HOLT INC.
INTEGRATED CIRCUITS

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AN-400

Surface Mount Plastic Packages for High Reliability Applications Applications Note

Introduction

Holt Integrated Circuits specializes in the design and manufacture of components for military and aerospace applications. Traditionally the aerospace industry has specified the use of ceramic or hermetically sealed packages. There continues to be an increasing trend toward the use of Commercial-Off-The-Shelf (COTS) devices where the use of surface-mount plastic packages is being specified.

This applications note is intended to provide the potential user of plastic encapsulated ICs with an overview of the available technology, guidelines for the use of plastic parts, and a summary of Holt's rigorous qualification and screening procedures.

Plastic or Ceramic?

Ceramic IC packages have proven to be inherently reliable. The silicon die is housed in a controlled, hermetically sealed environment. Moisture is removed from the package during the assembly process, the top surface of the die is not in direct contact with other materials, and the differential coefficent of thermal expansion between the die and package is well matched. The thermal conductivity of ceramic packages is high compared to plastic, reducing die operating temperatures, and extending product life expectancy.

The military aerospace industry has developed comprehensive product qualification and screening procedures for ceramic parts which have been in place for many years (decades). A wealth of reliability data and failure mechanism knowledge exists for ceramic packaged parts, as well as volumes of field use reliability data.

However, ceramic packages have the disadvantages of higher cost, large footprints, and lower pin-count compared with plastic alternatives. The market for ceramic packaged ICs is shrinking, the supplier base is dwindling, and therefore the pace of technological advancement is much slower than in the main-stream commercial IC industry.

Plastic packaged ICs offer the advantages of low cost, extremely small size, and well controlled process as a result of high volume manufacturing.

By their very nature, plastic packages are non-hermetic. All plastic molding materials absorb moisture from the environment which can lead to corrosion of the exposed IC metalization at the bonding pads and eventual device failure.

Additionally, special precautions must be taken during storage and board assembly to avoid potentially catastrophic thermo-mechanical failure of the part during solder reflow.

For safety-critical, flight-critical, or mission-critical applications there is no substitute for ceramic parts. However, with careful design, system redundancy, qualified manufacturing processes, application of additional moisture barriers, and appropriate use environments, plastic packaged ICs show acceptable levels of reliability during life.

Holt Products

Holt Integrated Circuits is committed to providing its customers with the highest level of reliability for plastic encapsulated ICs. A wide range of package styles is available, as shown in Figure 1. Holt uses a small number of qualified assembly sub-contactors to provide its plastic packaging capability. The entire process flow and material usage is specified and tightly controlled and monitored to ensure product quality and consistency. Critical process monitors and statistical process control are employed throughout the assembly process. All facilities are ISO 9001 registered, and use manufacturing processes and test methods that follow industry or military standards.

Materials choice is key to producing high reliability plastic ICs. Holt works closely with its assembly subcontractors, as well as independent technical consultants to specify the use of the best possible materials for aerospace applications. All Holt plastic surface mount products use the latest molding compounds best suited for low stress and moisture resistance.

Holt has developed extensive experience in analyzing plastic package designs for improved moisture sensitivity and has adopted a goal of only introducing new products that can be cited as MSL1 (No special handling required).

