shock
Naval, Unsheltered	NU	Low and High Temp, Vibration, Severe Shock, Humidity
Airborne, Inhabited	AI	Temperature, Vibration
Airborne, Uninhabited	AU	High and Low Temp, Temp Cycling, Vibration, Low Pressure, Shock

[†]Excluding space and ordnance — short-term, but very extreme high shock, vibration, temperature

*Plus electrical stresses

Typical Equipment Temperature Rises

Equipment Density Class	Internal Temperature Rise (°C)
Commercial	5
Industrial	15
Military (Fixed Ground and Naval)	35
Military (Mobile Ground, Portable, and Airborne)	50

Typical Electrical Stresses*

Excessive voltage (input, output, supply)
 Voltage transients, noise (input, output, supply)
 Excessive current drain
 Excessive power dissipation for thermal environment
 Signal transitions too fast (in excess of slew rate or clock rate)
 Inadequate output derating for thermal environment
 Load transients
 Excessive impedance to ground and references

*Assuming device design characteristics are followed; ie, fan out, rise/fall times, switching times, access times, propagation delays, etc, are all considered.

Assurance Class B) devices. RQL is really the only processing risk which is application oriented. The technical susceptibilities of the device arise from built-in failure mechanisms. The table of failure mechanisms (table A-2) shows an average failure mechanism distribution for mature processes producing mature devices of various complexities. Notice the failure rate multiplier at the bottom of the table. This multiplier may be applied to a given mechanism to estimate the expected rate of increase with complexity. All failure mechanisms (except substrate mounting defects) become more active with increased complexity. Thus, each mechanism becomes more significant even though it may be a lesser part of the overall distribution. Miscellaneous mechanisms include a wide variety of factors which may or may not comprise significant risks; these factors are largely connected with the manufacturing process technology and various device design characteristics. Undetermined mechanisms are of great concern because screens cannot target a specific stress to generate failure of weak devices. Immature devices and VLSI devices are most likely to be susceptible to undetermined failures. Suppliers can provide data on expected failure mechanisms for specific devices, generic experience on the manufacturing process, and the limitations of their standard quality control procedures.

Testing risks consist of test effectiveness and cost-schedule-facility requirements. Table A-3 shows the effectiveness of the standard methods used in production acceptance screens and incoming acceptance screens. Device complexity, device immaturity, and technology immaturity tend to drive the test effectiveness toward the low end of the scale. The percent effectiveness shown in the table applies only to relatively noncomplex devices (SSI-MSI). Device complexity degrades the test effectiveness in nonuniform ways and affects electrical testing the most. As test effectiveness drops, the amount of testing required to screen to any given level increases; therefore, test time and costs rise. Usually, nonscreening methods of risk reduction will prove to be more effective at controlling risks when testing effectiveness is degraded by more than 25%.

Table A-2. Failure mechanisms (% of total).

<u>Driving Factor</u>					
	<u>Mechanism</u>	<u>SSI</u>	<u>MSI</u>	<u>LSI</u>	<u>VLSI</u>
<u>Complexity</u>					
	Electrical	17.2	25.3	33.2	39.5
	Misc & undetermined	9.2	13.5	17.7	21.1
	Diffusion	6.3	9.3	12.1	14.5
<u>Size</u>					
	Oxide	13.3	13.1	11.4	9.1
	Substrate surface defects	6.9	6.8	5.9	4.7
<u>Number of Leads</u>					
	Lead bonding & wire defects	13.9	9.8	6.2	3.5
	Package defects	10.7	7.5	4.7	2.7
<u>Number of Interconnects</u>					
	Metalization	10.4	7.7	5.0	3.0
	Foreign material	4.5	3.3	2.1	1.3
<u>Other</u>					
	Substrate mount defects	7.6	3.7	1.6	.6
Failure Rate Multiplier		1.0	2.04	4.67	11.75

Table A-3. Test effectiveness of standard methods.

Test Method	Failure Mech													Application Stresses							
	Electrical	Diffusion	Oxide	Substrate surface	Bonding, wiring	Package	Metallization	Foreign material	Substrate mount	Corrosion	Classification	Seal	External leads	Bulk silicon	Electrical stress	High temperature	Extreme shock	Shock & vibration	Altitude	Temp cycling	Humidity
1010 Precap Visual	M	G	G	E	E	F	E	E	E	E	E			F			VG	VG			M
1001 Barometric																			M		
1008 Stabilization Bake	G			M	G						M			G		G					
1011 Thermal Shock				F	G	G			G			F				G				G	
1010 Temp Cycling				F	G	G			G			F				G				M	
1013 Dew Point							VG	G												F	
2001 Centrifuge					G	M			M					M			VG	VG			
2002 Shock					P	F			F								E	G			
2006 Vibration					G	F		G	P								M	G			
1014 Seal (Fine & Gross)								E				E							F		VG
2012 X-Ray					G	G	M	VG	E			G		E							
1015 Burn-in ⁵ (D or E)	VG	VG ³	E	G	G		E	M							VG	E					
2015 HTRB (A or C)	G	PVG ²	G												G	VG					
Electricals	G	M	M				M								G	G ⁴				E ¹	
1009 External Exam						M						F	VG								

Key: E-Excellent (90-99%) M-Moderate (40-60%)
VG-Very Good (80-95%) F-Fair (25-45%)
G-Good (60-80%) P-Poor (15-35%)

- (1) Delta computations required
- (2) Most effective on larger diffusions
- (3) Effective on larger diffusions
- (4) High temp static tests required
- (5) Effectiveness depends on test duration

ELECTRICALS

Electrical tests are the most versatile and basic tests incorporated into any screen. Electricals are basic to production process screens, production acceptance screens, and incoming acceptance screens; they are also applied to design evaluations. Electrical characteristics include functional, static, dynamic, and switching parameters. Functional characteristics are generally defined by a truth table for digital devices, but, in any case, they are the reason for the device's existence. Statics include the dc parameters such as input and output voltages, current characteristics, and nominal power dissipation. Dynamic characteristics cover ac parameters such as dynamic lead characteristics, dynamic power dissipation, gain characteristics, and noise characteristics. Switching characteristics embody switching propagation delays, transition times, and pulse slew rate. Frequently, switching characteristics are considered as part of the dynamic characteristics.

