National Semiconductor

Appendix C
Summary of Commercial Reliability Programs

General

National Semiconductor Commercial Reliability Programs provide a broad range of off-the-shelf enhanced semiconductor products that supply an extra measure of quality and reliability needed in high-stress or difficult to service applications.

National's A+ and B+ programs allow each individual customer to:

- Minimize the need for incoming electrical inspection
- Eliminate the need and associated costs of using independent testing laboratories
- Reduction in infant mortality rate
- Reduction in reworked board costs
- Reduction in warranty and service costs

A+ Product Enhancement

The A+ Product Enhancement incorporates the benefits of the Multiple-Pass and Elevated Temperature along with "BURN-IN."

The A+ Program provides:

- 100% Temperature Cycling
- 100% Electrical Testing at Room and High Temperature
- 100% Burn-In Testing Combining Increased Temperature with Applied Voltage
- Acceptable Quality Levels Greater than Industry Norm

Typical A+ Flow is:

- SEM
- Assembly and Seal
- Four Hour 150°C Bake
- Five Temperature Cycles (0°C to +100°C)
- High Temperature Electrical Test
- Electrical Test
- Burn-In (160 hours at a minimum junction temperature of 125°C)
- DC Parametric and Function Tests
- Tightened Quality Control Inspection Plans

Note: Certain products may follow slightly different process flows dictated by specific capabilities and device characteristics, consult NSC.

P+ Product Enhancement

The P+ product enhancement program applies to power devices and offers an added advantage. P+ involves dynamic tests that screen out assembly related and silicon defects that can lead to infant mortality and/or reduce the survivability of the device under high stress conditions. This includes but is not limited to the following devices:

Appendices/Physical Dimensions

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For additional information on Linear Products, see National Semiconductor's Linear Applications Handbook.

I. RELIABILITY vs. QUALITY

The words "reliability" and "quality" are often used interchangeably, as though they connoted identical facets of a product's merit. But reliability and quality are different, and IC users must understand the essential difference between the two concepts in order to properly evaluate which of National's extended screening programs, A+ or B+ will offer the most cost effective product improvement for his application.

QUALITY

The concept of QUALITY gives us information about the population of faulty IC devices among good devices, and generally relates to the number of faulty devices that arrive at a user's plant. Looked at in another way, quality then relates to the number of faulty IC's that escape detection at the IC vendor's plant.

At National, it is the charter of the Quality Control (QC) Operation to continually monitor and reduce the number of faulty IC's that escape detection. QC does this by testing the outgoing parts on an Acceptance Quality Level (AQL) basis.[1] The tighter the AQL testing, the more difficult it becomes for a defective part to escape detection, thus the quality of the shipped product increases.

RELIABILITY

The concept of RELIABILITY, on the other hand, refers to how well a part that is initially good will withstand its environment. *Reliability cannot be tested into a device.* Reliability is principally a function of device design, die size, power dissipation, assembly methods and material, etc. Still there are tests and procedures that an IC vendor can implement which will subject the IC to stress in excess of what it will endure in actual use, which will eliminate marginal, short-life parts.

On this basis, it is easily seen that it is possible that high quality IC's may, in fact, have low reliability, while low quality IC's may have high reliability. The object of extended screening programs is: (1) to enhance the quality by reducing the population of faulty devices among good devices and by so doing, eliminate the costly requirement of incoming tests by the user, and (2) provide maximum long term reliability minimizing equipment down-time, costly repairs and maintenance.

II. QUALITY SAVES YOU MONEY

When an IC vendor specifies 100% final testing of his parts then, in theory, every shipped part should be a good part. However, in any population of mass-produced items there does exist a small percentage of defective parts.

One of the best ways to reduce the number of such faulty parts is, simply, to retest the parts prior to shipment. Thus, if there is a one percent chance that a bad part will escape detection initially, retesting the parts reduces that probability to only 0.01 percent. This is exactly what tightening of the outgoing AQL level achieves.

WHAT IS AQL?

