Update to the Extended Shelf-Life Report on ASI Controls 80C196NT uProcessor

Original Date: December 13th, 2006

The analysis of the methodology selected in 2006, to extend the viable shelf-life of certain end-of-life purchases, including the 80C196NT micro-processor. Includes the results of using the methodology to date.

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3/5/2011

Extending Shelf Life of 80C196NT uController

The following discussion focuses on problems surrounding the large number of uControllers that ASI Controls has been required to acquire, as a result of an end of life declaration by Intel Corp. for the 80C196NT. The expected life span of the ASI products utilizing this uController is five (5) years from this writing.

In studying the available literature on the subject of Surface Mount Devices (SMD) such as this uController, a number of important issues pertaining to the storage and installation of the devices become evident.

1. Mounting SMD to a printed circuit board (PCB) during product manufacture.
2. Maintenance of SMD environment to ensure satisfactory yield and performance.
3. Packaging for shipment and storage.
4. Provision of suitable environment for extended shelf life over manufactures expectations.

At the risk of duplication of information found in the literature, this document will summarize all the salient information abstracted from that literature.

Mounting SMD to PCB during product manufacture.

There are countless references in the literature to high failure rates during reflow soldering of SMD devices onto their respective PCB. These failures are due to the very high temperatures to which the SMD package is subjected during soldering. This problem has not been noted in earlier ASI products, due to the fact that all components were either mounted 'through-hole' or were inserted in sockets after the socket had been soldered to the PCB. Components that are of the 'through-hole' type have metallic leads that are inserted through holes in the PCB and therefore are shielded from high soldering temperatures by the PCB itself. Temperatures of approximately 230degC are normal for reflow soldering of devices with tin-lead alloy coated leads. With the recent world-wide move toward 'leadless' products, new SMD leads are tin or tin-copper alloy and require a substantially higher solder temperature to ensure a good lead-PCB bond. These temperatures will be approximately 260degC.

The integrated circuits (ICs) within the body of the SMD can easily withstand short exposures to these high temperatures. Short meaning in the order of a few seconds. However the bodies that surround the ICs are typically made of plastics that absorb moisture out of the environment. When subjected to high soldering temperatures, the moisture contained within the plastic body rapidly vaporizes and is subject to diffusion into the inner cavity of the SMD. This rapid moisture vapor diffusion can raise internal pressures beyond the capacity of the plastic body to retain its integrity. If sufficient moisture is contained in the body plastic, this expansion can result in a severe fracture of the body. This phenomenon is referred to as the 'Popcorn' effect, because it results in an audible popping sound. Even if the moisture content is not sufficient to cause cracking of the plastic case, there may still be catastrophic failures of the ICs substrate and/or rupture of the metal bonds connecting the ICs to the substrate pads. In either case, serious yield problems will result from reflow soldering of SMDs that have an unacceptable exposure to moisture.

Virtually all of the available literature treats this problem as a manufacturing problem and therefore is concerned with the PCB assembly arena. Standards have been established with particular concern for SMD exposure after being first removed from the initial storage container. JEDEC/IPC J-STD-020A establishes specifications and testing requirements for determining the Moisture Sensitivity Level (MSL) of each type of SMD package. Increasing MSL numbers refer to increasing sensitivity to moisture exposure.

Floor life versus moisture sensitivity levels

MSL	CONDITIONS	FLOOR LIFE
1	30 °C / 90% RH	unlimited
2	30 °C / 60% RH	1 year
2a	30 °C / 60% RH	4 weeks
3	30 °C / 60% RH	168 hours
4	30 °C / 60% RH	72 hours
5	30 °C / 60% RH	48 hours
5a	30 °C / 60% RH	24 hours
6	30 °C / 60% RH	6 hours

Note that this diagram refers to 'FLOOR LIFE', as the time from removal of the SMD from protective packaging until it is soldered to the PCB. The reason so much attention has been paid to this time interval is that virtually all popcorn failures have occurred because of extending the time on the manufacturers floor waiting for soldering. There are a number of reasons this occurs, including throughput timing, changing lines to various products, overfill of dispensers for a given run quantity, etc.