Design evaluation electrical tests should be accomplished for all custom devices, including hybrids. These tests should include all specified parameters at nominal, high, and low temperatures. Functional tests should include in-circuit application checks using previously functioning brassboards where possible. Also, various overstress conditions should be selected and tested. Likely overstresses include transient conditions and excessive power dissipation; refer to table A-1 for candidate stresses. These tests are considered developmental and are not actually screening tests; however, design weaknesses uncovered in these tests should be corrected and targeted for the production process screens.

Electrical testing in screens can vary from simple functional or static tests at room temperatures to full-range function, static, dynamic, and switching tests at normal and extreme temperatures and employing delta computational statistical rejection techniques. Electrical tests can also be employed before and after each other test step of a screen or only as a final test. All of this testing costs, but the basic costs vary widely with the device, handling costs, and test facilities.

The device itself determines much of the basic electrical test cost. The device package affects handling costs directly as DIP packages can be handled automatically while cans usually require manual handling. Linear devices are more difficult to test than digital devices of the same complexity because narrow ranges of values are acceptable for most linear parameters, rather than single limits. Also, linear and new or uncommon digital devices will normally have programming costs for automatic testers.

The more times the parts are tested, the more handling that is required. With automatic testers, handling costs comprise more of the test cost. This fact tends to drive the number of electrical test phases.

Test facilities play an obvious role. Automatic testers are virtually indispensable to cost-effective electrical testing. The conditions favoring automatic testers include high test volume and relatively few different test parameters; very few users meet these conditions, whereas suppliers and independent test laboratories usually do.

Some LSI and hybrid devices are so functionally complex that even automatic testers cannot test them adequately. Most suppliers of these devices have worked out simulation test sequences and parameter sample tests to help overcome this difficulty, but custom devices have to have these sequences developed.

Testing at temperature extremes is more expensive than ambient testing because of the additional test equipment complexity, test facility maintenance, and handling requirements. Likewise, test equipment for dynamic and switching tests is significantly more complex than for static tests, and testing takes longer. So dynamic and switching tests tend to cost significantly more than static tests.

Usually, a number of ploys are available which reduce electrical test costs without compromising effectiveness.

1. Establish minimum static and functional tests to be used for all interim testing (incoming and preburn-in tests).
2. On standard devices, sample dynamic and switching parameters (which are usually geometry dependent) and establish a correlation to key static tests (such as leakage); device suppliers often have supporting information available. Then apply tightened static accept criteria.
3. Perform all tests at room ambient, and perform key static tests at the high temperature extreme. Omit low temperature testing.

These steps will maintain standard electrical test effectiveness; however, sometimes it is necessary to increase the test effectiveness by a grade level or so. Electrical tests can be made more effective by applying tightened acceptance criteria, computing drift factors (delta computations), and statistically eliminating aberrant devices. The additional steps increase costs by requiring (1) preburn-in testing, (2) data logging, (3) testing at temperature extremes, (4) computing facilities, and (5) rejection of devices otherwise tested as good. Table A-4 cites cost and quality factors of common electrical test levels. MIL-STD-883 Methods 5001 and 5002 and paragraph 4.6.1.2 of MIL-M-38510 describe some of the common statistical methods of tightening acceptance criteria. The costs will depend on the choice of parameter and the circuit demands on the device. A single well-chosen parameter should suffice. The supplier should be able to choose the best parameter for a given application.

Table A-4. Cost and quality factors for electrical testing.

Electrical Test Levels	Cost Factor	Relative Quality Factor
1. Production Process Screen Only (MIL-STD-883 Method 5005 or mfr equivalent)	0	1
2. (1) plus functional and static tests (100% at ambient temperature)	.035	14
3. (2) at worst-case input/output (25°C)	.04	30
4. (2) plus functional and static tests at 125°C (100%)	.07	30
5. (4) at worst-case input/output conditions	.08	55
6. (2) plus dynamic/switching tests (100% at 25°C)	.07	30
7. (3) plus dynamic/switching tests (100% at 25°C)	.08	45
8. (4) plus dynamic/switching tests (100% at 25°C)	.10	50
9. (5) plus dynamic/switching tests (100% at 25°C)	.11	65
10. (4), (5), (8), or (9) with delta limits	add .08 per delta limit	X1.25
11. (10) with statistics	add .18	X2 over (10) (typical)
NOTE: MIL-STD-883 Class B (without delta limits)	.10	60
MIL-M-38510 Class B (detailed specification electrical limits)	.10	70
12. MIL-M-38510 Class B with worst-case load conditions	.11	85

NOTE: For repeated electrical tests, the relative quality factor is improved by 10-25% of the prior test improvement.

VISUAL EXAMINATIONS

Visual examinations are the most effective single screens of device quality. However, they are moderately expensive and require trained labor. Direct visual examinations include internal inspections at the wafer, chip, precap, and postcap levels and external inspections. Wafer and chip level examinations are considered part of the production process. Precap visual (Method 2010) is both a production step and a production process screen (Method 2017 for hybrids). A postcap visual inspection (Methods 2013 and 2014) may be used to supplement precap visual or to offset the inability to obtain parts with valid precap visual screens. Some form of internal examination should be included in one of the acceptance screens on at least a sampling basis. X-ray (Method 2013) or SEM (Method 2018) can only be used to supplement direct visuals in high risk applications.