		Dimensions			
Format	**Pins**	**Body**	**Height**	**Lead Pitch**	**Thickness**
SOIC	8	0.150” wide	0.064”	0.05”	0.58"
	14	0.150” wide	0.064”	0.05”	0.58"
	16	0.150” wide	0.064”	0.05”	0.58"
	18	0.300” wide	0.100”	0.05”	0.92"
	20	0.300” wide	0.100”	0.05”	0.92"
	24	0.300” wide	0.100”	0.05”	0.92"
	28	0.300” wide	0.100”	0.05”	0.92"
Thermally Enhanced SOIC	8	0.150” wide	0.064”	0.05”	0.58"
	14	0.150” wide	0.064”	0.05”	0.58”
	16	0.150” wide	0.064”	0.05”	0.58"
	20	0.300” wide	0.100”	0.05”	0.92"
PQFP	32	7 x 7 mm	1.5 mm	0.8 mm	1.4 mm
	44	10 x 10 mm	2.1 mm	0.8 mm	2.0 mm
	52	10 x 10 mm	2.1 mm	0.65 mm	2.0 mm
	64	7 x 7 mm	1.5 mm	0.4 mm	1.4 mm
	100	14 x 14 mm	1.5 mm	0.5 mm	1.4 mm
TQFP	32	7 x 7 mm	1.0 mm	0.8 mm	0.9 mm
	44	10 x 10 mm	1.4 mm	0.8 mm	1.3 mm
	52	10 x 10 mm	1.4 mm	0.65 mm	1.3 mm
	64	7 x 7 mm	1.0 mm	0.4 mm	0.9 mm
PLCC	20	0.353 x 0.353 ”	0.173”	0.05”	0.150"
	28	0.453 x 0.453 ”	0.173”	0.05”	0.150"
	44	0.653 x 0.653 ”	0.173”	0.05”	0.150”
QFN	16	4 x 4 mm	1.0 mm	0.65 mm	0.9 mm
	40	6 x 6 mm	1.0 mm	0.5 mm	0.9 mm
	44	7 x 7 mm	1.0 mm	0.5 mm	0.9 mm
	64	9 x 9 mm	1.0 mm	0.5 mm	0.9 mm

Figure 1. Holt Plastic SMT Package Styles

Package Qualification

Holt’s product qualification procedure is detailed in Figure 2.

The qualification procedure is in two sections: Environmental Tests and Mechanical Tests.

ENVIRONMENTAL TESTS

Assembled samples are 100% tested using the production test program. Industrial range products are tested at -40°C, 25°C and 85°C. Military grade products are tested at -55°C, 25°C and +125°C.

Samples are then preconditioned to simulate moisture absorption and solder reflow temperature profile, prior to Autoclave, Temperature Cycle and Highly Accelerated Stress Testing (HAST). To ensure die level reliability, High Temperature Operating Life (HTOL) is performed, as well as High Temperature storage. Figure 2 details the conditions, applicable standards, sample sizes, and pass criteria for each test.

MECHANICAL TEST

The traditional tests of Solderability, Physical Dimensions, Lead Integrity, and Bond Pull are performed. Again Figure 2 shows the details for each test.

Thermal stresses experienced during solder reflow can lead to separation of the package lead frame, die, and mold material. Material composition, die dimensions, and package size are factors which influence a device’s sensitivity to delamination. Once damaged, the device is potentially more susceptible to contamination ingress, as well as stress-induced die cracking, package cracking, or bond wire damage.

Qualification data and periodic quality monitoring results for Holt products are updated quarterly and posted on the Holt web site at www.holtic.com.

