TOSHIBA

Transitioning to Lead(Pb)-Free Manufacturing with Toshiba Semiconductor Products

A White Paper from
Toshiba America Electronic Components, Inc.

Quality Assurance

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Legal Note. The definitions included in this document for Lead(Pb)-Free and RoHS-Compatible and the related discussions are not intended to interpret the Directive 2002/95/EC of the European Parliament and of the council of 27 January 2003 on the use of certain hazardous substances in electrical and electronic equipment (the "RoHS Directive") or any other law or regulation and do not constitute legal advice. The RoHS Directive itself and/or any other applicable law/regulation should always be read and understood (as it constitutes the law), in contrast with the information contained herein, which is intended to be informative but has no legal authority. You should refer to the RoHS Directive itself and/or any other applicable law/regulation for a full statement of the legal requirements and in the case of any doubt take independent advice, including your own legal advice. The RoHS Directive itself and/or any other applicable law/regulation may be revised from time to time, so users should take care to keep themselves informed.

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1. Introduction

As part of a commitment to respond to customer requirements for Lead(Pb)-Free (as defined below in section 1.1) electronic components, the Semiconductor Company of Toshiba Corp. (Toshiba Semiconductor Company), the parent of Toshiba America Electronic Components, Inc., (TAEC) is implementing new manufacturing procedures to support the current industry movement to Lead(Pb)-Free manufacturing. This document presents information on the industry initiative to transition to Lead(Pb)-Free products, along with technical information on Toshiba Semiconductor Company's Lead(Pb)-Free products, transition schedule, inventory management procedures and other related information.

1.1 Lead(Pb)-Free Definition

As discussed in more detail below, there are various regulations that will limit the use of lead(Pb) in products. As a result, the term "Lead(Pb)-Free" or "Pb-Free" has become a commonly used term to the electronics industry to designate products that are intended to satisfy the various regulations regarding lead(Pb). However, at present there is no legally established uniform standard for the level of lead(Pb) that will be allowed in a product under the various regulations. Notwithstanding the lack of a uniform legal standard, the electronics industry has generally adopted a standard of no more than 0.1 percent by weight. Under these circumstances, Toshiba Semiconductor Company will define "Lead(Pb)-Free" in accordance with this industry standard as no more than 0.1 percent lead(Pb) by weight in Homogenous Materials.This does not mean that Toshiba semiconductor products that are labeled Lead(Pb)-Free are entirely free of lead(Pb).

Toshiba Semiconductor Company defines "Homogonous Material" to mean a material that cannot be mechanically disjointed into different materials. The term "homogenous" is understood as "of uniform composition throughout," so examples of "Homogenous Materials" would be individual types of plastics, ceramics, glass, metals, alloys, paper, board, resins and coatings. Toshiba Semiconductor Company defines the term "mechanically disjointed" to mean that the materials can be, in principle, separated by mechanical actions such as unscrewing, cutting, crushing, grinding and abrasive processes.

During a transitional phase, in addition to Lead(Pb)-Free products (that contain no more than than 0.1 percent lead(Pb) by weight), TAEC will also offer products that have Lead(Pb)-Free terminals, which will be referred to as "Lead(Pb)-Free Finish". The Lead(Pb)-Free Finish products may contain greater than 0.1 percent lead(Pb) by weight in portions of the product other than the terminals.

2. Industry Lead(Pb)-Free Initiative

Current environmental initiatives facing electronics manufacturers include requirements under a variety of regulations and proposed regulations from various jurisdictions around the world that will regulate or restrict the use of lead(Pb) or impose additional requirements when lead(Pb) is used in products. For example, the RoHS Directive states that the use of lead(Pb) and certain other substances must be regulated by July 1, 2006.

Currently in the United States, a majority of individual states have proposed or adopted legislation that will regulate or restrict the use of lead(Pb) or impose additional requirements for products that contain lead(Pb). Some of these regulations are linked to the RoHS Directive. For example, California's SB20 will prohibit an electronic device from being sold or offered for sale in California if the electronic device is prohibited from being sold in the European Union on or after the date of its manufacture due to the presence of restricted substances. The bill will take effect January 1, 2007, or the date that the RoHS Directive takes effect, whichever is later. In addition, the California SB20 also incorporates provision of the Electronic Waste Recycling Act of 2003, which establishes provisions and fees for disposing of electronic devices. See Table 2-1 below for status of certain Lead(Pb)-Free initiatives in various regions.

