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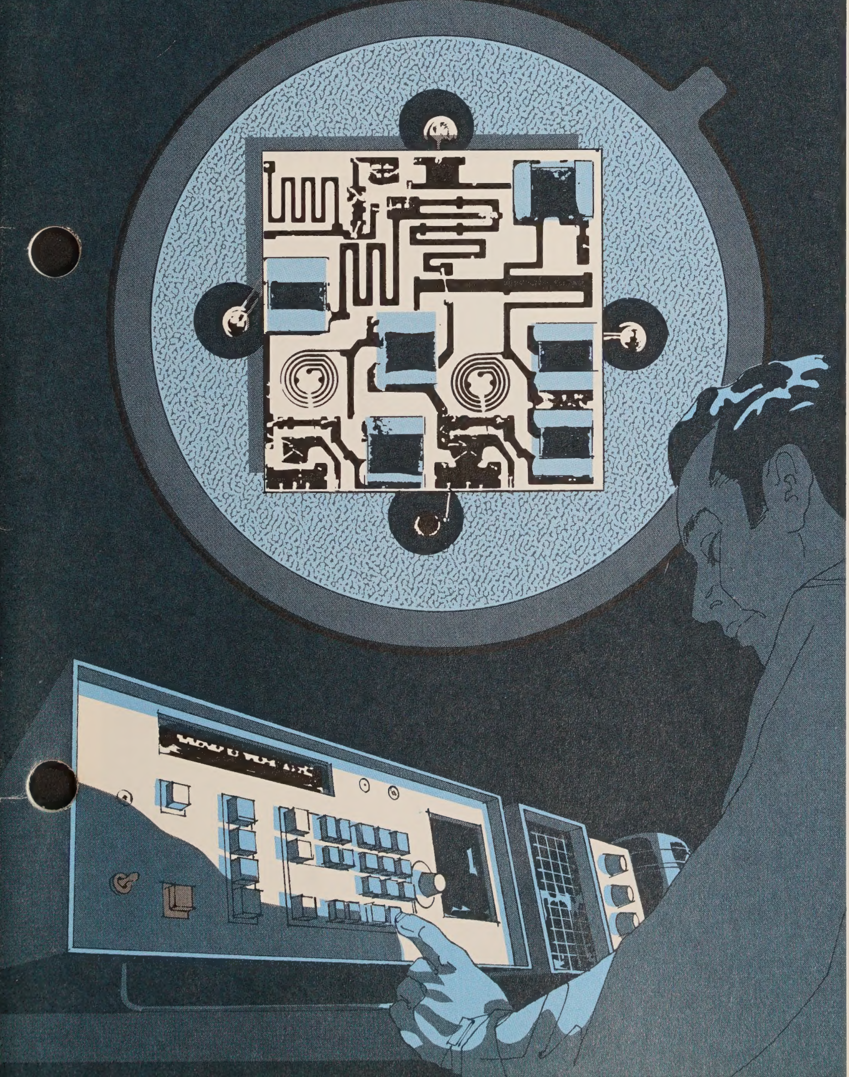
Specifying High-rel Mixers and Amplifiers



WATKINS-JOHNSON COMPANY

Tech-notes

While the subject of this article is a slight departure from that of the usual *Tech-notes* topic, it is, nevertheless, important to acquaint the reader with high reliability — a subject that is very much a part of the microwave industry. The specifying of high-reliability (hi-rel) items may sometimes be a mystifying process to vendor and equipment user alike, but it is important that designers, manufacturers, buyers and end users of microwave electronic equipment be aware of the various methods used to specify hi-rel products, what documented specifications entail in the way of testing, and the risks, in time and cost, of over- or under-specification. This article deals mainly with the specifying of mixers and RF hybrid amplifiers.

A hi-rel part is generally specified to ensure that its failure rate satisfies its intended use. The 1979 Environmental Stress Screening of Electronic Hardware Conference (ESSEH) concluded that failures could be mainly attributed to improperly constructed hardware and misapplication of the product. The goal of stress screening is to find flaws before a part is included in a sophisticated spacecraft, weapons system, or other high-performance electronic hardware. Since there is presently no universal standard for testing every type of microwave component and subsystem, and since there is no authoritative data base with which to compare test results, designers have developed their own set of rules and procedures from which are selected those that best describe the desired screening tests. These rules and procedures are often dictated by the designer's client and/or mandated by various military standards (MIL-STDs).

MIL-STDs have been established to standardize test methods and screening levels for general types of hardware (see Table 1). Unfortunately, they frequently become outdated or fail to cover a specific hardware type. Military standards are not "hard and fast" rules for testing, but, instead, are written to allow some latitude in the methods and levels of testing. For example, MIL-STD-883B, Method 5004.4 states: "This method establishes screening of microelectronics to assist in achieving levels of quality and reliability commensurate with the intended application."

There are three distinct levels of screening tests: Class S, Class B, and Class C. Class S represents the most stringent testing and Class C the least stringent. MIL-STD-883B, Method 5004.4, also states: "Since it is not possible to prescribe an absolute level of quality or reliability which would result from a particular screening level or to make a precise value judgment on the cost of a failure in an anticipated application. . .the method provides flexibility in the choice of conditions and stress levels to allow the screens to be further tailored to a particular source, product or application based on user experience."

MIL Specifications	Purpose and Application
MIL-STD-883 Test Methods and Procedures for Microelectronics	Standardizes environmental screens for IC's and hybrids and suggests series of tests for 100-percent screening and sample testing for qualification and production lot acceptance testing (QCI)
MIL-STD-202 Test Methods for Electronic and Electrical Parts	Standardizes environmental screens for general electronic components
MIL-M-38510 General Specification for Microcircuits	Establishes guidelines for hybrid physical design and the environment within which the hybrid is manufactured, including documentation
MIL-M-28837 General Specification for RF Mixers	Standardizes general requirements for RF mixers including manufacturing and qualification requirements
MIL-S-19500 General Specification for Semiconductor Devices	Defines product assurance levels for JAN, JANTX, JANTXV, and JANS semiconductor devices
MIL-HDBK-217C Reliability Prediction of Electronic Equipment	Provides formulas and data for calculating the failure rate/MTBF of electronic components and systems

Table 1. Primary mixer and hybrid amplifier military specifications.