The 80C196NT is classified by Intel, and according to the various JEDEC specifications as a MSL level of 3, thereby according the assembler a maximum of 168 hours of exposure prior to soldering. Now, seven (7) days seems like time enough to accomplish whatever is to be done prior to assembly, but one must take into account the number of shifts per day, extended breaks between specific product assembly, et al.

Should the allowable Floor Life be exceeded, the manufacturing assembler has several options to reset the Floor Life to allow continued exposure. One option is to simply re-bake the SMDs to de-absorb the moisture within the plastic body. The JEDEC specifications state appropriate bake times for restoring the Floor Life of SMDs.

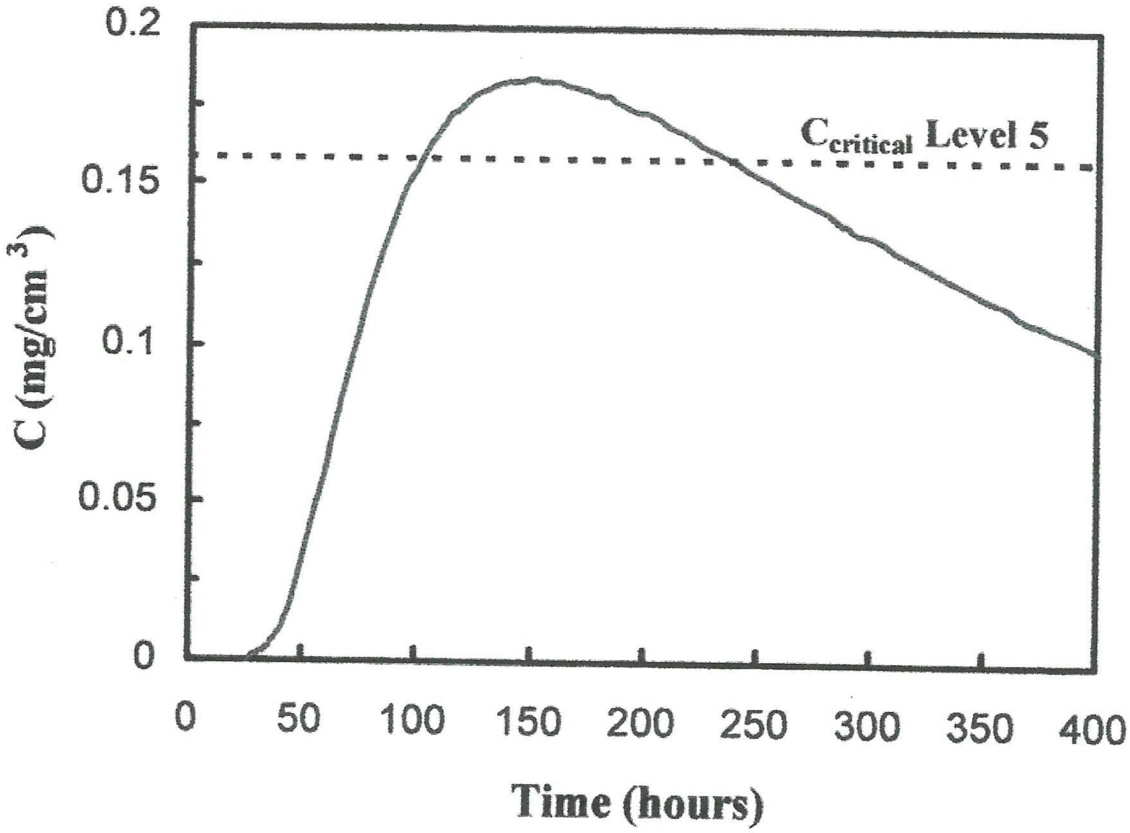
Baking Component Conditions

PACKAGE THICKNESS	LEVEL	BAKE AT 150°C	BAKE AT 125°C	BAKE AT 90°C	BAKE AT 40°C
≤1.4mm	2a	2 hours	3 hours	11 hours	5 days
	3	3 hours	6 hours	18 hours	8 days
	4	3 hours	6 hours	18 hours	8 days
	5	3 hours	6 hours	18 hours	8 days
	5a	3 hours	6 hours	18 hours	8 days
≤2.0mm	2a	8 hours	16 hours	2 days	22 days
	3	8 hours	16 hours	2 days	22 days
	4	8 hours	16 hours	2 days	22 days
	5	9 hours	19 hours	3 days	27 days
	5a	14 hours	31 hours	5 days	42 days
≤4.0mm	2a	20 hours	41 hours	6 days	47 days
	3	17 hours	35 hours	5 days	40 days
	4	17 hours	35 hours	5 days	40 days
	5	22 hours	46 hours	7 days	53 days
	5a	34 hours	70 hours	9 days	81 days

The 80C196NT package is approximately 4.0 mm thick and therefore as a Class 3 device, requires 35 hours of re-bake at a temperature of 125degC. The actual temperature of re-baking must also be influenced by the type of packaging of the SMDs. Typical trays are capable of being subjected to 125degC, but reels and some other packaging are not able to withstand temperatures exceeding 40degC. Those ASI 80C196NT SMDs that are shipped to ASI in reels would take 40 days of baking at that temperature to reset the floor life of the devices. None of these re-bake times are desirable, adding cost and complexity to the assembly process.

There is a technique used throughout the assembly industry to avoid re-bake of SMDs. This is known as Dry Storage. Those partially used trays and reels of SMDs removed from the assembly line can be stored in a dry environment until they are needed again. Such storage may consist of a dry cabinet or resealed dry bags containing a desiccant. Many assemblers assume that it is acceptable to 'stop the clock' of exposure time while the parts are in dry storage. In reality, once the parts have been exposed for a significant period, the absorbed moisture will remain in the package and diffuse toward the center of the SMD body, where it is most likely to do damage when reflow soldered.