These regulations limiting the use of lead(Pb) in semiconductors and electronics equipment will have a widespread impact on the global marketplace, requiring Lead(Pb)-Free assemblies by mid-2006 for products sold in Europe. Within this time frame, global suppliers must convert to Lead(Pb)-Free alternatives completely, or maintain dual production processes with duplicate sets of parts, with and without lead(Pb), which will have to be carefully tracked.

2.1 Definition of RoHS-Compatible

Reduction of lead(Pb) content to a level of no more than 0.1 percent by weight is considered to be one requirement of the RoHS Directive. However, to be RoHS-Compatible, a device must not contain more than the specified maximum concentration value of any of the

Table 2-1 Global Lead(Pb)-Free Trends

EU	Legislated RoHS Directive. Lead(Pb) use will be restricted beginning in July 2006.
US	Regulations similar to those in the EU are being proposed and adopted in various jurisdictions, e.g., California Senate Bill 20. Moreover, the Lead(Pb)-Free trend is accelerated by major customers from the Lead(Pb)-Free movement in EU.
Japan/Asia	Corporations propose to enhance competitive edge through voluntary compliance with Lead(Pb)-Free standards. Various electronic products using Lead(Pb)-Free solder have been manufactured and are available in Japan.
China	Currently drafting Lead(Pb)-Free legislation.

six regulated substances or fall within the scope of an exemption. Of the regulated substances, lead(Pb) is the most widely used in semiconductor manufacturing, which accounts for the greater emphasis on lead(Pb)-free materials than on the other regulated substances in the semiconductor industry.

Toshiba Semiconductor Company defines "RoHS-Compatible" semiconductor products as products that either (i) contain no more than a maximum concentration value of 0.1 percent by weight in Homogeneous Materials for lead(Pb), mercury, hexavalent chromium, polybrominated biphenyls (PBBs) and polybrominated diphenyl ethers (PBDEs) and of no more than 0.01 percent by weight in Homogenous Materials for cadmium; or (ii) fall within one of the stated exemptions set forth in the Annex to the RoHS Directive.

Almost all electrical and electronic products incorporate semiconductor devices soldered into printed circuit boards. For some time, tin-lead solder, which combines tin(Sn) and lead(Pb), has been widely used for electrical connections because of its electrical and mechanical characteristics. Today, based on the Lead(Pb)-Free initiative, the industry is seeking alternative Lead(Pb)-Free solders and soldering processes.

3. Toshiba Semiconductor Company's and TAEC's Plans to Support the Lead(Pb)-Free Initiative

As a technology leader, Toshiba Semiconductor Company and TAEC are making solutions available to assist customers in complying with pending Lead(Pb)-Free legislation by implementing new manufacturing procedures using new materials. Toshiba Semiconductor Company has given increased attention to finding Lead(Pb)-Free solutions for its products and transitioned a portion of its manufacturing to Lead(Pb)-Free in 2003.

TAEC is committed to working with its customers to be able to offer products that meet customers' specific Lead(Pb)-Free criteria. TAEC is also scrutinizing the business issues associated with such a manufacturing transition. These issues include customer service, supply chain and inventory management, materials management, supply continuity and industry coordination. TAEC is striving for a smooth transition by making sure the testing, qualification and re-qualification of parts meet its customers' needs. It is also carefully evaluating the entire supply chain in order to effectively manage all aspects required for supply continuity. Some of TAEC's customers are not considering the move to Lead(Pb)-Free components at this time, so this will involve management of duplicate parts as the market dictates. In cases where both Lead(Pb)-Free and non-Lead(Pb)-Free components will be available, new part numbers will be issued to enable identification of the Lead(Pb)-Free variant.

The Lead(Pb)-Free measures the company is pursuing vary from product to product. However, the first step in TAEC's transition plan is making the terminals for certain semiconductor products Lead(Pb)-Free (referred to as Lead(Pb)-Free Finish). Toshiba Semiconductor Company has carefully evaluated soldering in terms of materials, chemicals, terminal finishes and thermal resistance to choose the optimal alternative to be applied in each product category. For more detailed Lead(Pb)-Free plans for Memory products, please refer to the supplemental reference.

Memory: Lead(Pb)-Free Technology on Memory Products
http://www.semicon.toshiba.co.jp/eng/prd/memory/doc/doc.html

4. Classification of Lead(Pb)-Free Parts

The "Lead(Pb)-Free Soldering Roadmap" published by the Japan Electronics and Information Technology Industries Association (JEITA) classifies products into the following phases in view of the heat resistance in packaging, types of component parts and materials. Toshiba Semiconductor Company has adopted this classification scheme.