Users Must Request Proper Screens

Users of hi-rel parts must provide the proper tailoring of screening methods and levels when making a hi-rel request. Often, a hi-rel request specifies more than is needed for the intended application, resulting in high costs for unnecessary screening. It was pointed out in the 1979 ESSEH that the manufacturer is in the best position to determine what screens will be most effective for his type of hardware. It is risky for a vendor to change his fabrication process simply to meet customer specifications. Such a change means a departure from familiar construction techniques to procedures whose results are not yet proven.

The customer should be flexible in his hi-rel requests. Also, a design engineer knowledgeable in hi-rel can be influential in determining realistic needs, and in making recommendations to both customer and manufacturer.

Screening and Reliability Relationships

A screening test causes a flaw to become a failure, but quality assurance and process control should be aimed toward preventing and finding potential failures before they enter the screening process. Screening increases the expected *mean time between failure (MTBF)* of the final product (see Figure 1), but at some level (point B), the return on investment begins to decline. The specifier must decide when the increased reliability warrants the added expense. Screening the completed items yields a higher return than testing piece parts (individual components) or subassemblies.

Overstressing a part can reduce its MTBF (see Figure 2). Screening tests which exceed the design limits of a piece of hardware may weaken some part of the assembly. The resulting MTBF figures fail to indicate the component's reliability in the intended environment, thus needlessly adding cost and time.

An optimum screening level exists for each hi-rel item, which will minimize total system cost (see Figure 3). A typical $100 part may require $50 in testing to reach point A, but an additional $250 to reach point B. The relationship shown in Figure 3 is similar to that shown in Figure 1, but determining the screening level also depends on the expense of locating and repairing a system failure, which includes lost business, reduced mission effectiveness and fixed overhead costs.

Screening must maximize potential failures to control the cost of a hi-rel part. The proper sequence must be determined through empirical data

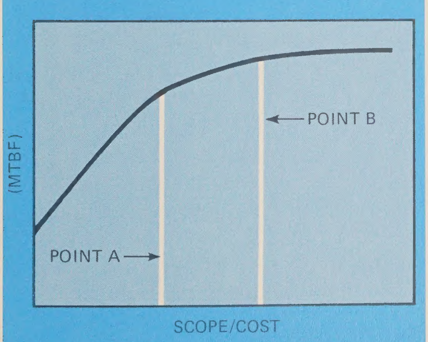


Figure 1. Screening increases the expected MTBF of the final product.

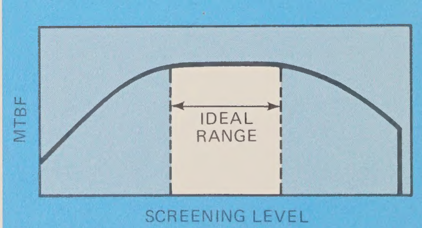


Figure 2. Overstressing a part can reduce its MTBF.

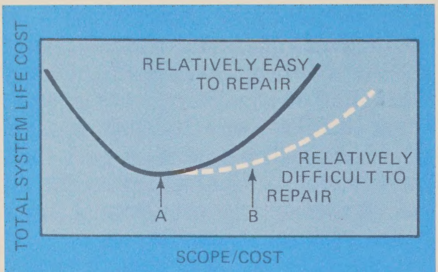


Figure 3. An optimum screening level exists for each hi-rel item, which will minimize total system cost.

developed by the vendor (see Figure 4). Also, costs can be minimized by using the vendor's in-house standards rather than implementing new and untried fabrication methods.

Specifying Hi-rel Hybrid Microcircuits

The trend in the design of RF components and thin-film RF and microwave mixers is to use hybrid microcircuit construction and manufacturing techniques. These circuits, which are called MICs (microwave integrated circuits) by many manufacturers, are being procured with an increased interest in reliability. In spite of the well-established use of the hybrids, the best way to maximize cost/quality value while minimizing manufacturing and procurement cycles is still unknown.

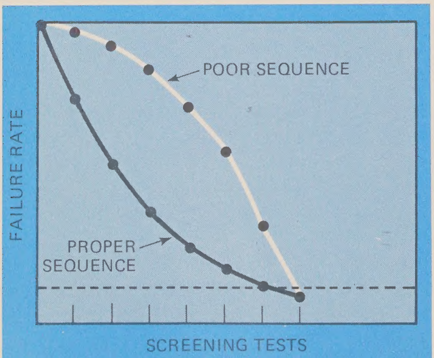


Figure 4. Screening must maximize potential failures to control the cost of a hi-rel part.

A hybrid microcircuit consists of a single-package electronic subsystem utilizing a substrate, with film interconnects and some film passive components, onto which unpackaged discrete active and passive components are attached. Low-frequency linear and digital hybrids have been popular since the late 1960's, even for non-military applications.

Because of the microwave industry's specialized nature, it has been isolated from the general semiconductor component developments from which the hybrid has evolved. As a result, it has taken more time to adapt the new manufacturing technology. In addition, the design of hybrids for microwave applications are difficult to modify for optimum manufacturing. Unlike low-frequency components in which parasitic effects can be neglected, the performance of an MIC depends more on its physical configuration.

Today, most of the hurdles have been overcome and an increased number of new designs are using microcircuit techniques with increasing advantage and confidence.

Figure 5 shows a typical cascadable amplifier arrangement. Hybrids of this type are inherently more compatible with high-reliability applications than their printed-circuit counterparts. Most significantly, the number of interconnects (potential weak links in the reliability chain) is reduced by a factor of two to four. Furthermore, all of the components in a hybrid are in a small, common, hermetic package. The same production facilities used for a standard product line can also produce high-reliability units. The best manufacturing philosophy establishes a high-quality base on the standard line. Most high-reliability requirements should be able to be met through additional processing or testing rather than changes in the manufacturing procedures.