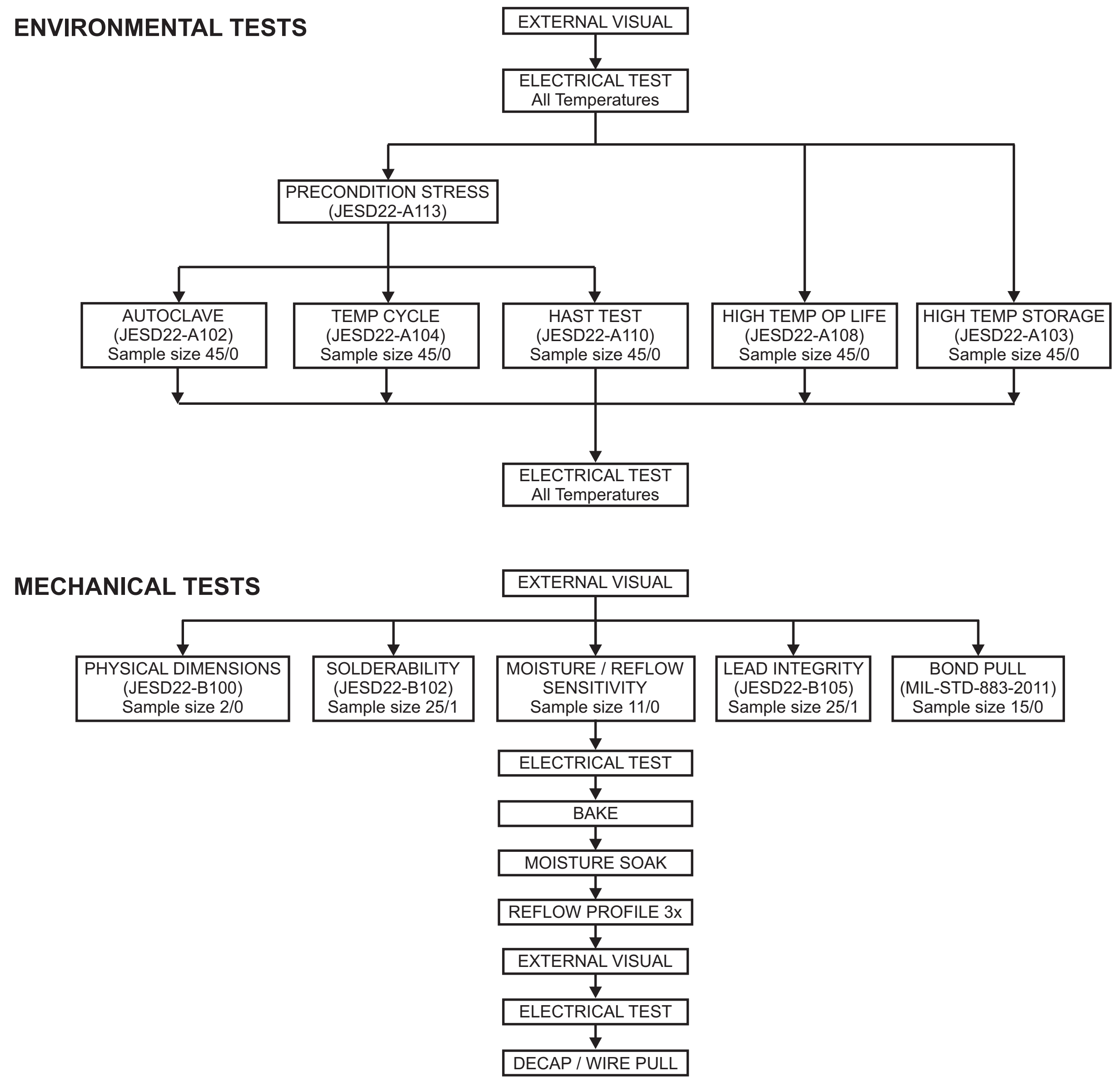

Figure 2: Holt Plastic Package Qualification

Lot Acceptance

Each new product is initially qualified to MSL level 1 or MSL level 3 per IPC/JEDEC J-STD-020D. To make sure that each subsequent assembly lot meets the established MSL level, Holt Integrated Circuits has developed a simulation procedure used for lot acceptance. Figure 3 details this procedure.