Table 4-1 Classification of Lead(Pb)-Free Parts

Classification	Criteria
Parts that withstand Lead(Pb)-Free soldering temperature	Parts with the solder heat resistance to withstand the higher temperature soldering requirements for Lead(Pb)-Free manufacturing processes.
Parts with Lead(Pb)-Free terminals	The plating of the terminals to be fitted to the board and electrodes of the part should be Lead(Pb)-Free. However, it is acceptable for the other components and materials of the part to have greater than 0.1 percent lead(Pb) by weight.
Lead(Pb)-Free parts	All sections of the part, including internal connections and/or components and materials are Lead(Pb)-Free.

4.1 Terminal Finish

The Toshiba Semiconductor Company products with lead-type and ball-type packages will have Lead(Pb)-Free Finishes, according to Table 4-2, next page. However, the materials may differ according to the production site and package type. Refer to the supplemental technical documentation for each business unit for more detailed information.

Table 4-2 Lead(Pb)-Free Plating by Product Category

Discrete Products			
Product Family	**Package Type**	**Original Finish**	**Lead(Pb)-Free Finish**
MOS Logic	DIP 14, 16, 20, 24	Sn-Pb (plating)	Sn-Ag (plating) or Sn (plating)
	SOP 14, 16, 20 SSOP 24 TSSOP 48, 56	Sn-Pb (plating)	Ni-Pd-Au (plating)
	TSSOP 14, 16, 20 US 16, 20	Ni-Pd-Au (plating)	Ni-Pd-Au (plating)
Small Signal	TESC,TESM, TESM2, TESM3, ESV, ESM/ES6, SSC, SSM, USQ/TU6/US8 TSM, SM8 SSOP 18/HSOP20 sESC/sES6, UFV/UF6	Sn-Pb (plating)	Sn-Ag (plating)
	ESC,USV, US6	Sn-Pb (plating)	Sn-Ag (plating) or Sn-Ag-Cu (dip)
	FM8 TO-92, and other lead type	Sn-Pb (dip)	Sn-Ag-Cu (dip)
	SM/SMQ/SMV/SM6	Sn-Pb (dip) or Sn-Pb (plating)	Sn-Ag-Cu (dip) or Sn-Ag (plating)
	SS-CSP	Au (plating)	Au (plating)
	TESQ fSC/fSM/fS6	Sn-Ag (plating)	Sn-Ag (plating)
	USC, USM	Sn-Pb (dip) or Sn-Pb (plating)	Sn-Ag (plating)

Table 4-2 Lead(Pb)-Free Plating by Product Category (Continued)

Discrete Products			
Product Family	**Package Type**	**Original Finish**	**Lead(Pb)-Free Finish**
Power Device	UFV/FMV PW-MOLD(through hole type)/ New PW-MOLD TSSOP-8 TSM SSOP 10, 20, 24 VS-6, VS-8 PS-8 DP SP TO-220SM TFP/Slim-TFP I-FLAT/S-FLAT/ M-FLAT/US-FLAT/ MR	Sn-Pb (plating)	Sn-Ag (plating)
Power Device	SOP-8	Sn-Pb (plating)	Sn-Ag (plating) or Sn (plating)
Power Device	Pw-Mini TO-220FL TO-220AB TO-220NIS TO-3P(N), (N)IS, (H)IS, (L), (LH) F-12, 18,23/S-10, 12 TM-IPM TO-126IS TPS/TPL MSTM TO-92/TO-92MOD DO-15/41 Series	Sn-Pb (dip)	Sn-Ag-Cu (dip)
Opto Device LED	Small Size SMD Lamp (PCB type: TLxx1002A/ 1008A series, TLxx1005B series are excepted)	Au (plating)	Au (plating)
	Small Size SMD Lamp (SSH: TLxx1020 Series)	Sn-Pb (plating)	Sn-Ag (plating)
	Large Size SMD Lamp	Ni-Pd-Au (plating)	Ni-Pd-Au (plating)
	Lead Type (i.e,f3/f15, etc. except general purpose lamps)	Sn-Pb (dip)	Sn-Ag-Cu (dip)

Table 4-2 Lead(Pb)-Free Plating by Product Category (Continued)