A good example of savings which can be achieved by taking advantage of tighter AQL[(1)] inspection levels is illustrated as follows:

> Assume a system uses 100 devices of a certain type which are procurred to a 1% AQL level, and no incoming inspection/testing is done by the user. Statistically it can be shown that the number of systems that will require rework will be 80% of all systems manufactured! If enough devices are purchased to manufacture 100 systems (10,000 devices) and the cost to trouble shoot and repair each system is $30.00, the total cost of repair will be $2,400 (80% of 100 systems at $30.00 each).

Thus, the need for some preliminary component screening prior to system assembly becomes obvious.

However, if the same devices are procurred to a 0.14% AQL level, which is seven times tighter than originally assumed, it can be shown that the number of systems requiring rework is reduced by a factor of four, *without the need for incoming inspection.*

Thus, on a 100 system basis, 20 systems will require repair at $30.00 per system, or a total of $600.00. A savings of $1,800 is realized, and the user need not invest in expensive capital equipment, procedures, and paper work.

On a "savings per device" basis, this is a savings of 18¢ per device. Indeed, *Quality saves you money!*

This is the value added by the A+ and B+ Linear programs.

III. RELIABILITY SAVES YOU MONEY

With the increased population of integrated circuits in modern electronics systems has come an increased concern with IC failures. And rightly so, for at least two major reasons. First, the effect of component reliability on system reliability can be quite dramatic. For example, suppose that you, as a system manufacturer, were to choose an IC that is 99% reliable. You would find that if your system used only 70 such IC's the overall reliablility of the system's IC portion would be only 50%.

In other words, one out of every two systems in the field would fail. The result? A system that is very costly to produce, costly to maintain, and probably very difficult to sell.

Second, whether the system is large or small you cannot afford unnecessary maintenance costs. Not only have labor, repair and rework costs risen – and promise to continue to rise – but also, field replacement may be prohibitively expensive or impossible. If you ship a system that contains a marginally performing IC, and that IC later fails in the field, the cost of repair and replacement may be literally hundreds of times more than the cost of the failed IC itself.

(1) AQL testing is not to be confused with "in process" or electrical parameter testing in the normal product flow. All National products are 100% tested for electrical data sheet parameters.

IV. IMPROVING THE RELIABILITY OF SHIPPED PARTS

As was previously mentioned, reliability, in the true sense cannot be tested into a product. The most important factors that affect reliability are design, construction, materials and the assembly method. However, many of these can be examined and monitored by testing. As a matter of routine, National frequently performs 1000 hour burn-in life test and accelerated life tests to continually guarantee the quality and reliability of the linear product which is being shipped to customers. For example, the quality of the die attach for voltage regulators can be monitored by observing the thermal characteristics associated with "pulse loading" the regulator. This is a technique which National Linear pioneered over 10 years ago and still performs on a 100% basis on three terminal regulators at no additional cost to the user. Many such tests, including destructive and non-destructive wire bond pull tests are a matter of routine with National.

Further, in any test of reliability, the weaker parts will fail first. Stress tests will accelerate, or shorten the time of failure of the weak parts. Because the stress test causes weak parts to fail prior to shipment, the population of shipped parts will in fact demonstrate a higher reliability.

One of, if not the most effective screening procedures in the Semiconductor industry, is the use of a burn-in to stress and accelerate the failure of weak parts.

Thus, burn-in screen plus the tightened AQL outgoing testing, is the key to the A+ Linear Program.

QUALITY AND RELIABILITY PROGRAMS FOR MOLDED LINEAR PRODUCTS

One concern, with regard to quality and reliability in molded plastic products, is the problem of thermal intermittents. This problem first came to light in 1970 and plagued all semiconductor manufacturers. Since that time considerable efforts have been focused on improving lead bonding and lead frames to make them stronger and more reliable as well as improvements in the package molding material itself.

To better understand the problems a brief discussion of thermal intermittents is in order.

Because wires and bonds are completely imbedded in plastic, molded integrated circuits are extremely rugged devices. They can survive mechanical shock and vibration conditions which would literally tear the bonds and wires to pieces in a cavity type package. However, the non-cavity construction does present a unique problem. Sould a bond fracture or a wire break for some reason, the broken bond will remain in contact as long as the surrounding encapsulant continues to exert a compressive force on the bond. However, as the temperature increases, the compressive forces tend to relax due to the thermal mismatches between the lead frame, die, wires and the plastic.