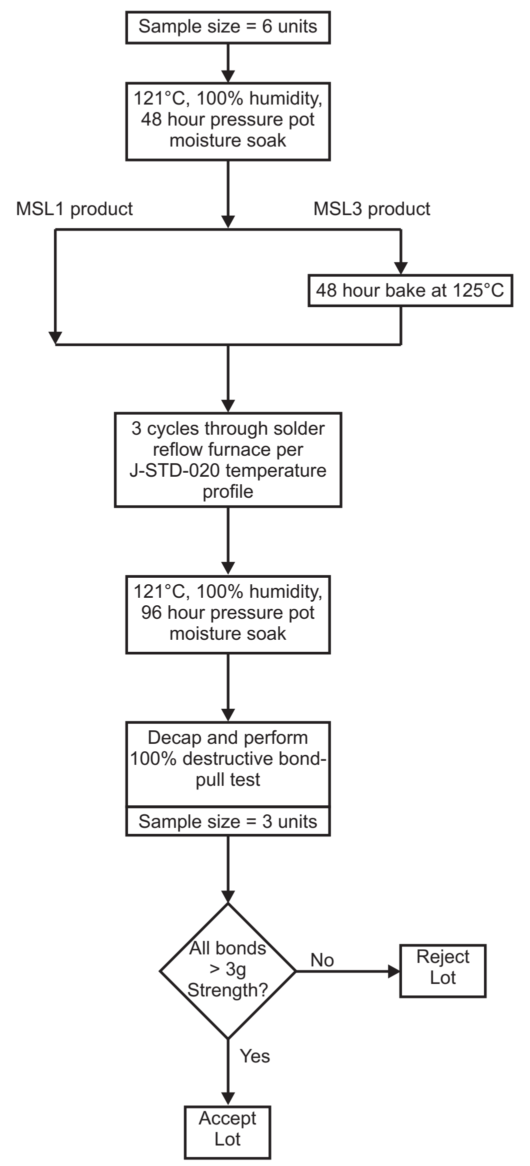

Figure 3: Lot Acceptance Procedure

Lot Processing Flows

The highest level of screening is the "M" flow of Figure 4 and is strongly recommended. However, for those customers who have duplicate screens in their flow, it may be cost effective to use the "T" or "I" flow.

INDUSTRIAL (I) FLOW

Industrial grade devices are 100% electrically tested at room temperature. An AQL sample from each lot is tested at -40°C and at +85°C. The lot is accepted if no failures occur during the sample test.

EXTENDED TEMPERATURE (T) FLOW

For flow "T" devices, a 100% electrical test is performed at room temperature, -55°C and +125°C.

MILITARY (M) FLOW

Holt's "M" screening flow represents the highest level of screening offered for plastic packaged devices. This level includes 100% testing to the "T" flow plus a 160 hour, +125°C burn-in.

The purpose of burn-in is to identify and remove infant mortality failures from the product population prior to shipment and use. The failure rate of product screened to flow "M" is then determined solely by the normal inherent (constant) failure rate of the process which is less than 10 FIT (55°C) for Holt's silicon gate CMOS technology.

The "M" flow is strongly recommended for all applications where board level burn-in is not performed, or where maximum early-life reliability is required.

Moisture Sensitivity

All plastic IC packages are non-hermetic. The plastic molding compounds will absorb moisture from the atmosphere during storage. Holt employs state-of-the-art low stress molding compounds and, where appropriate, polyimide die coating layers to minimize thermo-mechanical stresses during the board assembly process. For MSL3 rated products, the most common problem encountered with plastic components during board mount is known as "popcorning". Popcorning is the excessive delamination or cracking of the plastic from the pressure generated by the entrapped moisture turning to steam during board soldering. This may be evidenced by open or thermally sensitive open pins.

As part of Holt's ongoing commitment to quality and customer service, most plastic parts are baked at 125°C for 48 hours and then vacuum sealed in conductive dry bags prior to storage and shipment to a customer. A label attached to the bag states the maximum time and humidity to which parts may be exposed prior to board attach.

The dry bags may be re-sealed so that only sufficient material is removed from the controlled environment to facilitate a production run. A heat-seal machine is needed for this operation. Any excess material can be returned to the dry pack for later use provided its "out-of-bag" time has not been exceeded or it has been properly re-baked. Due to solderability issues, rebake should only occur once unless the solderability of post-bake components has been verified.