Hybrid Screening

Since the hybrid microcircuit extends from the semiconductor industry, two

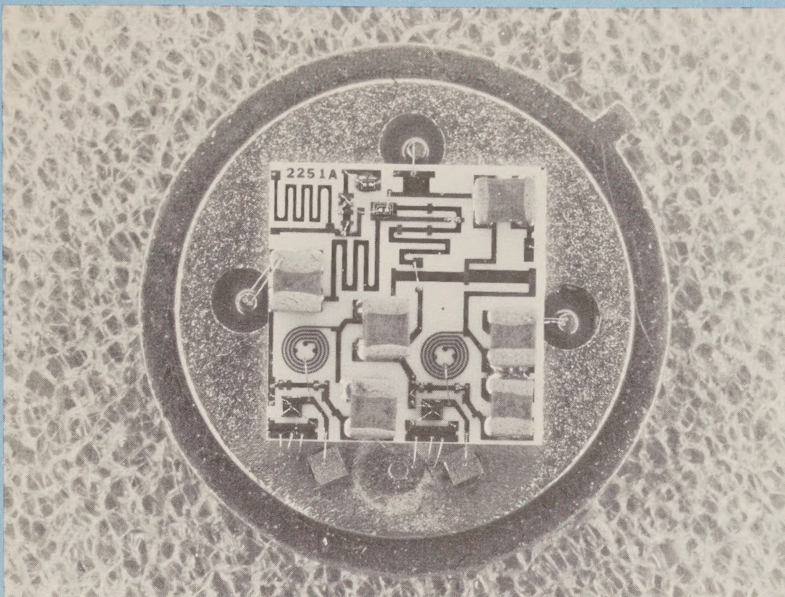


Figure 5. Typical cascadable amplifier arrangement.

previous MIL-STD documents are used by all experienced hybrid customers and manufacturers: MIL-STD-883, "Test Method and Procedures for Microcircuits," and MIL-M-38510, "General Specifications for Microcircuits." Since "883" and "38510" provide such appropriate industry standards, less applicable documents (such as MIL-STD-202 and MIL-STD-750) merely add time and cost to the specifying/manufacturing cycle.

MIL-STD-883 compiles the many environmental tests, electrical tests, and process controls to which any semiconductor-based electronic component may be subjected to detect quality and reliability problems. Methods 5004 and 5008 of this standard suggest tests to be performed on a 100-percent basis (testing of each and every part) to screen potential failures. In particular, Method 5008, the more current section, is being adopted by the hybrid industry.

Ninety percent of all hi-rel hybrid microcircuits are currently screened to the Class B level of Method 5004, with minor variations according to the specified product and application. Because of the widespread use of the hybrids and the resultant standardization of screening, both customer and manufacturer benefit with lower costs and better test correlation. For these reasons, the continued use of MIL-STD-883 is very important.

Screening, and monitoring of fabrication processes can be applied during three stages of production: on the individual parts (piece parts) that go into the assembly, during manufacture, and after a unit is sealed and functionally complete. The relative costs usually decrease for these successive stages, unless a well-identified yield or reliability problem exists that can be best addressed at a lower level.

Because the extremely small hybrid piece parts, such as silicon chip bipolar transistors (see Figure 6) and multilayer chip capacitors, have no attached leads or packages, screening at this level is very expensive. Due to the uniqueness of small, unpackaged and leadless devices, the customer needs to be

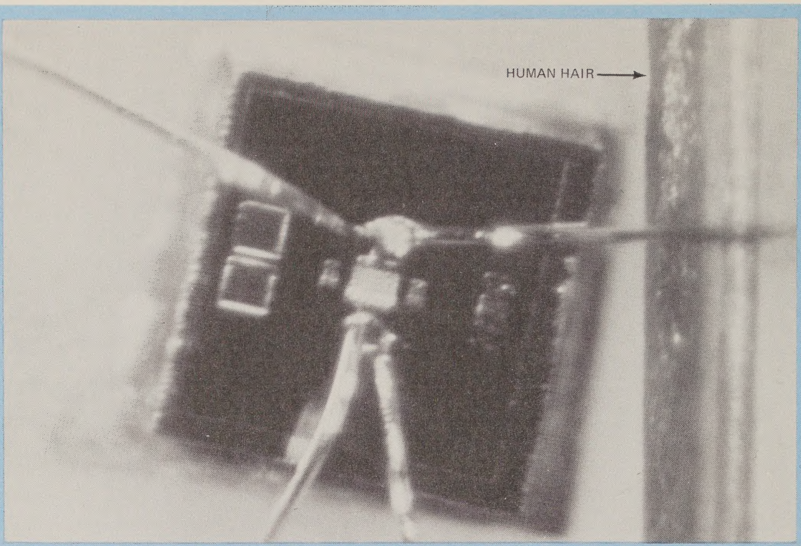


Figure 6. Because hybrid piece parts, such as silicon chip transistors, have no attached leads or packages and are extremely small, screening at this level is very expensive.

especially well informed about the necessity of screen requirements at this level of manufacture.

Chip transistors can be tested by scanning electron microscope inspection, 100-percent visual inspection, 100-percent DC probing, visual and sheer-strength testing of die attachability, wire bonding test, and burn-in or life tests. The sample testing is performed on a wafer or on a wafer diffusion lot for qualification.

Chip capacitors can be screened by 100-percent electrical testing (dielectric withstanding voltage, insulation resistance, and dissipation factor), 100-percent visual inspection, and sample bondability testing. Life and burn-in tests can be performed for multilayer double-end terminated capacitors, but these are expensive and time-consuming. Delamination and voiding problems can be detected through destructive physical analysis.

Piece-part screening usually extends schedules by three to five months. Since many programs cannot tolerate this type of delay, hybrid manufacturers should establish standard in-house specifications, for additional screening on their standard parts inventory, based on their customers' most common needs. They should also maintain an in-house stock of screened piece parts. Customers must assist by forecasting upcoming needs as early as possible.

Screening can also be applied during manufacture. This type of screening includes pre- and post-process destruct sample monitoring, and post-process, 100-percent nondestruct screening of component attachment and wire bonding. Hybrid manufacturers have a responsibility to provide their customers with an established level of process quality control based on the best known common denominator of customer needs. Screens which are more stringent than those established by the manufacturer will, therefore, be expensive.

The third and best stage to screen a hybrid is after it has been sealed. Screening at this point produces the highest mean time before failure per dollar ratio. The most cost-effective screens are a manufacturer's own adaptation of Method 5004 of MIL-STD-883 (as shown in Table 2).

Test	Method	Condition
Internal visual	2017	B modified
Stabilization bake	1008	B; 24 hrs. 125°C
Temperature cycle	1010	B; −55°C to +125°C
Acceleration	2001	B; 10,000 Gs, Y1
Seal, fine and gross	1014	A, C; 5 x 10^{-8} at mcc/sec
Burn-in	1015	B; 160 hrs. T_c = 85 to 125°C
Final electrical	App. Doc.	Per applicable document
External visual	2009	

Table 2. Typical RF hybrid basic screening per method 5008 of MIL-STD-883.