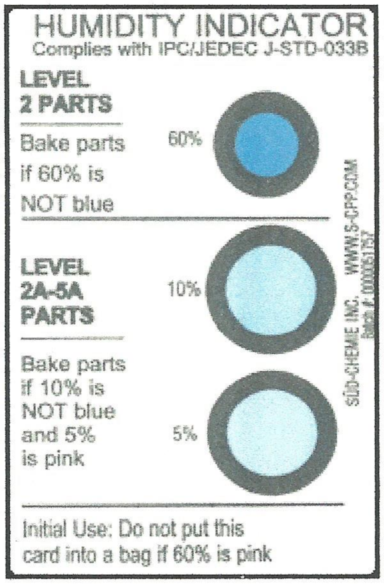
The following graph is typical of an SMD substrate interface moisture level, in this case for a Class 5 device. It is shown here to demonstrate that after an exposure to the assembly line environmental conditions, and then placed into a dry storage container, the diffusion of the moisture absorbed by the plastic body during exposure will take many hours to migrate to the substrate where it will do the most damage during reflow soldering. Of course, with many more hours of dry containment, the moisture content drops below a dangerous level and sooner or later, will drop down to original conditions. The time to achieve this is also much too long for practical applications. Note that the 'moisture' axis in this diagram is in weight of water per volume. This indicates that by carefully weighing SMDs, the moisture content can be determined. This would require very sensitive weighing instruments and probably is not a viable method for our use.



All of the discussion to this point assumes that the product delivered to the manufacturing assembly house is without absorbed moisture, and that these Floor Life times are applicable.

Packaging for Storage and Shipping

It appears that all SMD producers utilize the same bake and dry-pack procedures as specified in JEDEC standard J-STD-020A. That is a dry bake of 125degC for 24 hours prior to dry packing the product for distribution. It has been adequately demonstrated by many interested parties that this creates a dry-pack environment that is well below the 5% RH that is specified in the standard cited. Virtually all producers of SMDs warrant their product for a shelf life of at least one (1) year, prior to removal from the dry pack and subsequent soldering for assembly. The standard dry pack consists of a Moisture Barrier Bag (MBB) containing a tray or reel of SMDs, together with an amount of desiccant sufficient to maintain a satisfactory RH for the storage time, and a Humidity Indicator Card (HIC) with three active locations indicating RH at 5%, 10% and 60%. The 60% applies only to the level 2 devices and is not of interest to us here.