There are a dozen attributes checked by internal visual inspection. These attributes include direct failure mechanisms and major contributory factors to electrical failures. MIL-STD-883 specifies two test conditions (A and B) for precap visual. The more stringent (A) requires many quantitative assessments of suspect areas; skilled inspectors and much more time are needed. The less stringent (B) is much more qualitative and, therefore, requires less time and lower inspector experience levels. Test condition B can be as effective as A, but its effectiveness is much more variable. Typically, test condition A adds a cost factor of about 1.00 per part, and B adds 0.50 per part. The most time-consuming inspections are those for diffusion and passivation (oxide) faults and for metalization scratches, voids, and alignment. Precap visual inspection costs tend to rise geometrically as complexity increases because the most time-consuming inspection sites are increased likewise. As an alternative, MIL-STD-883 allows deletion of these most time-consuming inspections if temperature cycling (Method 1010) is performed for 50 cycles and burn-in time is extended to at least 240 hours (special electrical tests may also be specified). For most high reliability purposes, precap visual to level B is adequate. The high reliability screens of some manufacturers include precap visual, but the test method does slow down production and does not lend itself to high volume continuous production. Other suppliers use a postcap visual sampling inspection (Methods 2014 and 2013) and increased screening in other areas in an attempt to compensate for the lost effectiveness. Since some suppliers do not offer MIL-STD-883 screening, some parts are not available with precap visual. If high screening effectiveness is required, the following compensations are recommended:

- Double stabilization bake (1008) to 48 hours
- Include thermal shock (1011)
- Extend thermal cycling (1010) to 50 cycles
- Conduct dew point (1013) sampling 5% – no failures
- Add monitored vibration (2006) and X-Ray (2012)
- Extend burn-in to 240 hours
- Ensure electricals include dynamic tests

In the most extreme cases, postcap visual (2014) sampling is recommended for 1 part (no rejection) only if all parts are from the same production lot. If the sample tests are failed, the entire lot should be rejected. In the cases in which the lot cannot be rejected, do not conduct postcap visual and extend dew point to all devices; this will result in some

probably insignificant reduction in screening effectiveness. Modifications to these compensations are possible on a case-by-case basis.

Table A-5. Cost and quality factors for visual inspection.

Visual Inspection Levels	Cost Factor	Relative Quality Factor
A. External Inspection (100%)	.03	1.05
B. Internal Inspection		
1. Precap or postcap visual (sample 2 devices/lot, no rejects)	1.5 # devices	12
2. Precap visual (100%) (condition B)	.5	45
3. (2) plus X-ray (100%)	.66	55
4. Precap visual (100%) (condition A)	1.00	60
5. (2) plus SEM on batch processes	.66	60
6. (3) plus SEM on batch processes	.80	75
C. Compensations for no precap visual (per text)	1.5	40-50

MECHANICAL AND THERMAL TEST REQUIREMENTS

Thermal and mechanical tests are not highly effective screens by themselves; rather, they are effective conditioning tests for the screening tests which follow, especially seal. Thermal tests should precede mechanical tests, and mechanical tests should precede seal, burn-in, and electrical tests. The centrifuge test, Method 2001, is the only test which can be used effectively as a stand-alone screen; it also serves as a conditioning set for the monitored vibration tests (Methods 2006 and 2020).

Usually only one of the two thermal test methods, thermal shock (1011) or temperature cycling (1010), is required. They are about equal in effectiveness (quality factor is 12) and cost in most cases (cost factor is .015). For military environments, Method 1010 is probably more accurate, but Method 1011 does often apply greater stress to the part. Higher stress levels are much easier to achieve with 1011; this would be important in environments in which thermal cycling is a factor. The two methods exert stresses in slightly different ways, so both should be required for extreme reliability requirements.

Generally, only Method 2001 acceleration (centrifuge) is required and applied to the Y1 axis only (see MIL-STD-883). For naval environments exposed to gunfire concussion, near catapult stops or large reciprocating pumps, or in aircraft making arrested landings, Method 2002 shock testing should be added. Method 2006 should be employed for partial detection of foreign material when precap visual is not used and should be applied when the device application requires very low noise combined with a high vibration environment. Monitored vibration is relatively expensive (about the same as HTRB). The cost factor is .11 for Method 2001 and .15 for Method 2006 and 2002. Method 2020 (PIND) is recommended only for extremely high risk applications. The reliability factor of Method 2001 is 10; additional mechanical tests may raise the total to 15.

SEAL TESTS

Even though device hermeticity may not be required due to conformal coating of the subassembly and equipment enclosure design, seal tests can reveal package flaws which will promote other failure mechanisms. Method 1014 is one of the most effective screens after burn-in/electrical and precap visual. Typically 20% of the total screen rejects will be from this test (when the thermal and mechanical tests are used). The seal test should be required as it is one of the best tests of the final mechanical device assembly. The pressure cooker is considered a preferred substitute for plastic devices.

Test Method 1014 has a cost factor of .2 and a relative quality factor of 30 (with conditioning) or 15 (without conditioning).

BURN-IN AND BAKE

Test Method 1008, commonly known as stabilization bake, is a very inexpensive test (cost factor less .01). However, it is also a very ineffective screen. The real value of Method 1008 is as a conditioning test, reducing the reject rate of otherwise good devices and rejecting unstable devices.