Ultimately, if a high enough temperature is reached, the broken bond will separate, causing an electrical discontinuity. The phenomenon is frequently reversible, that is, as temperature decreases, electrical continuity is restored. This type of discontinuity is commonly referred to as a THERMAL INTERMITTENT OPEN. If electrical continuity does not return when the package temperature returns to ambient, then a permanent open has occurred.

If such defects occur during the manufacturing cycle of the device, and are not screened out by the manufacturer's testing sequence or by some screening test imposed by the user, they will show up as infant mortality failures in the user's equipment. If they occur during the user's equipment manufacturing cycle (due to solder heat exposure, for example) they will also show up as infant mortality failure.

The best way to screen for this phenomenon is to perform temperature cycling and "Hot Rail" testing after the device has been manufactured. The temperature cycling will stress the package mechanically to force the intermittent to occur if such a failure exists. The "Hot Rail" testing is performed to determine the functionality of the device at 100°C to ensure there are no open bonds at the worst case condition.

NATIONAL'S B+ LINEAR PROGRAM GETS IT ALL TOGETHER

We have stated that the B+ program improves both the quality and reliability of National's molded integrated circuits, and pointed out the difference between those two concepts. Now, how do we bring them together? The answer is in the B+ program processing, which is a continuum of stress and double testing. With the exception of the final QC inspection, which is a tightened sample program, *all steps of the B+ process are performed on 100% of the parts.* The following flow chart shows how we do it, step by step.

EPOXY B PROCESSING FOR ALL MOLDED PARTS –
At National, all molded semiconductors, including IC's have been built by this process for some time. All processing steps, inspections and QC monitoring are designed to provide highly reliable products. (Reliability reports are available that give, in detail, the background of Epoxy B, the reason for its selection at National and reliability data that proves its success.)

SIX HOUR, 150°C BAKE –
This stress places the die bond and all wire bonds into a combined tensile and shear stress mode, and helps eliminate marginal bonds and electrical connections.

FIVE TEMPERATURE CYCLES (0°C to 100°C)
Exercising the circuits over a 100°C temperature range further stresses the bonds and eliminates marginal bonds missed during the bake.

ELECTRICAL TESTING
These room-temperature functional and parametric tests are the normal final tests through which all National products pass.

HIGH TEMPERATURE (100°C) FUNCTIONAL ELECTRICAL TEST –
A high temperature test such as this with voltages applied places the die under the most severe stress possible. The test is actually performed at 100°C – 30°C higher than the commercial ambient limit. *All devices are thoroughly exercised at the 100°C ambient.* (Even though Epoxy B processing has virtually eliminated thermal intermittents, we perform this test to ensure against even the remote possibility of such a problem.)

100% DC FUNCTIONAL AND PARAMETRIC TESTS –
This is the second time that room-temperature functional and parametric tests are performed to National data sheet electrical limits.

TIGHTER-THAN-NORMAL QC INSPECTION PLANS –
Most vendors sample inspect outgoing parts to a 0.65% (or in some cases a 1%) AQL. When you specify the B+ program, however, not only do we sample your parts to a 0.28% AQL for all data sheet dc parameters, but they receive a 0.14% AQL for functionality as well. (Functional failures – not parameter shifts – cause most system failures.) Thus, the five to seven-times tightening of the AQL procedure gives a substantially higher quality to your B+ parts. And you can rely on the integrity of your received IC's without incoming tests at your facility.

SHIP PARTS

Here are the QC Procedures used in our B+ test program:

TEST	TEMPERATURE	AQL
Electrical Functionality	25°C	0.14%
Parametric, dc	25°C	0.28%
Major Mechanical	25°C	0.25%
Minor Mechanical	25°C	1%

NATIONAL'S A+ LINEAR PROGRAM – THE ULTIMATE IN QUALITY AND RELIABILITY

National has combined the successful B+ program with the Military/Aerospace processing specifications and provides the A+ program as the best cost-effective approach to maximum quality and reliability on molded devices. The following flow chart shows how we do it step by step. *The major difference between B+ and the A+ is the burn-in associated with the A+ program.*

SEM –
Randomly selected wafers are taken from production regularly and subjected to SEM analysis.