MIL-STD-883 leads to several standardized screens including: internal visual inspection, bake tests, temperature cycle tests, centrifuge tests, fine and gross leak tests, burn-in, and external visual inspection. Method 5004 states: "The user is cautioned to collect experience data so that a legitimate value judgment can be made with regard to the specification of screening level." Again, the manufacturer usually has the best experience data.

Although internal visual inspection is the only screen in this sequence prior to seal, it is performed after completion of an otherwise functional unit. Method 2017, the only appropriate MIL-STD internal visual specification for hybrid microcircuits, is comprehensively written for a "typical" unit. It must be modified and amended for unique piece parts and other aspects of specific applications. The detail specifications should call for internal visual inspection according to the manufacturer's approved standards in compliance with the intent of 2017.

Stabilization bake and temperature cycle tests are listed in Methods 5004 and 5008 with test condition level C (150°C and −65° to +150°C, respectively). Level A (75°C and −55°C to +85°C) or level B (+125°C and −55°C to +125°C) should be specified for most hybrids with multilayer chip capacitors or other large components, substrates and packages, and relatively hard attachment alloys.

The general screening levels, which were somewhat arbitrarily chosen for MIL-STD-883, originally addressed only monolithic circuits which do not possess the special conditions of hybrids. Similarly, a suggested constant acceleration level of 30,000 G (Condition E) was originally selected only for stressing wire bonds on monolithics without large mass components. Hybrids should only be stressed at 5,000 or 10,000 G (Condition A and B, respectively). Excessive stress testing can actually reduce the MTBF of the components.

For cost considerations, pre-burn-in electrical tests should only be specified if a critical parameter drift is expected. Burn-in temperature commensurate with a maximum operating junction temperature of the highest stressed active device must be selected. A typical burn-in time for hybrids is 160 hours (one week); the less common Class S level testing requires 240 hours!

Differences Between RF Hybrids and Non-RF IC's

It is vital to understand the electrical and manufacturing construction differences between non-RF integrated circuits and RF hybrids relative to cost and type of testing. For example, a non-RF integrated circuit may only require 30 minutes for complete testing. One lot of 100 RF hybrids with a similar number of tested parameters and with customer-specified (rather than manufacturer standard) electrical testing takes two days of senior technician time plus supervision and engineering consultation. To maximize product value, customers should utilize the manufacturer's standard testing or, at least, carefully select the number and type of test points.

Radiographic (X-ray) inspection, which is specified by approximately 15 percent of RF hybrid users, is relatively inexpensive to perform but can produce very expensive yield losses, since radiographic detail may vaguely show

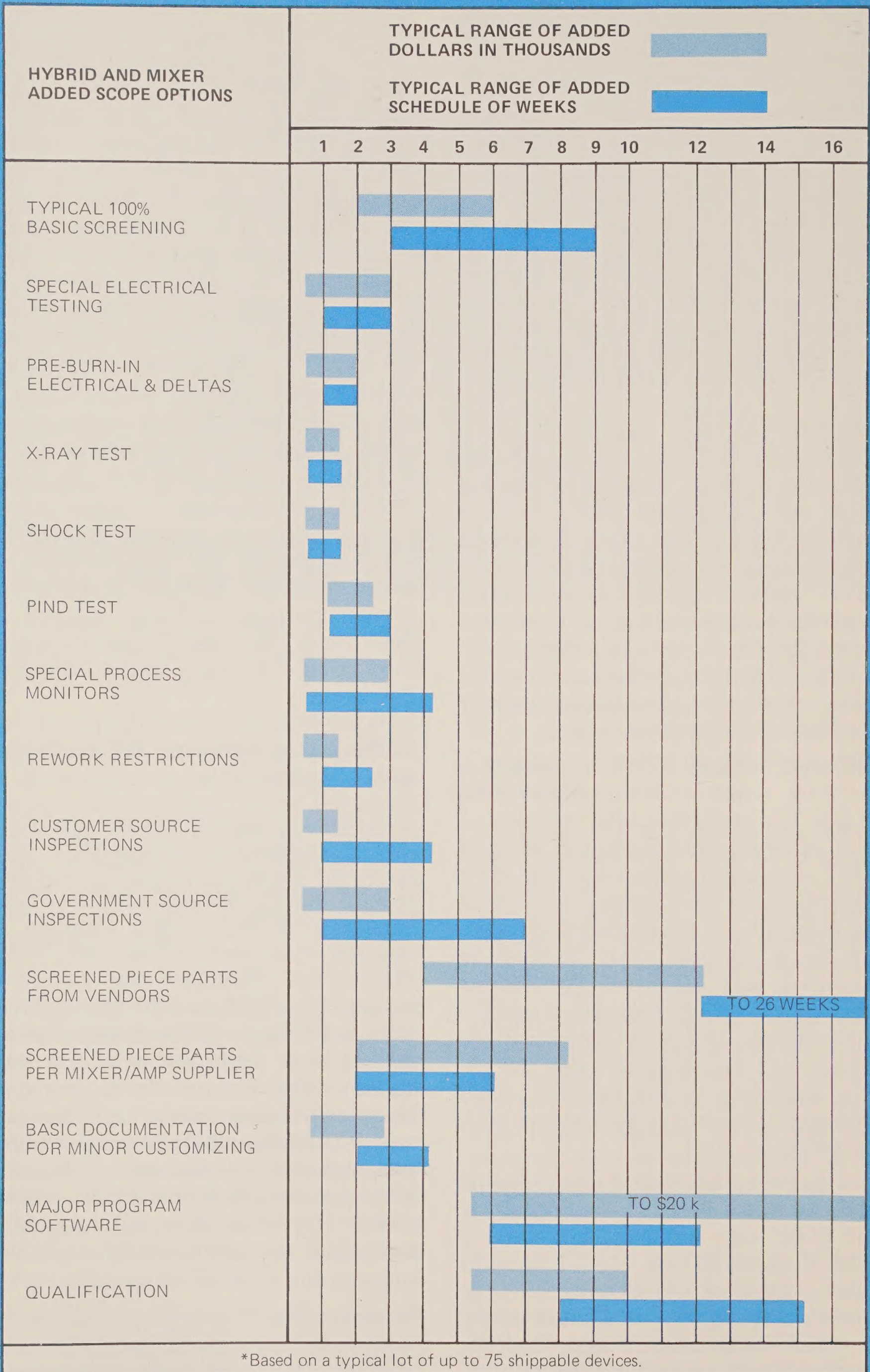


Table 3. Cost and schedule impact of standard screens (based on a typical lot of up to 75 shippable devices).

possible flaws that will not affect the operation of the part under test. Strict adherence to X-ray inspection rejection standards will often cause many good parts to be scrapped. Since it can very effectively determine catastrophic damage occurring after internal visual inspection, X-ray testing is generally performed near the end of the screening sequence. Because of the ambiguous nature of X-ray images, the inspection parameters and accept/reject levels should be sparingly and carefully chosen. This exemplifies the need to prevent misapplication of standards which could result in a very poor MTBF return per invested dollar.