Discrete Products			
Product Family	**Package Type**	**Original Finish**	**Lead(Pb)-Free Finish**
Opto Device Sensor	Ultra Small Photo-interrupter Photoreflective Sensor (except TLP910)/Small Side View	Sn-Pb (plating)	Sn-Ag (plating)
	Lead Type (f3/f5 Mold Type) Side View	Sn-Pb (dip)	Sn-Ag-Cu (dip)
	Photo-interrupter with Connector	Sn-Pb (plating)	Sn (plating)
	Illuminance Sensor (SMD)	Au (plating)/ Sn-Ag (plating)	Au (plating)/ Sn-Ag (plating)
	TO-18 (CAN)	Sn-Pb (dip)	Au (plating)
	SOP (Camera – only some products are applied) Double end	Ag (plating)	Ag (plating)
Opto Device TOSLINK	Module For Audio Mold Resin Package Type (except Audio type)	Sn-Pb (plating)	Sn-Ag (plating)
	Ceramics Package Type	Sn-Pb (plating)	Au (plating)
Opto Device Photocoupler	DIP (Reflective Structure)	Ni-Pd-Au (plating)	Ni-Pd-Au (plating)
	DIP (Face to Face Structure)	Sn (plating), Sn-Pb (plating) or Ni-Pd-Au (plating)	Sn (plating), Sn-Ag (plating) or Ni-Pd-Au (plating)
	DIP (Face to Face, Double Mold Structure)	Sn (plating) or Sn-Pb (plating)	Sn (plating) or Sn-Ag (plating)
	MFSOP (Reflective Structure)	Sn-Pb (dip)	Sn-Ag-Cu (dip)
	MFSOP (Face to Face Structure) MFSOP (Face to Face. Double Mold Structure)	Sn-Pb (dip) or Sn-Pb (plating)	Sn-Ag-Cu (dip) or Sn-Ag (plating)

Table 4-2 Lead(Pb)-Free Plating by Product Category (Continued)

Discrete Products			
Product Family	**Package Type**	**Original Finish**	**Lead(Pb)-Free Finish**
Opto Device Photocoupler	SOP (Reflective Structure)	Sn-Pb (dip)	Sn-Ag-Cu (dip)
	2.54SOP (Face to Face Structure)	Sn-Pb (plating)	Sn-Ag (plating) or Ni-Pd-Au (plating)
Opto Device Visible Laser Diode	f5.6 (Can Type) Lead Frame Type	Au (plating)	Au (plating)
Opto Device OCD	2.5G RX (Butterfly Type)	Sn-Pb (dip)	Sn-Ag-Cu (dip)
	2.5G TX (DIP)	Sn-Pb (plating)	Au (plating)
	Others OCD (Mini-DL, etc.)	Au (plating)	Au (plating)
Memory Products			
Package Type	**Original Finish**	**Lead(Pb)-Free Finish**	**Comments**
SOP TSOP	Sn-Pb Sn-Pb	Sn-Ag or Sn-Cu plating with 42 Alloy for leads	
LGA	Au-terminal plating	Au terminal plating	
BGA	Sn-Pb Ball	Sn-Ag-Cu Ball	
System LSI Products			
Package Type	**Original Finish**	**Lead(Pb)-Free Finish**	**Comments**
Lead Type	Sn-Pb Plating	Sn-Ag Plating Sn-Bi Plating Ni/PD/Au Plating (PFF)	PFF: Pre-Plated Frame
Ball Type	Sn-Pb Ball	Sn-Ag-Cu Ball	

5.0 Precautions for Lead(Pb)-Free Soldering

Generally, the soldering temperature of Lead(Pb)-Free solder is higher than that of conventional tin-lead (Sn-Pb) solder, so it is essential to ensure that the soldering temperature is not in excess of the heat resistance temperature of the components. Figure 5-1 shows the melting point and characteristics of various compositions of Lead(Pb)-Free solders.

5.1 Considerations for Backward and Forward Compatibility

The conversion to Lead(Pb)-Free manufacturing cannot be accomplished overnight. Surface mount (SMT) assembly lines, especially in the USA, may need to have dual lines using Lead(Pb)-Free products and traditional products that are not Lead(Pb)-Free. The Lead(Pb)-Free manufacturing process may allow for Lead(Pb)-Free products to be processed on a traditional line (i.e., backwards compatibility) and for traditional products to be processed on a Lead(Pb)-Free line (i.e., forward compatibility).

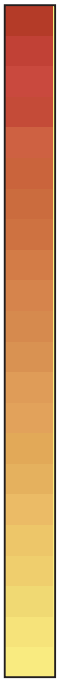
5.2 Reflow Temperature for Lead(Pb)-Free Soldering

The maximum heat resistance assured temperature of reflow soldering is increased from the present 240°C to 260°C for Lead(Pb)-Free soldering, as shown in Figure 5-2, which compares the temperature profiles of Lead(Pb)-Free soldering with conventional tin-lead(Sn-Pb)-based soldering. As a result, Lead(Pb)-Free manufacturing requires careful planning and inventory control to ensure that Lead(Pb)-Free parts are not intermixed with products that are not Lead(Pb)-Free.