Process Step	Process Flow I	Process Flow T	Process Flow M	Comments
Incoming Wafer Inspection	X	X	X	Parametrics, Die Visual
Wafer Probe	100%	100%	100%	
Saw	X	X	X	
Die Visual Inspection	100%	100%	100%	MIL-STD-883, Method 2010, Condition B
Die Attach	X	X	X	Epoxy
Wire Bond	X	X	X	Gold Wire
Mold	X	X	X	
Mark & Cure	X	X	X	
Trim & Form	X	X	X	
Lead Finish	X	X	X	Solder Plate
Electrical Test @ Room Temperature	100%	100%	100%	
Electrical Test @ Hot Temperature	Sample (85°C)	100% (125°C)	Sample (125°C)	Military Grade Product - 100% Temperature Test After Burn In
Electrical Test @ Cold Temperature	Sample (-40°C)	100% (-55°C)	Sample (-55°C)	
Burn-In			100%	160 Hours, MIL-STD-883, Method 1015
Post Burn-In Electrical Test			100%	@ 25°C, 5% PDA
Final Electrical Test @ Cold & Hot			100%	@ -55°C & +125°C
Group ‘A“ Electrical Test			X	MIL-STD-883, Method 5005
Solderability			X	MIL-STD-883, Method 2003
External Visual	X	X	X	
Bake & Dry Pack	X	X	X	
QC Plant Clearance	X	X	X	
Pack & Ship	X	X	X	

Figure 4. Holt Plastic Package Manufacturing Flows

Board Assembly

A number of established processes exist for board solder reflow. The three common methods are Vapor Phase Reflow, Infrared Reflow, and Forced Air Convection Reflow.

The exact board process is not the primary factor in terms of field reliability. However, peak temperatures and the temperature profiles experienced during board mount are major factors.

The temperature profile must be adjusted to minimize the thermal shock to the package and to minimize exposure to the peak temperatures. Holt manufactures their plastic products to be both forward and backward compatible with the current industry–standard SnPb-based soldering process and higher temperature Pb-free processes. See Table 4.1 and Table 4.2 of J-STD-020D for package specific classification temperatures.

Note that in many board assembly operations, the profiles are adjusted for the most uniform soldering. These profiles may not be optimum for the plastic package. The board soldering temperature can be a significant factor in package reliability.

Ideally, maximum temperature and temperature ramp rates should be characterized for each plastic IC on the board, as thermal mass loading factors can lead to a wide variation in actual device temperatures across the assembly.

The Joint IPC/JEDEC Standard J-STD-020D provides detailed reflow temperature profiles for board level assembly. Figure 5 summarizes the recommended reflow profiles.

The primary concern during a rework cycle is residues of solder fluxes, which could cause leakage and / or dendrites. However, this problem exists with any type of package. As with the board soldering profile, the heat chuck or other methods of heating the leads should be programmed to minimize thermal shock to the package. Again, an indication of an excessive temperature profile could be open or thermally sensitive open pins.

Similar precautions must be taken if a part is removed from a board for failure analysis. Thermo-mechanical damage to the part may occur if moisture bake-out and temperature profile requirements are not met. The damage to the device may make further analysis impossible.

Profile Feature	Sn-Pb Assembly	Pb-Free Assembly
Preheat & Soak Temperature min (T_{smin}) Temperature max (T_{smax}) Time (T_{smin} to T_{smax}) (t_s)	100°C 150°C 60 - 120 seconds	150°C 200°C 60 to 120 seconds
Average ramp-up rate (Tsmax to T_p)	3°C / second Maximum	3° / second Maximum
Liquidous temperature (T_L) Time at liquidous (t_L)	183°C 60 - 150 seconds	217°C 60 - 150 seconds
Peak package body temperature (T_P)*	See Classification temp in Table 4.1 of J-STD-020D	See Classification temp in Table 4.2 of J-STD-020D
Time (t_P)** within 5°C of the specified classification temperature (T_c)	20** seconds	30** seconds
Average ramp-down rate (T_P to T_{smax})	6°C / second max.	6°C / second max.
Time 25°C to peak temperature	6 minutes max.	8 minutes max.

* Tolerance for peak profile temperature (T_P) is defined as a supplier minimum and a user maximum.
** Tolerance for time at peak profile temperature (t_P) is defined as a supplier minimum and a user maximum.