In researching the literature and standards for this discussion, very little information was found regarding extended shelf life, such as is needed for the ASI 80C196NT SMD. Luckily, there is one very well documented reference to tests that had been conducted with standard dry packaging over a period of 32 months. The testing was done at the request of a prominent SMD producer, but was performed by an industry recognized authoritative test firm, MOCON.

Both trays filled with SMDs and filled tapes and reels were tested. The tests consisted of utilizing standard bake and dry pack procedures as described above, with desiccant and HIC included. Periodic test samples were opened at intervals of three to six months for two years (24 months) to verify the continued integrity of the dry-pack system performance.

The %RH values at the 32 month test ranged from 2.5% to 4.3% for the tape and reel samples, and 3.4% to 4.4% for the tray samples. These values are all below the 5% threshold specified by JEDEC standard J-STD-020A.

Table 3. Headspace Moisture Level for Tape-and-Reel and Matrix Tray Stack Dry-Pack Systems during 24-Month Storage Test

	%RH as Indicated by Water Vapor Headspace Testing							
	Time Zero	6 months	12 months	15 months	18 months	21 months	24 months	32 months
Tape and Reel	2.4	1.9	3.8	2.6	2.5	3.5	2.0	3.2
Tray	1.8	3.0	3.7	2.1	3.4	2.4	3.9	4.0

NOTE 1: All humidity indicator spots were blue when checked including 32-month readings.
NOTE 2: %RH readings are the average of ten (10) readings taken at each period for each dry pack format.
NOTE 3: Storage conditions were ~23C at room ambient humidity levels.

Note that the storage conditions were 23degC (73.4degF) at typical room ambient humidity levels.

How do We achieve 60 Months of Shelf Life?

There is NO satisfactory demonstration of 60 month shelf life in the literature. The closest we can come is what we have presented above. The results of the 32 month testing appears promising. The objective is to avoid high cost alternatives due to an extended shelf life. There are several methods that predict a successful extended life.

1. Be prepared to convert to PLCC sockets at or about 3 years.
2. Have a commercial facility re-bake and dry-pack when samples indicate moisture levels above 5%RH.
3. Store product in a commercial dry environment facility.
4. Provide an enclosed space at ASI with control of both temperature and RH.
5. Provide an enclosed space at ASI with a dry Nitrogen environment.

All SMD product at ASI Controls will be contained within dry packaging. The process of osmosis is universal and for gases simply reacts to a difference in vapor density on either side of the applicable barrier. The MBB is very effective, but to enhance the bags ability to keep moisture out, we must keep the vapor density outside the bags as low as possible.

Since the mechanism by which catastrophic failure occurs in an SMD during soldering is really the amount of moisture contained within the plastic body, usually designated by vapor density, or weight of water/volume, it seems reasonable to maintain as low a temperature as possible.

This chart demonstrates a factor of two at least, in the Saturated Vapor Density difference between holding the enclosure at normal room ambient and 50degF

Temp (°C)	Temp (°F)	Saturated Vapor Pressure (mmHg)	Saturated Vapor Density (gm/m^3)
-10	14	2.15	2.36
0	32	4.58	4.85
5	41	6.54	6.8
10	50	9.21	9.4
11	51.8	9.84	10.01
12	53.6	10.52	10.66
13	55.4	11.23	11.35
14	57.2	11.99	12.07
15	59	12.79	12.83
20	68	17.54	17.3
25	77	23.76	23
30	86	31.8	30.4
37	98.6	47.07	44

Further advantage toward extending the shelf life of the SMDs can be achieved by applying a drying agent to the environment. A dryer could be inserted into an enclosure that would then be both temperature and humidity controlled. Because of the typically 50% to 80% RH levels in the San Ramon region, it is uncertain how low a humidity could be attained, however anything below ambient would be an asset.

Dry Nitrogen enclosures with single point humidity control of 5% are commercially available with enclosure sizes up to 125 cubic feet. With the large volume of packages that the Intel end of life purchase entails, this may not be a viable solution?