Figure 5-1 Characteristics of Typical Lead(Pb)-Free Solder

Melting Point/ Composition

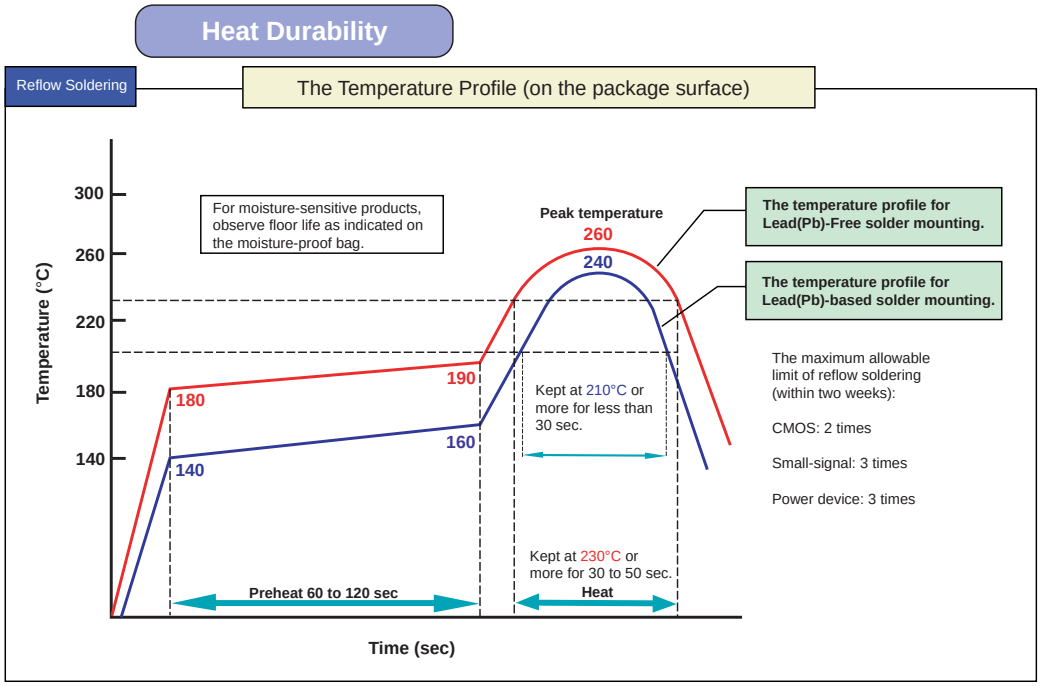
Melting Point °C



- 236 Sn-5Sb	High melting point
- 227 Sn-0.7Cu	Chiefly used for flow soldering
- 221 Sn-3.5Ag	Has solder strength compared to Sn-Pb, but the range of mounting temperature is narrow
- 217 Sn-3Ag-0.5Cu	General composition ratio used in Japan
- 199 Sn-9Zn	Melting point of Sn-Zn system is approximate to Sn-Pb. Care should be taken to ensure adequate wettability and oxidization
- 190Sn-8Zn-3Bi	Bi additives have the effect of lowering the melting point of solder
- 189 Sn-7.5Bi-2Ag-0.5Cu	Bi additives have the effect of lowering the melting point of solder
- 183 Sn-37Pb	Conventional solder (eutectic)
- 139 Sn-57Bi	Good wettability. Care should be taken to test the compatibility with Sn-Pb plating