Particle impact noise detection (PIND) testing, one of the newest screens, is now being specified more often. PIND detects loose particles within sealed units by electronic monitoring through an acoustic coupler while the device is vibrated and mechanically shocked.

The buyer (customer) of electronics parts will sometimes request a *customer source inspection*, in which the buyer sends his own inspector to observe certain phases of the fabrication process and to inspect test data and observe the taking of test data.

Customer source inspection is recommended only when the buyer has no experience with a particular manufacturer's product or knows of recent problems that warrant monitoring. Government source inspection (similar to customer source inspection, but with government inspectors) seldom contributes to the quality of the product if customer source inspection has already been performed, and can significantly contribute to schedule delay and costs.

Table 3 summarizes the costs and schedule impact of most of the standard screens for both mixers and RF hybrid microcircuits. A detailed description of the screens and their purposes is shown in Table 4.

Specifying Hybrid Microcircuits

The other appropriate document that should be applied in specifying hybrid microcircuits is MIL-M-38510. It establishes guidelines for the design and manufacturing environments. This specification is intended to be broad and comprehensive in its interpretation. The scope paragraph states: "Detail requirements, specific characteristics of microcircuits, and other provisions which are sensitive to the particular use intended shall be specified in the applicable device specification." Because of its general nature, MIL-M-38510 should never be specified without supplemental detail.

Interpretation of MIL-M-38510

Some areas of MIL-M-38510 frequently need further definition. Design is the first of these. Most hybrid manufacturers use epoxy in some stage of construction. MIL-M-38510 states: "No organic or polymeric materials shall be used inside the microcircuit package. . .unless otherwise specified." The supplier should not assume that his epoxy will be approved. The customer should state in his detail specification which epoxies can be accepted, and the supplier must state in his quotation what epoxy he proposes to use.

Paragraph 3.7.1 (Rework Restrictions) of MIL-M-38510 is frequently overlooked. A manufacturer rarely imposes MIL-M-38510 rework restrictions on his standard product line. Although most manufacturers will not experience a serious cost impact from the minor yield loss caused by such restrictions, the labor required to keep track of all the rework on unserialized and unsealed circuits can be substantial. This area should be addressed in some detail with the manufacturer before the specification is written.

Documentation helps maintain and insure reliability, but it can also create unnecessary additional costs if it isn't

Stabilization bake
- A redistribution process for impurity atoms, following assembly and seal.
- Believed to be most effective when followed by thermal shock and burn-in.
- A low-cost screen.

Temperature cycle/thermal shock
- Temperature cycling allows for an ambient dwell period between extremes; thermal shock has no dwell period and induces higher stress.
- Intended to produce stress due to differences in thermal expansion of the materials in the assembly.
- Exercise solder joints, welds, bonds and package seals. Also test adhesive quality of interface between trace and dielectric material on microstrip/stripline designs.
- A low-cost screen.

Constant acceleration
- Hybrid screen to detect weak bonds, poor component mountings, and poor substrate attach.
- A moderate-cost screen.

Hermeticity
- For gross leak, a fluorocarbon immersion technique is used (1×10^{-5} atm cc/sec). For a fine leak, a helium tracer gas is detected with a mass spectrometer (1×10^{-8} atm cc/sec. typical).
- Both tests performed on hermetic designs to screen hardware which could have moisture or other package contaminants.
- A moderate-cost screen.

PIND testing (particle impact noise detection)
- Vibration of the packaging while monitoring both visually (oscilloscope) and audibly for loose particles inside the package.
- Sensitivity standards for particle size yet undefined in the industry and test results are frequently nonrepeatable and ambiguous.
- Detection of both conductive and nonconductive particles causes many reliable devices to be rejected.
- Discussion with the vendor recommended to determine program impact.
- A very expensive screen.

Mechanical shock
- Performed to demonstrate mechanical integrity and to verify design in worst-case handling conditions.
- Typically specified as a qualification test or sample test; may be considered a destructive test.
- An expensive screen.

High frequency vibration
- Demonstrates mechanical integrity; verifies ability of a design to withstand vibration levels encountered in aircraft, missiles, and tanks.
- Typically specified as a qualification test or sample test; may be considered a destructive test.
- A very expensive screen.

Random vibration (unmonitored)
- For lumped element and microstrip/stripline designs; very effective in locating weak solder joints and poor epoxy bonds.
- Specified in lieu of acceleration for lumped element and microstrip/stripline designs.
- A moderate-cost screen.

Burn-in
- Stresses the semiconductors, indicates parameter stabilization, and identifies marginal metallization defects and potential oxide shorts.
- Marginal units and infant mortalities detected in the electrical test following burn-in.
- A moderate-cost screen.

Radiographic inspection (X-ray)
- One radiograph taken and inspected for particles or contaminants (greater than a predefined diameter) and for cracked or broken connections and components.
- Radiographs verify adequate coverage of solder for chip and substrate attach.
- Either the vendor's certified inspector should perform the review or assist an inspector certified by the procuring agency.
- Value of test depends upon design, package, and seal techniques. (X-ray is often a cost driver due to subjectivity of the inspection, reduction in manufacturing yields and, therefore, higher unit costs.)
- Program impact and details of accept/reject criteria should be discussed with vendor.
- An expensive screen.