EPOXY B SEAL –
At National, all molded semiconductors, including IC's have been built by this process for some time. All processing steps, inspections and QC monitoring are designed to provide highly reliable products.

SIX HOUR, 150°C BAKE –
This stress places the die bond and all wire bonds into a combined tensile and shear stress mode, and helps eliminate marginal bonds and electrical connections.

FIVE TEMPERATURE CYCLES (0°C to 100°C) –
Exercising the circuits over 100°C temperature range further stresses the bonds and eliminates any marginal bonds missed during the bake.

ELECTRICAL TESTING –
These room-temperature functional and parametric tests are the normal final tests through which all National products pass.

BURN-IN TEST –
Devices are stressed at maximum operating conditions to eliminate marginal devices. Test is performed per MIL-STD-883A, Method 1015.1.

HIGH TEMPERATURE (100°C) FUNCTIONAL ELECTRICAL TEST –
A high temperature test with voltages applied places the die under the most severe stress possible. The test is actually performed at 100°C – 30°C higher than the commercial ambient limit. *All devices are thoroughly exercised at the 100°C ambient.*

100% DC FUNCTIONAL AND PARAMETRIC TESTS –
This is the second time that room-temperature functional and parametric tests are performed to National data sheet electrical limits.

TIGHTER-THAN-NORMAL QC INSPECTION PLANS –
Most vendors sample inspect outgoing parts to a 0.65% (or in some cases a 1%) AQL. When you specify the A+ program, however, not only do we sample your parts to a 0.28% AQL for all data sheet dc parameters, but they receive 0.14% AQL for functionality as well. (Functional failures – not parameter shifts beyond spec – cause most system failures.) Thus, the five- to seven-times tightening of the sampling AQL procedure gives a substantially higher quality to your A+ parts. And you can rely on the integrity of your received IC's without incoming tests at your facility.

SHIP PARTS

Here is the QC procedure used in our A+ test program:

TEST	TEMPERATURE	AQL*
Electrical Functionality	25°C	0.14%
Parametric, dc	25°C	0.28%
Major Mechanical	25°C	0.25%
Minor Mechanical	25°C	1%

* Note: New AQL's will be in effect June '82. Consult your local Sales Office.

QUALITY AND RELIABILITY PROGRAM FOR HERMETIC PACKAGED LINEAR PRODUCT

An improved quality and reliability program, similar to that which is available for molded products, is also available for commercial temperature range hermetic packages.

There is one major difference between the molded A+ program and the hermetic package A+ program. Since there is no material in contact with the wire bonds in a hermetic package, the need for "Hot Rail" functional testing at 100°C is of no benefit and therefore not included. The devices are electrically tested (100%), then burned-in and then 100% electrically tested again. If a bond failure were to occur during burn-in, there is no material in contact with the bond (such as plastic in the case of molded products) that would tend to restore the bond when the device cooled. The result is that a weak bonding wire, once broken causing an "open" will remain open and be caught at the second 100% electrical screening.

The A+ hermetic package program flow chart is shown below.

NATIONAL'S A+ PROGRAM FLOW CHART FOR HERMETIC PACKAGES

National has extended the successful B+ and A+ molded product programs to hermetic packages. We believe this to be the best practical approach to maximum quality and reliability for commercial devices. The following flow chart explains this program step by step.

SEM –
Randomly selected wafers are taken from production regularly and subjected to SEM analysis.

ASSEMBLY AND SEAL –
All processing steps, inspections, and QC monitoring are designed to provide highly reliable products. MIL-STD-883 is the guideline by which all linear products are manufactured.

SIX HOUR, 150°C BAKE –
This stress places the die bond and all wire bonds into a combined tensile and shear stress mode, and helps eliminate marginal bonds and electrical connections.

FIVE TEMPERATURE CYCLES (0°C to 100°C) –
Exercising the circuits over 100°C temperature range further stresses the bonds and eliminates any marginal bonds missed during the bake.

ELECTRICAL TESTING –
Every device will be 100% tested at 25°C for functional and dc parameters.