Note 1: All temperatures refer to the center of the package, measured on the package body surface that is facing up during assembly reflow (e.g., live-bug). If parts are reflowed in other than the normal live-bug assembly reflow orientation (i.e., dead-bug), T_P shall be within ±2°C of the live-bug T_P and still meet the T_C requirements, otherwise, the profile shall be adjusted to achieve the latter. To accurately measure actual peak package body temperatures refer to JEP140 for recommended thermocouple use.

Note 2: Reflow profiles in J-STD-020D are for classification / preconditioning and are not meant to specify board assembly profiles. Actual board assembly profiles should be developed based on specific needs and board designs and should not exceed the parameters of Table 5-2 of the standard.

For example, if T_C is 260°C and time t_P is 30 seconds, the time above 255°C must be at least 30 seconds.

For a supplier: The peak temperature must be at least 260°C. The time above 255°C must be at least 30 seconds.

For a user: The peak temperature must not exceed 260°C, the time above 255°C must not exceed 30 seconds.

Note 3: All components in the test load shall meet the classification profile requirements.

Note 4: SMD packages classified to a given moisture sensitivity level by using Procedures or Criteria defined within any previous J-STD-020, JESD22-A112 (rescinded), IPC-SM-786 (rescinded) do not need to be reclassified to the current revision unless a change in classification level or a higher peak classification temperature is desired.

Figure 5. J-STD-020D Classification Reflow Profiles

Operating Environments

The ideal operating environment for plastic package devices is the following:

- **Constant power applied**
- **Constant environmental temperature (30°C to 50°C)**
- **Low humidity**

A plastic package operating with constant power and under a constant warm environment will not exhibit any abnormal failure rate and will be just as reliable as any hermetic package. Typical operating lifetimes of 30 years have been reported. Keeping a plastic device warm will prevent moisture from migrating to the die surface.

Compared to cavity type hermetic packages, a plastic molded package will have no failures due to shock and vibration or conductive particles.

Typically plastic mold compounds should not be exposed to temperatures above 155°C for long periods of time. This means that the maximum ambient temperature should be adjusted to keep the maximum junction temperature below 155°C.

The worst case environmental conditions are continuous temperature cycling and high humidity or long term storage in high humidity conditions. Humidity and the resultant potential for corrosion is considered to be the major long-term application problem for plastic devices. In such environments the use of hermetically sealed ceramic packages is usually mandated.

Summary

Holt Integrated Circuits is a major supplier of both plastic and ceramic components to the aerospace industry worldwide. Every effort is made by Holt to ensure that all our products are manufactured using the best possible materials, manufacturing processes, and screening practices for this demanding market. With appropriate precautions, plastic packaged ICs will give long and reliable service.

REVISION HISTORY

Revision	Date	Description of Change
AN-400, Rev. I	04/24/08	Changed “advancement much slower” to “advancement is much slower” - Page 1 Corrected spelling - “sited” to “cited” - Page 1 Removed 32 and 56 pin QFN format from Figure 1 Changed “monthly” to “quarterly” in 3rd paragraph under MECHANICAL TEST - Page 2 Changed 48 hour pressure pot to 96 hour pressure pot in Figure 3 Changed “A sample of 20 devices from” to “An AQL sample from” - Page 4 Removed Solderability and Marking Permanency tests under EXTENDED TEMPERATURE (T) FLOW - Page 4 Changed “all” to “most” in 2nd paragraph under Moisture Sensitivity - Page 4 Removed the “X” for Solderability in the “T” Process Flow in Figure 4 Removed specific solder flow recommendations from 3rd paragraph of Board Assembly and replaced with “Holt manufactures their plastic products to be both forward and backward compatible with the current industry –standard SnPb-based soldering process and higher temperature Pb-free processes.” - Page 5 Changed 4-1 to 4.1 in 3rd paragraph of Board Assembly - Page 5 Added REVISION HISTORY - Page 7