Test Method 1015 (burn-in) contains two basic types of burn-in — steady state and dynamic. MIL-STD-883 specifies dynamic test conditions D or E. D is a parallel-series excitation which requires an external driving signal source; E is ring oscillator excitation.

In either case, dynamic tests stress the device under conditions most closely approximating its use. The steady state conditions A, B, and C stress the device by maximizing internal bias potentials, power dissipation, or both. Condition C (both) is the most effective of the three. Normal burn-in is always conducted at the maximum rated temperature of the device, allowing derating so that specified junction temperatures are not exceeded.

When device packages are connected for dynamic burn-in, they should be independent of each other; ie, driven in parallel or self-excited (ring oscillator established within the package). Within a given package containing multiple functional devices, series connection is possible. These conditions ensure that each part is stressed equally; otherwise, the first part failing in a series or ring oscillator would eliminate the dynamic conditions from the others. Also, rated loads should be established for each device.

Steady state normal burn-ins are about one grade less effective than dynamic burn-ins, but they are usually slightly less expensive (by about 20%). A major expense in burn-in is the test equipment maintenance; steady state burn-ins require less complex, easier to maintain, and more reliable test frames.

High temperature reverse-bias burn-in (HTRB) uses test conditions A or C, but the test temperature is 25°C above normal device ratings. HTRB is very good at detecting wafer-related failure mechanisms. Wafer processing has progressed to the point that these mechanisms are not very significant in the SSI technologies except when very small circuit structures are prevalent. However, the newer technologies employ smaller structures, and higher circuit densities are common with LSI. So HTRB should be employed as a screen in addition to normal burn-in where these conditions apply.

Dynamic burn-in has a cost factor of .2; the static burn-in cost factor is .16. The cost factor varies directly with test time, which is nominally established at 160 hours to conform to common practice and MIL-STD-883. Burn-in effectiveness is dependent on burn-in time and burn-in temperature; however, these are not linear relationships. Temperature is the primary driver once some minimal time threshold is reached (96 hours). Burn-in at 125°C is three times as effective as burn-in at 70°C, but only 60% as effective as at 150°C. Dynamic burn-in drives the actual junction temperatures above the nominal by 5 to 30°C depending upon device complexity, loading factors, and the device technology; therefore, it is significantly more effective (up to 60%) than static or steady state burn-in for devices of large complexity (MSI or greater) in non-low-power technologies. On the other hand, virtually no difference would be noticed for MOS-SSI devices. The relative quality factor for a 160-hour static burn-in at 125°C is 45; this can be scaled up for dynamic burn-in and higher temperature. A shorter burn-in is possible with a slight reduction in effectiveness; the quality factor is 40 for 96 hours and 30 for 54 hours. Burn-in above specified operating temperatures can damage the devices; the supplier should be consulted if accelerated (high temperature) burn-in is anticipated for high reliability applications.

For maximized effectiveness of post-burn-in electricals, the electricals should be performed within 24 hours of the completion of burn-in.

SUMMARY

The tailoring process is usually iterative. It is usually better to start from a minimum effectiveness level and to "add" screening effectiveness as indicated by the application and the RQL. Effectiveness is added through additional test methods as well as through higher inspection/stress levels. The greatest flexibility in test levels is in the electricals and burn-in followed by visual, seal, thermal, and mechanical test methods. The adding of effectiveness is tempered by added costs and the true effectiveness estimated for the design application. An effectiveness "score" can be made by summing the quality factors for the various test methods invoked.

Table A-6. Typical total quality factors for common screens.

Class A/S screens	270-300
MIL-M-38510 Class B using MIL slash sheets	245-265
MIL-STD-883 Class B vendor parameters	215-240
Vendor Class B equivalent	190-225
MIL-M-38510 Class C using MIL slash sheets	140
Class C (MIL-STD-883 or vendor equivalent)	90-125
Commercial standards	3-15

PROCUREMENT TAILORING

Procurement tailoring is intended to establish a balance among reliability requirements, costs, and design constraints and to further identify suitable sources of devices and services.

SOURCES

Suitable sources of devices and services are essential to meeting high reliability requirements at affordable costs. Most device suppliers specialize in the manufacture of specific device families (such as TTL, TTL-LS, CMOS, memory, hybrid, and linear). Also, most suppliers do not offer every device type in a family. The following precedence is advised:

- | | |
|--------------------|--|
| Grade M devices | 1. QPL-38510 suppliers for device type only |
| Grade P, T devices | 1. QPL-38510 suppliers for device type |
| | 2. QPL-38510 suppliers for device family |
| | 3. Experienced commercial source for device type (2 years minimum) |
| Grade Z devices | 1. QPL-38510 suppliers for device family |
| | 2. Experienced commercial source for device type (2 years minimum) |
| | 3. Commercial source specializing in device family |

Supplier yield experience is also a useful criterion of source selection for each device. In addition to the functional device, testing services are required. Possible sources of testing services include the device supplier, independent testing laboratories (ITLs), and in-house facilities. Normally, the device supplier should be selected for the production process screen and production acceptance screen, especially when a precap visual inspection is required in the acceptance screen, unless the supplier's quality assurance procedures do not meet the baseline production process screening requirements (see 4.2.2) or unless the supplier lacks specific facilities required to perform a required test. ITLs may be selected for production process screen, production acceptance screen, or incoming acceptance screen; however, the same ITL shall not perform both the production acceptance screen and the incoming acceptance screen. Tightened inspection criteria should be applied whenever facilities other than the device supplier perform the production process screen. Note: the facility assembling hybrid devices is acting as a device supplier.