BURN-IN –
Devices are stressed at maximum operating conditions to eliminate marginal devices. Test is performed per MIL-STD-883A method 1015.1.

DC FUNCTIONAL AND PARAMETRIC TESTS –
These room temperature functional and parametric tests are the normal, final tests through which all National products pass. This is the second time 100% electrical testing is performed.

TIGHTER-THAN-NORMAL QC INSPECTION PLANS –
Most vendors sample inspect outgoing parts to a 0.65% (or in some cases a 1%) AQL. When you specify the A+ program, however, not only do we sample your parts to a 0.28% AQL for all data sheet dc parameters, but they receive 0.14% AQL for functionality as well. (Functional failures – not parameter shifts beyond spec – cause most system failures.) Thus, the five- to seven-times tightening of the sampling procedure gives the highest quality to your A+ parts. And you can rely on the integrity of your received IC's without incoming tests at your facility.

SHIP PARTS

Here are the QC Sampling plans used in our A+ test program:

TEST	TEMPERATURE	AQL*
Electrical Functionality	25°C	0.14%
Parametric, dc	25°C	0.28%
Major Mechanical	25°C	0.25%
Minor Mechanical	25°C	1%

* Note: New AQL's will be in effect June '82. Consult your local Sales Office.

PROCESS FLOW	MOLDED N PACKAGE		HERMETIC H AND J PACKAGE
DESCRIPTION	A+	B+	A+
100% High Temperature Storage – 6 Hours @ 150°C	X	X	X
100% Temperature Cycling, 5 Cycles – 0° to 100°C	X	X	X
100% Burn-in per MIL-STD-883A, Method 1015.1	X		X
100% High Temperature Test for Functionality at 100%	X	X	
100% DC Functional parametric Tests at Room Temperature	X	X	X
Tightened QC Inspection Plan	X	X	X

Q.C. SAMPLE PLAN

TEST	TEMPERATURE	AQL
Electrical Functionality	25°C	0.14%
Parametric, dc	25°C	0.28%
Major Mechanical	25°C	0.25%
Minor Mechanical	25°C	1%

A synopsis of the A+ and B+ programs is shown on the preceding page. Also shown below is a listing of some of the most popular devices which are processed to this program and are readily available.

For more information about this, or other National Linear programs, please contact your local representative.

LF13331	LM1458	LM307	LM324	LM3900	LM723C
LF13741	LM1496	LM308	LM3301	LM393	LM725C
LF347	LM2900	LM3080	LM3302	LM4250C	LM733
LF351	LM2901	LM310	LM339	LM555C	LM741C
LF353	LM2902	LM311	LM3401	LM556	LM747C
LF355	LM2903	LM318	LM346	LM566	LM748C
LF356	LM2904	LM319	LM348	LM567	
LF357	LM301A		LM358	LM709C	
			LM360		
			LM361		

SUMMARY

The B+ program, although offering improved Reliability attendent with additional stress testing, is primarily aimed at enhancing the quality of incoming devices and thus eliminating the need for incoming testing by the user. This program offers significant cost savings to the user and eliminates the need for the investment in expensive capital equipment to perform this testing. For all general, but relatively non-critical circuits, the B+ program is the most cost-effective.

The A+ program incorporates not only the quality inherent with B+ program, but also adds burn-in for the ultimate in Reliability testing. The A+ program is recommended as the most cost-effective program for components which the user deems to be the most critical in his system.

Both programs, A+ and B+, incorporate high temperature stress, double testing, and very tight out-going AQL QC proceedures.

ORDER INFORMATION

Any of the devices listed molded or hermetic package, may be ordered to the A+ program simply by adding the term A+ behind the device number, with a slash (/) in between.

Examples:

LM348N/A+

LF356H/A+

LM1458J/A+

Likewise, any molded (N package) product may be ordered to the B+ program by adding the term B+ behind the device number.

Examples:

LF351N/B+

LM741CN/B+

For devices not listed, contact your local National Semiconductor Sales office for information on availability and ordering information.