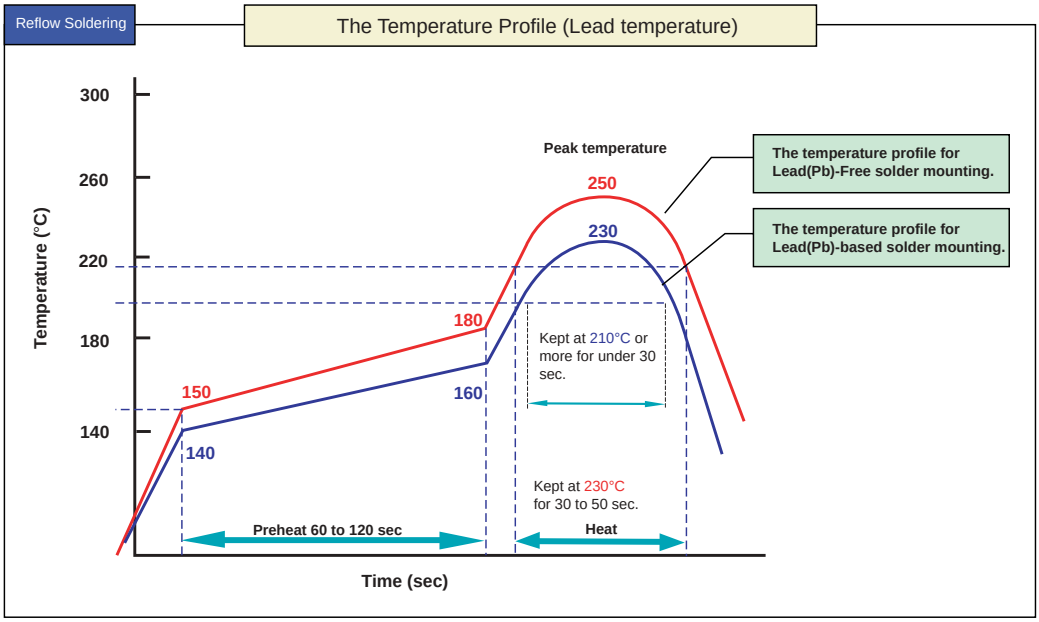
Note: Melting points are determined by representative value, which depends on composition ratio. Please consult solder maker for details.

Figure 5-2 Temperature Profile Comparing Lead(Pb)-Free and Lead(Pb)-Based Solders



Generally, the soldering temperature of Lead(Pb)-Free solder is higher than that of lead(Pb)-based solder, which means that precautions must be taken to ensure that the soldering temperature is not in excess of the heat resistance of the components. Figure 5-3 provides an example of a reflow temperature profile for Lead(Pb)-Free paste (Sn-3Ag-0.5Cu).

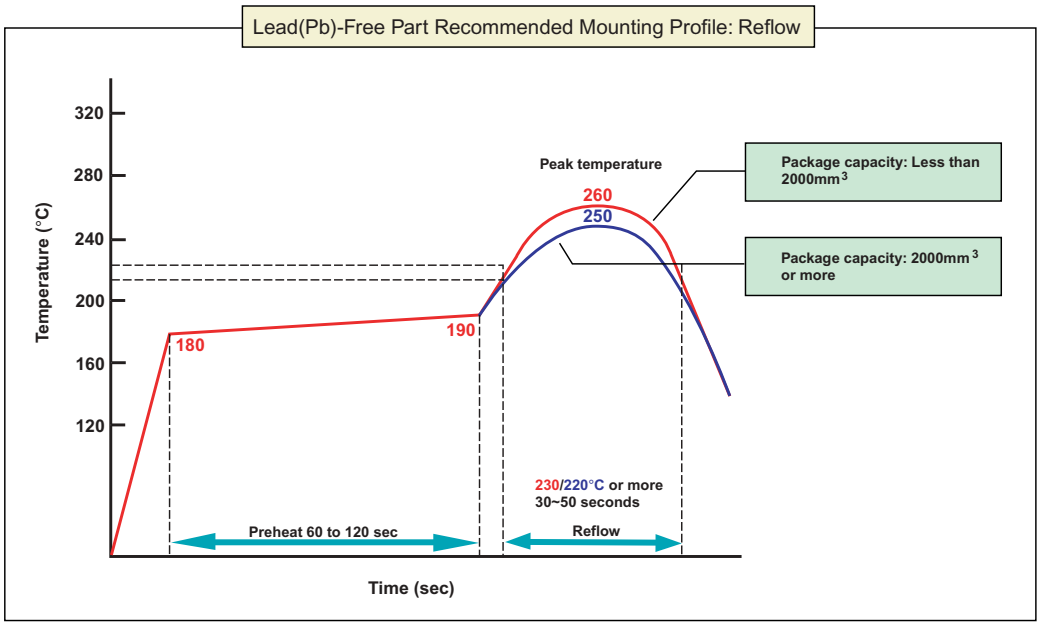
Figure 5-3 Characteristics of Typical Lead(Pb)-Free Solder



Lead(Pb)-Free solder paste: 250°C at peak. Solder paste: 230°C at peak.

One difference, for larger packages that are sometimes utilized for LSI devices, is that for packages with a great heat capacity (cubic capacity of 2,000 mm^3 or above), the maximum temperature may be 250°C. The temperature does not easily go up due to the larger capacity, as shown in Figure 5-4.