METHODS

The method of procurement has a greater impact on costs than device design and screening requirements. Microelectronic device costs, as with any high technology, consist of high nonrecurring costs and virtually nonexistent recurring costs. Test costs share many of these same cost characteristics and are related to the device manufacturing cost by complexity/yield considerations. Sources of devices and services have established manufacturing/testing process flows, automated programs, and QA procedures; deviations to established techniques cause significant nonrecurring costs which must be amortized over the procurement requirement. Therefore, it is very desirable to avoid forcing deviations. Also, the way requirements are stated can create administrative cost burdens in the labor required to interpret and check the requirements against the supplier's established specifications. Therefore, procurement costs can be widely influenced by factors which have no bearing on the technical requirements.

Procurement by part number (Method A) is a procurement technique designed to minimize nonrecurring costs by allowing the maximum flexibility in processes and procedures and by minimizing the interpretation of requirements by utilizing supplier part numbers and process references which inherently meet or exceed project requirements. Furthermore, schedule delays are minimized since normal distribution channels can be used as appropriate. Warranty control (Method AA) can be added when greater control is desired to reduce procurement risks, but only in larger quantity procurements in which an economic incentive exists to the supplier (ie, a big sale). Other methods of reducing procurement risks include buying insurance quantities and splitting the procurement to several qualified sources; however, these methods must be reviewed in the context of the program requirements, resources, and risks. Specification control may be added when critical device characteristics and test requirements exist, especially for Grade T devices, Type IV screens, and Class 4 nonstandard devices. The specification control used in Method B procurements specifies exceptions to supplier specifications which are otherwise controlled by part number or process reference. Method A procurements are particularly useful for small quantity procurements.

Procurement by specification control (Method C) has inherently lower procurement risks but inherently higher costs and longer delivery times. Method C should be used for all Class 5 and Class 6 nonstandard devices, Grade T devices which require a design change

to the basic device to meet the technical requirements, and screening requirements for Class 3 nonstandard devices. Method C may also be used to establish qualified sources for future Method A, AA, and B procurements. Specification control, either Method B or C, should be considered whenever substantial technical risks cannot be reduced by upgrading supplier part number/process references without introducing unacceptable procurement risks (such as lack of competition, schedule delays, and high costs); however, this decision must be made on a case-by-case basis.

LOT ACCEPTANCE

Table A-7 shows the typical yields for devices produced under acceptable standard quality assurance procedures and the lot dropouts due to additional screening. Lots exceeding the maximum acceptable screen should be rejected and either reprocedured or rescreened against tightened acceptance criteria.

Table A-7. Yield vs dropout.

	<u>YIELD</u>			
	SSI	MSI	LSI	VLSI
<u>Digital</u>				
Bipolar	.85	.50	.15	.03
MOS	.90	.75	.15	.10
<u>Linear</u>				
Bipolar	.70	.40	.10	.02
MOS*	—	—	—	—
<u>Memories</u>	.90	.70	.25	.07
	<u>EXPECTED SCREEN DROPOUT (%)</u>			
	SSI	MSI	LSI	VLSI
<u>Digital</u>				
Bipolar	1.5	5.0	8.5	9.7
MOS	1.0	2.5	7.0	9.0
<u>Linear</u>				
Bipolar	3.0	6.0	9.0	9.8
MOS*	—	—	—	—
<u>Memories</u>	1.0	3.0	7.5	9.3
	<u>MAXIMUM ACCEPTABLE SCREEN DROPOUT (%)</u>			
	SSI	MSI	LSI	VLSI
<u>Digital</u>				
Bipolar	4.5	10.0	16.0	16.0
MOS	3.5	8.5	14.0	16.0
<u>Linear</u>				
Bipolar	7.5	10.0	16.0	16.0
MOS*	—	—	—	—
<u>Memories</u>	4.0	9.0	15.0	16.0

*MOS Linear device data are sketchy

SSI chip size 40-90 mil square

MSI chip size 100 mil square

LSI chip size 200 mil square

VLSI chip size 300 mil square

APPENDIX B: RECOMMENDATIONS TO PROJECT MANAGERS

GENERAL

While the selection of individual component parts may not be a concern to the project manager, the established policies concerning the selection, procurement, and documentation of components can have gross effects on material costs, design time, project schedules, documentation costs, and logistics costs. Where policy is not specifically established for a project, a broad spectrum of policies regulating design, procurement procedures, logistics, and documentation practices may be invoked at different times through the project life cycle. These policies, while they may be optimized for the majority of circumstances in a specialized area, may conflict with project goals and with each other, creating very expensive problems. For instance, it is highly desirable to standardize for logistics purposes; however, standardization at the device level may not meet the technological goals of the project. Furthermore, standard devices may be neither readily available nor cost-effective in design or even production stages. Standardization policies encourage the use of standard devices, but the use of nonstandard devices may be forced upon the project by schedule or cost considerations. On the other hand, nonstandard devices may create unacceptable logistics problems later. Also, the rapidly evolving technologies of microelectronics create circumstances which are generally opposed to standardization unless active measures are taken to resolve the difficulties which arise. Additionally, the project requirements change through its life cycle; provisions need to be made to assure a smooth transition from one phase to another. A project needs to have a definitive policy to manage components throughout its life cycle which ultimately becomes compatible with its provisioning actions and logistics support. However, no blanket policy can apply to the broad spectrum of projects, so policies must be tailored to each project. The document of which this is a part provides guidance in establishing parts management policy.

The purpose of this appendix is to provide a standard framework to serve as a point of reference for the formulation of parts management policy. As such, it incorporates successful commercial and government practices within the framework of established procedures for microelectronic devices. The resulting actions may be classified as design items, testing items, documentation items, and procurement items.