Table 4. Standard screening tests and their purposes.

properly utilized and interpreted. More than $100,000 can be added to the average hybrid manufacturer's documentation system if MIL-M-38510 is directly and literally applied, because it is of such a general nature. Nevertheless, some hybrid customers consistently apply the full interpretation of MIL-M-38510 to contracts. In many cases, a customer only intends to use Appendix A (defines documentation requirements), which is a good general guideline. In such cases, the specifications should state that the supplier's documentation should meet the general intent of Appendix A and "shall be subject to review and approval." That simple statement can save money, problems, and rebid cycles.

Qualification

Qualification (also called "first-article testing") requires a set of sample environmental tests, many of which are destructive, that establish the reliability of a design. Qualification of a product type can be accomplished in any of the following ways:

- A vendor can perform qualification testing before or during the delivery of the first product hardware.
- The procuring organization can perform qualification of the first production hardware before and/or after it is in the system.
- If qualification testing has been previously performed on the same or a

similar design, the vendor can provide the procuring activity with a duplicate of or access to the data and history (qualification by similarity).

Qualification by similarity (which is specifically allowed by MIL-STD-883) represents the most cost- and schedule-effective approach to verifying mechanical and electrical integrity.

If new testing is definitely needed, sample sizes should be carefully discussed with the vendor, since hybrids can be two orders of magnitude more expensive than the monolithic ICs for which most of the traditional sample sizes have been established.

Nondestructive testing levels should be selected carefully and modified to be consistent with, and not to exceed, those chosen for 100-percent production acceptance screening. The specific tests performed in sample lot acceptance testing or quality conformance inspection can be similar, or even identical, to those performed in qualification. However, qualification is intended to verify a design, whereas sample lot acceptance testing identifies lot-oriented flaws resulting from production processes and materials.

Because of normal schedule constraints, hybrid production quality conformance inspection almost always serves to satisfy qualification requirements if qualification by similarity is unacceptable. Qualification and/or quality conformance inspection for amplifiers and mixer hybrids is performed according to MIL-STD-883, Method 5008, Groups A through D.

Group A, electrical testing, which frequently duplicates and occurs concurrently with final production electrical testing, is customized for the particular device and application. Groups B, C, and D are generally performed without major modification to the MIL-STD. Frequently, tests can be omitted to reduce costs; these should be discussed with the manufacturer before specifying. Included in the tests that may be omitted are PIND testing (Method 2020), internal water-vapor content (Method 1018), and salt atmosphere testing (Method 1009).

Specifying Hi-rel Mixers

Because of the variety of military/OEM (original equipment manufacturer) systems applications which employ RF and microwave mixers, a great demand has developed for high-reliability programs of vastly varying scope. Several approaches may be selected for hi-rel RF and microwave mixer programs for the military/OEM market:

- "Off-the-shelf" catalog products can be screened to customer requirements ("screened standard").
- A catalog design can be specified with hi-rel manufacturing controls (including assembly by certified personnel) and screening.
- A custom design can be specified with hi-rel manufacturing controls and screening.
- Mixers can be specified according to MIL-M-28837.

The first, screened-standard option offers quickest delivery at the lowest cost. In many cases, the catalog model may be a stock item and only lead time (generally, the length of time from when an item is ordered to the time that it is shipped) for the specified environmental screening and/or selected electrical testing will be required. Costs of the screened-standard option consist of the catalog model unit price, plus the yield factor (associated with the screening or the electrical selection) and a lot charge determined by the magnitude of the screening program. Lot charges can range from $2,000 to $5,000 and are often amortized over the quantity of units in a screening lot. Deliveries of screened catalog items can range from four weeks (if the item is in stock) to nine weeks.

A hi-rel program utilizing a catalog design, the second program option, offers the customer a wide range of flexibility. If a reliability-proven catalog design can be used, all other aspects of the program can be tailored to the needs of the customer. A hi-rel specialist can recommend the most effective screening options, and a program can be proposed to meet the cost, delivery, and performance guidelines specified. In some cases, trade-offs on specified performance versus cost and delivery are considered, and a unique program is defined to meet critical requirements.

The magnitude of the hi-rel program, including cost and delivery, is determined by any or all of the following factors:

- Utilization of screened internal components.
- Hi-rel assembly by certified assemblers at laminar flow benches (work benches with a filtered air system) in a controlled area.
- Hi-rel documentation (i.e., acceptance and qualification test documents, assembly procedure, electrical test procedure, screened internal component, etc.).
- Design reviews.
- Customer and government source inspections.
- Acceptance testing.
- Qualification testing.

Specifying screened internal components has a major impact on cost and delivery. For example, hi-rel diode quads which are used in many mixers, can range from $75 to $175 in small quantities, and require lead times from 12 to 20 weeks. Recently, lead times on "special" order or hi-rel SMA connectors have become extremely high, requiring up to 30 weeks. If screened internal components are required, delivery of the mixers can range from 24 to 30 weeks after completion of acceptance testing (excluding "special" connector procurements).

If a customer requires mechanical and/or electrical characteristics which cannot be satisfied by a catalog design, a custom design (the third program option) can be proposed. This option is constrained by the high cost and long lead time associated with new designs and prototype tooling and machining. A risk factor is also involved with qualifying a new design. A custom design can require 6 to 12 months for first-article delivery, and nonrecurring engineering (NRE — a one-time design cost) charges can run $15,000 to $30,000 or more. Any or all hi-rel options of a preestablished design are also available with a custom design.

The MIL-M-28837 mixer specification has fostered the fourth program option. Since the military system designer must use MIL standard parts when available, a military specification to govern the design and performance characteristics of RF and microwave mixers has been needed. With the availability of MIL-M-28837 (which includes addendums or "slash sheets" to detail the mechanical and electrical characteristics for each previously-provided mixer), the system designer can specify any existing component and be assured that a nonstandard parts request will not be required.

Unfortunately, MIL-M-28837 is very new and the Defense Electronics Supply Center (DESC), which governs vendor qualifications, has only recently authorized manufacturers to begin qualification of various slash-sheet products. Therefore, *no vendor* currently has mixers qualified under MIL-M-28837.

Although qualified "off-the-shelf" devices are not yet available, a customer can specify: "The subject mixer shall be capable of meeting the requirements of MIL-M-28837." A nonstandard parts request must continue to be submitted to the military for any mixer not qualified to an existing slash sheet or having its own slash sheet.