Figure 5-4 Lead(Pb)-Free Part Recommended Mounting Temperature Profile



5.3 Condition after Opening Moisture-proof Bag

As a result of the higher reflow temperature required for Lead(Pb)-Free solder, JEDEC re-classified the Moisture Sensitivity Level (MSL) of the standard J-STD-020C. After extensive testing, Toshiba Semiconductor Company has found that its Lead(Pb)-Free products meet the current JEDEC standard. Typically, the maximum usable time of Lead(Pb)-Free products out of moisture-proof bag, i.e., 168 hours under 30°C, 60 percent relative humidity (RH) or less, is approximately equivalent to that of products that are not Lead(Pb)-Free. Some products, including power and opto devices, have additional handling requirements. Please refer to specific instructions provided on the package of each device.

6.0 Quality and Reliability of Lead(Pb)-Free Products

Reliability test results of Lead(Pb)-Free products and board-mounted testing results are provided as examples in this section. Since the test conditions may vary by each product, please contact your TAEC sales representative for additional detail.

Table 6-1 Solder Compositions

Item	Stated in this document	Composition
Solder/Solder Paste	Sn-Pb	Sn-37Pb
	Sn-Ag-Cu	Sn-3Ag-0.5Cu
Solder Plating	Sn-Pb	Sn-10Pb
	Sn-Cu	Sn-2Cu
	Sn-Ag	Sn-3.5Ag
Solder Ball	Sn-Pb	Sn-37Pb
	Sn-Ag-Cu	Sn-3.5Ag-0.75Cu

6.1 Package Quality and Reliability

6.1.1 Heat Resistance for Reflow Soldering

As the melting point of Lead(Pb)-Free solder is higher in general, the reflow soldering temperature may be higher than tin-lead (Sn-Pb) soldering. The heat resistance test for Lead(Pb)-Free packaging is performed with the use of higher temperature reflow than that of the packages that are not Lead(Pb)-Free.

The test sequence is (1) open moisture proof package, (2) soak and (3) reflow four times. Visual inspection is first used to check for deformation or fracture, then electrical characteristic tests are performed. Scanning Acoustic Tomograph (SAT) is applied to detect delamination and cracks. An example of heat resistance testing is shown in Table 6-2.

Table 6-2 Sample Results of Reflow Soldering Heat Resistance Test Memory Products

Test	Condition	Package	Result	
			Quantity	Failure
Reflow Heat Resistance (Electrical Characteristics)	30°C/70%RH 192h IR Reflow (260°C Max x 4 times)	TSOP I 48-P-1220-0.5	500	0
		P-TFBGA56-0710-0.8	500	0
Reflow Heat Resistance (Visual, SAT)	30°C/70%RH 192h IR Reflow (260°C Max x 4 times)	TSOP I 48-P-1220-0.5	60	0
		P-TFBGA56-0710-0.8	60	0

Table 6-3 shows the results of a heat resistance test for reflow soldering of a Lead(Pb)-Free TSOP package (TSOP I 48-P-1220-0.5) and Table 6-4 shows the results of a heat resistance test for reflow soldering of a ball-type package that is Lead(Pb)-Free (P-TFBGA56-0710-0.8).

Table 6-3 Reliability Test Results of TSOP I 148-P-1220-0.5 Memory Products

Test	Condition	Package	Result	
			Quantity	Failure
HAST (Highly Accelerated Stress Test)	130°C/85%RH/3.6V 100h	Sn-Cu	100	0
		Sn-Ag	100	0
THB (Temperature-Humidity and Bias Test)	85°C/85%RH/3.6V 1,000h	Sn-Cu	200	0
		Sn-Ag	200	0
TCT (Temperature Cycle Test)	-65°C/150°C 500cyc	Sn-Cu	200	0
		Sn-Ag	200	0

Pre-conditions: 30°C/70%RH 192h, IR Reflow (260°C, 4 times max)

Table 6-4 Reliability Test Result of P-TFBGA56-0710-0.8 Memory Products

Test	Condition	Solder Ball	Result	
			Quantity	Failure
HAST (Highly Accelerated Stress Test)	110°C/85%RH/3.6V 100h	Sn-Ag-Cu	100	0
THB (Temperature-Humidity and Bias Test)	85°C/85%RH/3.6V 1,000h		200	0
TCT (Temperature Cycle Test)	-55°C/125°C 500cyc		200	0

Pre-conditions: 30°C/70%RH 192h, IR Reflow (260°C, 4 times max).

6.1.2 Whisker Evaluation

Whisker evaluation tests are typically performed for 1,000 hours. A comparison of whisker evaluation test results for tin-lead (Sn-Pb), tin-copper (Sn-Cu) and tin-silver (Sn-Ag) plating of a TSOP I 48-P-1220-0.5 are shown in Table 6-5.