DESIGN RECOMMENDATIONS

Specifically, it is recommended that Grade P devices be automatically approved for use in design and developmental production. This provides the maximum flexibility in schedule and cost tradeoffs in parts procurements while preserving the advantages of using Grade M devices for logistics support. The provisions of this document are intended to promote flexibility in meeting project objectives while minimizing costs and risks. Also, it is advised that working level communications be encouraged between designers and potential suppliers to promote good engineering application of each device and design whose reliability is primarily dependent on inherent component reliability.

TESTING RECOMMENDATIONS

It is recommended that minimum test standards be established for the project. However, existing screens which meet or exceed these minimum standards are preferred over tailored screens unless a clear economic advantage exists for the tailored screen. Maximum screening cost-effectiveness is the desired goal.

DOCUMENTATION RECOMMENDATIONS

Documentation should be held to a minimum in procurement actions; this minimizes administrative overburden and promotes a clear understanding of hard requirements. Quality documentation and device design documentation should be minimized. On the other hand, information defining the end use of the part should be sufficient to support the procurement and provisioning of the end item throughout its service life. Even when not used for procurement, properly prepared specification control documentation may be important to future provisioning.

PROCUREMENT RECOMMENDATIONS

Procurement practices which promote quality through economic incentives and which minimize nonrecurring costs are encouraged. "Legislative" (specification controlled) procurement practices should be avoided wherever possible. However, flexibility in procedures should be maintained, and the procurement method tailored to the circumstances to minimize the total risk to the project.

SUMMARY

This appendix provides guidance for the management of microelectronic devices tailored to development project requirements. When implementing this document, it is recommended that the following actions be taken in development contracts:

1. Grant automatic approval for the use of Grade P devices.
2. Closely scrutinize documentation requirements.
3. Establish parts management policy tailored to project requirements.
4. Provide the maximum amount of flexibility in making decisions throughout the project life but establish priorities to guide decisions away from unacceptable risks.

APPENDIX C: PARTS MANAGEMENT GOALS

GENERAL

Five factors must be considered in setting a parts management policy:

Performance
Reliability
Maintenance
Provisioning
Cost

In addition, the project manager must consider parts availability, since delays in parts deliveries may have a very negative effect on the project schedule. These factors, as they interact with each other, may be lumped into three categories of issues:

Standardization
Effectiveness
Efficiency

STANDARDIZATION

There are two types of standardization – intrasystem and intersystem. The goals of intrasystem standardization are to:

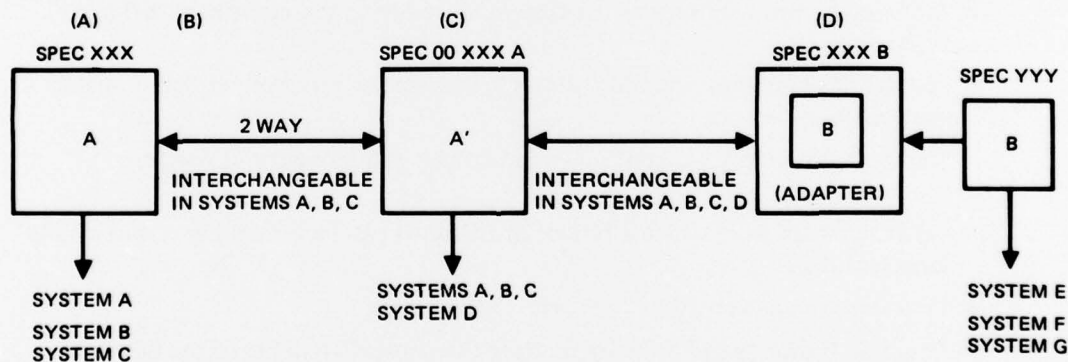
- Increase the producibility of the system by reducing the number of different kinds of components
- Increase system supportability through widespread intrasystem commonality of designs, modules, etc
- Decrease system documentation costs through commonality of designs, modules, etc
- Create a situation in which all items provisioned can be ordered in economically large quantities
- Decrease system downtime for parts
- Decrease system design time by limiting the choices available to the designer
- Establish standard intrasystem interfaces

Most simply, intrasystem standardization strives to make the widest possible use of the fewest possible different kinds of parts and designs. The greatest advantages of such programs as the Standard Electronics Module (SEM) and the Standard Hardware Program (SHP) lie in the ready availability through them of design building blocks for application in intrasystem standardization efforts. The goals of intrasystem standardization are to minimize the number of different logistics items which must be supported and to maximize interchangeability between items of like functions.

The following steps are recommended to implement the standardization objectives of parts management:

1. Establish a project policy of maximizing intrasystem standardization.
2. Wherever possible, make use of existing standards (standard interfaces, standard modules, standard parts, standard equipments, standard test provisions, etc); however, do not enforce this provision to the degradation of other project requirements. Established industry standards should be considered as well as military standards.
3. Minimize system-peculiar design and components.
4. In selecting parts, choose preferred parts (MIL-STD-242) over other standard parts (controlled by military specification), standard parts over controlled parts (non-standard parts already supported in the National Stock System), and controlled parts over all other parts. This step is implemented in accordance with MIL-STD-965 and MIL-STD-143.
5. Where other factors (such as cost or availability) militate against the use of the part which would otherwise be selected under step 4, select a part which can be replaced by the step 4 selection for repair/provisioning purposes and show the step 4 selection in the provisioning documentation. This step is implemented in accordance with Requirement 7 of MIL-STD-454.
6. Document all system interfaces, down to the level of standardization, using functional specifications.

Step 6 is particularly important, since it establishes the mechanism for future design evolution within the framework of standardization; figure C-1 illustrates this mechanism.