In summary, MIL-M-28837 will provide end users and manufacturers with the following advantages:

- An option to procure qualified parts without nonstandard parts request — saving time, dollars and effort.
- Eventual "off-the-shelf" availability of MIL-M-28837 qualified screened or unscreened mixers.
- An industry standard for mixers allowing specification uniformity.
- Lower costs due to higher volume of standard units and deletion of qualification testing.
- "Plug-in" replacement availability from all qualified vendors.
- Elimination of "special" procurement documentation and associated cost.

Mixer Design Technologies

The three mixer design technologies now available in industry vary in frequency capabilities. In some cases the technologies can be interchanged to produce performance as well as reliability advantages, but the recommended screening for each will remain quite different. The most effective screening program is not only determined by the system environment, but also by the design technology used.

Lumped element mixers with toroidal transformers are applied at frequencies below 3 GHz (see Figure 7). One or two monolithic diode ring quads (hermetic or epoxy encapsulated) are combined with discrete resistors, capacitors, and diodes. This type of mixer is constructed in a variety of packages with highly adhesive, low-outgassing epoxies, and has bi-, tri-, or quadfilar wired assemblies. MIL-STD-202 screening is most applicable to this technology.

Microstrip and stripline mixers find application between 3 and 18.5 GHz (see Figure 8). The low-loss, printed transmission lines offer consistent cir-

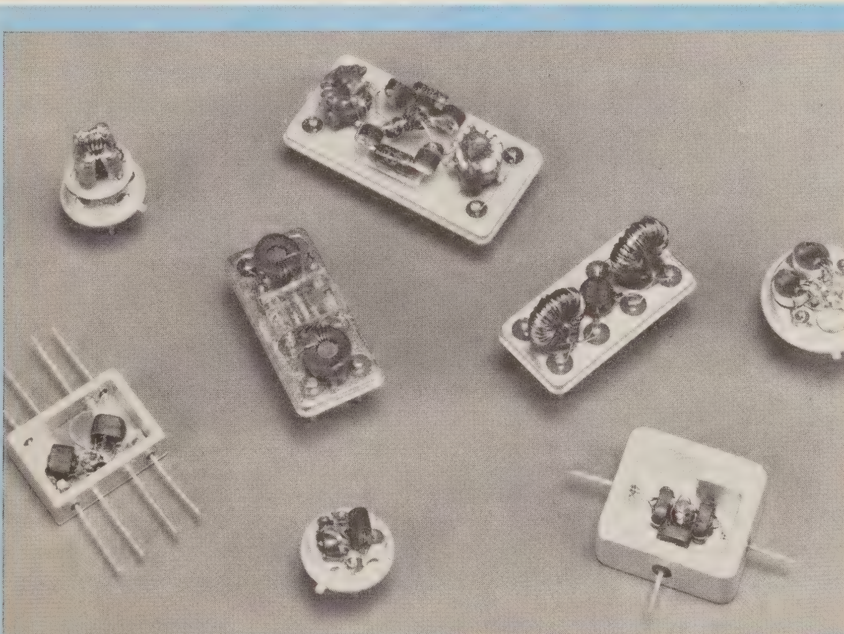


Figure 7. Lumped element mixers with toroidal transformers are applied at frequencies below 3 GHz.

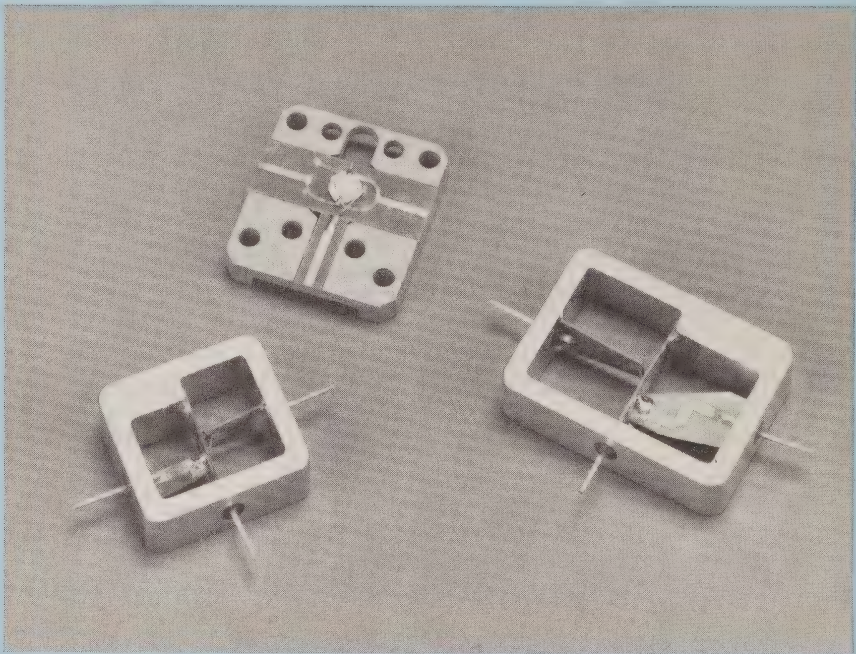


Figure 8. Microstrip and stripline mixers find application between 3 and 18.5 GHz.

cuit repeatability. One or two monolithic diode quads are used, each in epoxy-encapsulated or hermetically sealed ceramic packages. Since this construction uses fewer components and solder connections, it produces higher MTBF than lumped element designs. Highly adhesive, low outgassing epoxies are used in the microstrip/stripline as well as the coaxial packages. MIL-STD-202 is also appropriate for screening these mixers.

Thin-film technology produces mixers for use between 10 MHz and 18.5 GHz with the lowest loss characteristics and the highest circuit repeatability (see Figure 9). Below 3 GHz, designs usually include a ceramic (alumina) substrate with printed tantalum nitride resistors, chip capacitors and diodes, and toroidal coupling. Such mixers use solder reflow or gold epoxy for component attachment, and TO-8 or flatpack hermetic packaging.

At higher frequencies, alumina (3 to 18.5 GHz) and quartz (above 8 GHz) substrates are used and are brazed to a gold-plated carrier assembly. Beam lead diodes and capacitors predominate and are attached through thermocompression. The carrier assembly is normally housed in a nonhermetic coaxial housing with SMA connectors. Of the three technologies, thin film requires the highest investment and the longest lead times. It is covered by MIL-STD-833.