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MIL-STD-883

Mil-Standard-883 is a Test Methods and Procedures Document for Microelectronic Circuits. It was derived from MIL-S-19500, MIL-STD-750, and MIL-STD-202C for transistors and diodes at about the time that National Semiconductor Corporation was entering the military microelectronics market. As a result, our standard quality control operations are written around MIL-STD-883. The bonding control, visual inspections, and post seal screening requirements set forth by 883 (as well as added control procedures beyond the requirements of 883) have been part of National's quality control procedures almost from the start. Our Quality Assurance Procedures Manual is available upon request.

We offer a complete line of linear/883 (Class B) products as standard, off-the-shelf items. Special Linear/883 data sheets have been prepared to reflect this capability. They show process flow, electrical parameters, end of test criteria, and test circuits. We save you the problem of specifying test and inspection procedures, and offer significant cost savings by having an off-the-shelf, "to the letter" 883 program. In addition, we will test any of our integrated circuits to any class of MIL-STD-883.

MIL-M-38510

MIL-M-38510 specifies the general requirements for supplying microcircuits. These are; product assurance, which includes screening and quality conformance inspection; design and construction; marking; and workmanship. The screening and quality conformance inspection are conducted in accordance with MIL-STD-883.

Screening

All microcircuits delivered in accordance with MIL-M-38510 must have been subjected to, and passed all the screening tests detailed in Method 5004 of MIL-STD-883 for the type of microcircuit and product assurance level.

The device electrical and package requirements of MIL-M-38510 are detailed by a device specification referred to as a slash sheet. Each slash sheet defines the microcircuit electrical performance and mechanical requirements. Each device listed on a slash sheet is referred to as a slash number and the group of the microcircuits contained on a slash sheet is defined as a family of devices. The device may be Class B or C as defined by MIL-STD-883, Method 5004 and 5005. Three lead finishes are allowed by the slash sheet, pot solder dip, bright tin plate, and gold plate.

The MIL-M-38510 specs for standard linear devices require 100% DC testing at 25°C, −55°C and +125°C. AC testing is performed at +25°C. The electrical parameters specified are tighter than the normal data sheet guaranteed limits. Additionally, MIL-M-38510 requires device traceability, extensive documentation and closely matched maintenance.

Quality Conformance

Quality conformance inspection is conducted in accordance with the applicable requirements of Group A, (electrical test), Group B and C, (environmental test) of Method 5005, MIL-STD-883. These tests are conducted on a sample basis with Group A performed on each sublot, Group B on each lot, and Group C as specified (usually every three months).

To supply devices to MIL-M-38510, the IC manufacturer must qualify the devices he plans to supply to the detail specifications. Qualification consists of notifying the qualifying activity of one's intent to qualify to MIL-M-38510. After passing comprehensive audits of facilities and documentation systems, the IC manufacturer will subject the device to and demonstrate that they satisfy all of the Group A, B, and C requirements of Method 5005 of MIL-STD-883 for the specified classes and types of IC. The qualification tests shall be monitored by the qualifying agency. Finally the IC manufacturer shall prepare and submit qualification test data to the qualifying agency. Groups A, B, and C inspections then shall be performed at intervals no greater than three months.

The purpose of qualification testing is to assure that the device and lot quality conform to certain standard limits. In effect, lot qualification tests tend to ensure that once a particular device type is demonstrated to be acceptable, it's production, including materials, processing, and testing will continue to be acceptable. These limits are specified in MIL-STD-883 in terms of LTPD's (Lot Tolerance Percent Defective) for the various qualification test sub-groups. Qualification testing is performed on a sample of devices which are chosen at random from a lot of devices that has satisfactorily completed the screening of Method 5004 must be performed on each device, i.e. on a 100% basis as opposed to qualification testing (Method 5005) which occurs on a random sample basis.

In summary, the entire purpose of MIL-M-38510 and MIL-STD-883 is to provide the military, through its contractors with standard devices.

We at National Semiconductor have supplied and are supplying devices to the MIL-M-38510 specifications. To order a MIL-M-38510 microcircuit, specify the following:

For example; to specify an LM741 in a DIP processed to the requirements of MIL-M-38510, Class B, with gold plated leads, specify M-38510/10101BCC.

MM38510/	XXX	XX	X	X	X
Specifies the General Requirements of MIL-M-38510	Slash Sheet No.	Device Type	Device Class	Case Outline	Lead Finish