- (A) ITEM A IS DEVELOPED FOR SYSTEM A AND DOCUMENTED BY SPEC XXX
- (B) ADDITIONAL USE FOR ITEM A IS FOUND IN SYSTEM B AND SYSTEM C
- (C) TECHNOLOGY ADVANCES LEAD TO ITEM A', CAN ALSO BE UTILIZED IN SYSTEM D, WHICH REQUIRES THE IMPROVED CHARACTERISTICS. ITEM A' IS DOCUMENTED BY SPEC 00 XXX A
- (D) A NEW GENERATION OF TECHNOLOGY LEADS TO ITEM B WHICH IS DEVELOPED FOR SYSTEM E AND DOCUMENTED BY SPEC YYY. ITEM B IS FUNCTIONALLY LIKE ITEM A' BUT SIGNIFICANTLY SMALLER IN FORM FACTOR AND LESS EXPENSIVE, SO SPEC XXXB IS DEVELOPED TO ADAPT ITEM B TO SYSTEMS A, B, C, AND D AND TO SUPERSEDE SPEC XXX AND SPEC 00XXX A. LATER, NEW APPLICATIONS FOR ITEM B ARE FOUND IN SYSTEMS F AND G

Figure C-1. Growth of a standard.

EFFECTIVENESS

Parts management for overall system effectiveness is most often cloaked as "good engineering practice." The performance of the system hinges on proper parts selection and application. The reliability of the system depends on (1) the inherent failure rate of the selected parts and (2) the stresses put on the parts by their design application. The availability of the system depends on its achieved reliability and the time to restore it to operation when a failure occurs. The availability of parts is a major factor in the ability to repair a system; therefore, consideration of both current and future part availability is warranted. Undoubtedly, performance factors play a major role in part selection; a partial list of these factors would include size, weight, form factor, power consumption, environmental ratings, and tolerance. Suggestions for Designers of Navy Electronic Equipment (1975 edition, NELC TD 390) provides many points to aid in avoiding pitfalls in part selection; the appropriate military specifications and "selection and use" standards are also useful. Beyond these standard factors, parts should be selected as follows:

1. Select high reliability parts.
2. Use parts well within their rated limits; derate the parts for the environment they must endure in service (temperature, EMI, vibration).
3. Choose parts whose dominant failure mode has minimum effect on the equipment.
4. Select parts and designs which do not require other components to correct their deficiencies (for instance, vibrator-type power supplies will normally require filtering to take out the EMI they produce).
5. Take into account part tolerances and value changes under stress and aging.
6. Choose parts which are produced by mature, large-volume manufacturing processes where other factors (size, weight, speed, etc) do not dictate a less mature technology.
7. Avoid sole source and proprietary parts.
8. Conform to standardization steps 4 and 5. When specialized screening is indicated, cite the screening requirements which are in excess of high reliability/standard parts qualification requirements.

EFFICIENCY

Cost and availability of parts are factors which must always be weighed in part management decisions. However, these factors should not be given primacy over other part selection factors since the initial cost of components is only a small portion of an equipment's cost (typically 10% for military electronics) and supposed savings are quickly obscured by high support costs. Nevertheless, a number of alternatives may be available to the project in its parts decisions.

1. In more complex parts (assemblies and units), off-shelf items should be considered in preference to developing a new item.
2. Manufacturers' high reliability lines of commercial parts are often much more readily available than military parts and are usually less expensive; these parts can be used to advantage in design and even in limited production as long as the military standard part is used as the provisioning part (see standardization step 5).

3. High reliabilities meeting or exceeding military standards are often attainable by applying an appropriate screen to commercial parts; this applies to piece parts and whole equipments alike. In applying screens to piece parts, large enough volumes of parts must be screened to amortize the screening setup costs and the costs of rejected parts. When a high reliability/standard part exists, it should be specified in provisioning documentation.

4. When parts-peculiar are justified (such as custom LSI), consideration should be given to total life-cycle procurement techniques to preclude uneconomical small-lot procurements. (A total life-cycle procurement combines initial requirements and all projected support requirements.)

APPENDIX D: RELIABILITY PREDICTIONS

Reliability predictions should be performed in accordance with MIL-HDBK-217 with special attention to the learning factor, π_L . The MIL-HDBK-217 prediction, properly performed, should yield a conservative prediction because of true variances in the quality factor, π_Q . These variances are the result of many circumstances, such as product process maturity at any given supplier, vacation schedules, and raw material quality control. However, product process maturity is an overriding factor in the majority of cases. An extremely mature device from one supplier may be immature from another supplier. Since the MIL-HDBK-217 quality factor is determined across a broad spectrum of devices, it is not able to compensate for gross differences in device maturity. The values contained in table D-1 are suggested substitute quality factors for those in MIL-HDBK-217; these will yield less conservative, more realistic predictions. There is, of course, an increased risk that devices will not be as good as predicted. However, if proper attention is paid to source selection, this risk is minimized.

An expedient method of performing the reliability prediction is to group the devices according to their generic part description, compute the MIL-HDBK-217 prediction, then adjust the prediction by multiplying the failure rate attributable to each descriptive type category by the corresponding ratio of suggested quality factor to MIL-HDBK-217 quality factor.

Table D-1. Reliability prediction quality factors.