Because of the significant differences in mixer design technologies, one screening program can't suffice for all devices. With the exception of thin-film mixers, all other designs adapt directly to MIL-STD-202 ("Test methods and procedures for microelectronics"). The earlier screening discussion for thin-film hybrid products applies to thin-film mixers as well.

In addition to improperly specifying MIL-STD-883 for lumped element and microstrip/stripline mixers, there are several other misconceptions concerning high reliability screening for mixers.

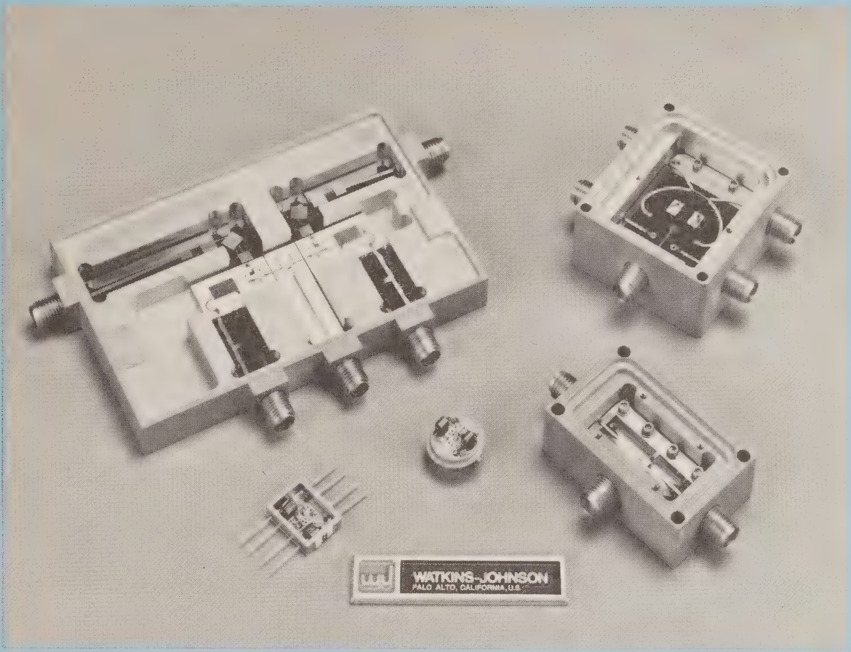


Figure 9. Thin-film technology produces mixers for use between 10 MHz and 18.5 GHz.

Time and money can be saved by adhering to the following suggestions:

- Don't specify hermeticity, humidity, and salt spray tests on non-hermetic packages.
- Don't specify fine-leak hermeticity testing on packages with coaxial (SMA) connectors. (There are solutions to this problem; discuss this with the vendor before specifying.)
- Recognize that utilization of connectors greatly reduces MTBF.
- Realize that most mixer designs are not repairable. (Discuss this matter with the vendor before specifying repair clauses.)
- Don't specify burn-in with an RF source due to the cost impact of commiting expensive test equipment. (A burn-in requirement can be easily satisfied by injecting a 60-Hz signal into the I port of the mixer. While the diodes are repeatedly switched on and off, the junction is heated to the maximum recommended temperature.)
- Don't specify large samples for "destructive" testing. A typical sample of two units serves to verify design integrity while minimizing costs.
- Don't specify operating temperatures above 100°C. (Most mixer designs carry a 100°C maximum operating temperature with maximum storage temperatures to 125°C. However, for ease of specification, a 100°C maximum for storage and operating is common.)
- Don't specify acceleration tests for the lumped element or microstrip/stripline technologies unless truly applicable. (In most cases, vibration is a much more effective and applicable screen.)

Mixer Tests Undefined

No military test specification exists which clearly defines qualification and acceptance tests for lumped element and microstrip/stripline mixers. Although MIL-STD-202 delineates many screening tests applicable to mixers, this specification was not prepared specifically with mixers in mind. Consequently, numerous discrepancies are created when only test conditions guide general specifications, they must be modified for different designs and environments.

As stated earlier, qualification testing is performed specifically to demonstrate design integrity, while acceptance testing (Group A) demonstrates lot integrity. If specified, temperature (Group B) and mechanical (Group C) tests are performed for proving lot acceptability.

Qualification tests can cost from $5,000 to $10,000 and involve lead times from 10 to 15 weeks. The costs of acceptance testing (through Group A) typically ranges from $3,000 to $6,000, with the magnitude of the electrical test program determining the higher cost. Delivery upon completion of Group A testing requires five to seven weeks after completion of assembly, pre-seal visual inspection, electrical testing, and seal. Group B and Group C testing can add $4,000 to $6,000 to the cost, depending on the extent of the electrical and mechanical screening, and requires another five weeks following completion of Group A.

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Mr. Cheadle has been responsible for the design and development of over fifty thin-film cascadable amplifier models, many of which are performance leaders in the field. As a result of thin-film experience, he designed several TO-8 mixers, including the M9G, M9H and M2E. The M9G and M9H were the first Class III mixers to exceed 500 MHz, and the M2E was the first mixer to offer +20 dBm input level that exceeded 500 MHz that was commercially available. As part of the cascadable amplifier development activity, he wrote a computer program that is uniquely tailored for multi-octave cascadable amplifier analysis.

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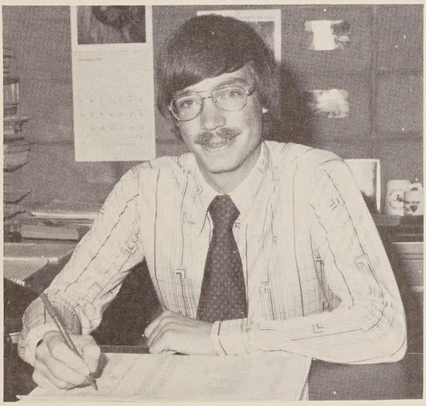

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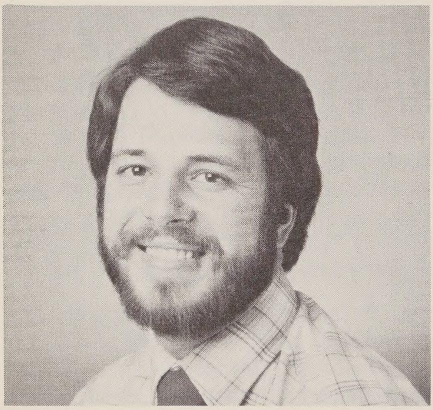

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