Generic Part Description	MIL-HDBK-217 π_Q	Applicable Risk π_Q
1. MIL-M-38510 Class B, all types (Grade M)	2	2
2. Class B-1, per MIL-HDBK-217	5	
a. Grade P or T digital devices		2
b. Grade P or T linear devices		4
c. Grade Z, Nonstandard Class 1 or 2 digital		2
d. Grade Z, Nonstandard Class 1, 2, or 4 linear		5
e. Grade Z, Nonstandard Class 4 digital		3
f. Grade Z, Nonstandard Class 3 or 6 (all)		5
3. Class B-2, per MIL-HDBK-217	10	
a. Grade P or T digital		2
b. Grade P or T linear		6.5
c. Grade Z, Nonstandard Class 1 or 2 digital		3
d. Grade Z, Nonstandard Class 1 linear		7
e. Grade Z, Nonstandard Class 2 linear		8
f. Grade Z, Nonstandard Class 4 digital		4
g. Grade Z, Nonstandard Class 4 linear		9
h. Grade Z, Nonstandard Class 3 or 6 digital		10
i. Grade Z, Nonstandard Class 3 or 6 linear		12
4. Hybrids (Nonstandard Class 5) (Class B)	1	1

APPENDIX E: CUSTOM DEVICES

The maturation of device manufacturing and design technologies has opened the whole field of custom devices. Basically, there are four types of custom devices, each with its advantages and disadvantages.

The hybrid is the lowest-risk type of custom device, especially when all the component parts are not custom devices. Since the design can be functionally checked out in breadboard form, the primary design risk is environmental performance, especially thermal design, with most hybrids. Quality controls should be designed to screen package-related fault mechanisms including trapped foreign particles, which are most likely with hybrids. Hybrids offer moderate functional density, relatively low design costs, and utility to low-quantity applications; however, they have high unit costs and a large number of additional interconnects (which lowers reliability performance).

Another type of customized device is the programmable device which can be tailored to the user's needs through either pin or mask programming. Pin programmable devices (mostly PROMs) are largely user programmed and may be considered equivalent to a non-custom device for procurement purposes. Mask programming is an inexpensive, low-risk method of customizing which may also be considered equivalent to noncustom for procurement purposes; special design costs are minimized to the mask setup charge. Programmable devices have the advantages of noncustom devices — low costs, utility to low-quantity applications, and validated designs — but they are relatively limited in the scope of their functional adaptability.

Building block customized devices use standard design cells which are assembled into the desired functional configuration. There is a moderate design risk, and there are moderate costs associated with the process, which must be amortized over a moderately large quantity application (1000 to 10 000 pieces minimum, depending on functional complexity). The major device suppliers offer services for building block custom devices, and a number of smaller suppliers specialize in such services. The design should be thoroughly validated functionally and environmentally. Building block customization is highly flexible and can satisfy virtually all applications which cannot use hybrid or programmable processes; however, the problems entailed by the high risk of establishing the detailed production process must be overcome.

Ground-up customization is generally a last-resort process because of the high costs and moderately high risks involved. It should normally be used only when the technical requirements demand LSI performance and functional building blocks are not available (as in many linear applications). The functional performance should be validated through computer simulation prior to beginning a ground-up custom design. The design should be thoroughly validated functionally and environmentally, and the production process quality controls should utilize tightened inspection procedures. Ground-up customization offers the ultimate in design flexibility and performance; however, its costs restrict its applicability to large quantity applications (at least 10 000 pieces) in which the technical requirements are stable. Stable technical requirements are requisite for both building block and ground-up processes because changes are so expensive.

The successful procurement of custom devices rests heavily on the supplier selection. The supplier must have capabilities which fully satisfy the customization process requirements of the application. Some building block customizers may not have a library of design

cells which can satisfy the functional requirements. The supplier must also have the production and inspection capabilities needed to produce high quality devices. These requirements are less stringent for hybrid devices; therefore, more flexibility is possible in supplier source selection for hybrids.

The device validation process starts with the design of the end-item equipment. Functions which are candidates for customization should be identified early, and working prototypes should be integrated into prototype equipment designs and subjected to operating and environmental tests (thermal tests as a minimum). Working prototypes for custom LSI may be hybrids. These prototypes may be used to stabilize the design requirements so that expensive changes can be avoided. Functional validation should include the full gamut of electrical parameter tests to fully characterize the device. Environmental validation should include thermal characteristics, MIL-STD-883 Method 1012, and life tests (MIL-STD-883 Method 1016 or 1007 is recommended). The design should be inspected by use of MIL-STD-883 Method 2010 Condition A visual and Method 2018 SEM procedures. The full groups of Method 5005 sampling inspections should be completed on the production run. In critical applications, Class A quality levels might be applied in lieu of normal Class B levels.

Custom devices can be highly cost-effective when properly applied and may be the only means of achieving application goals. However, the long-term benefit of custom devices can be destroyed if no advanced plans are made for future provisioning. Custom devices may be effectively provisioned through the Life-Of-Type (LOT) technique whereby an entire life-cycle device requirement is procured with the initial production (an appropriate insurance quantity is included which may run as high as 200%).

Table E-1. Custom device delivery risk.

Device Design Time	1-5 months (2 months typical)*			
Trial Pass Time	2 1/2-3 months per pass			
	<u>Estimated Chance of Success</u>			
	Building Block Custom		Ground-up Custom	
Trial Pass (lead time)	Digital	Linear	Digital	Linear
First Pass (4-5 mo)	20%	15%	3%	1%
Second Pass (6 1/2-7 mo)	80%	70%	20%	12%
Third Pass (9 1/2-10 mo)	95%	90%	80%	60%
Fourth Pass (12 1/2-13 mo)	99+%	98%	95%	90%
Fifth Pass (15 1/2-16 mo)	99+%	99+%	99+%	98%

*Assumes that characteristics of the required technology are well established. Hybrid devices may be useful as suitable "breadboards" to establish functional and circuit-critical requirements for many custom integrated devices.