Table 6-5 Whisker Evaluation and Result of Sn-Cu and Sn-Ag Plating of TSOP I 48-P-1220-0.5 Memory Products

Test	Condition	Package	Result	
			Quantity	Failure
Whisker	60°C/90%RH 1,000h	Sn-Pb	240	0
		Sn-Cu	240	0
		Sn-Ag	240	0

Criteria: Inspected by Stereo Microscope (x50 magnified); whisker length should be less than 50 µm.

6.2 Solderability

Extensive testing has been conducted to evaluate solderability of Lead(Pb)-Free products. Standard solderability tests have been conducted in which leads are soaked in a soldering bath to evaluate solderability, using the criteria that the solder wetting area should be more than 95 percent, as shown in Table 6-6.

Table 6-6 Solderability Test Result Memory Products

Test	Condition		Solder	Solder Plating	Result	
	Solder Temp.	Soak Time			Quantity	Failure
Solderability	215°C	3 sec.	Sn-Pb	Sn-Pb	30	0
	230°C		Sn-Pb	Sn-Cu	30	0
				Sn-Ag	30	0
	245°C		Sn-Ag-Cu	Sn-Cu	30	0
				Sn-Ag	30	0

Pre-conditions: 85°C/8% RH, 16 hour test criteria: The solder wetting area should be more than 95%.

Meniscograph tests have also been used to study the wetting time of Lead(Pb)-Free package solder plating compared to package solder plating that is not Lead(Pb)-Free. Measuring the time to reach the zero buoyant level (zero-cross time = wetting time) of wetting force vs. time. When zero-cross time is shorter, wettability is better. Figure 6-1 shows zero-cross time of Sn-Pb solder paste and Figure 6-2 shows that of Sn-Ag-Cu solder paste.

Figure 6-1 Zero Cross Time of Sn-Pb Paste

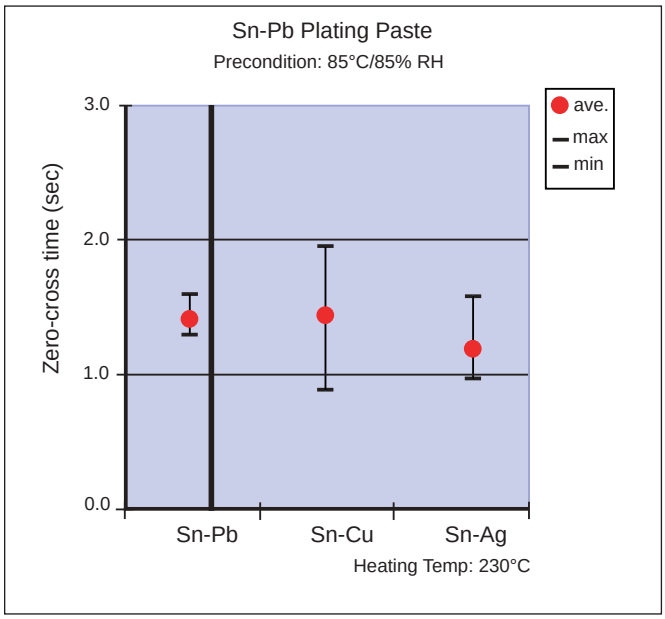
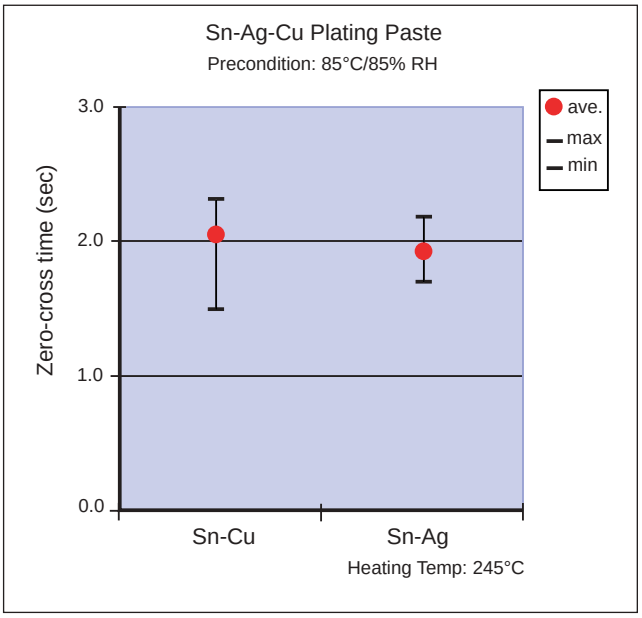


Figure 6-2 Zero-Cross Time of Sn-Ag-Cu Paste



Criteria: Zero-cross time should be less than 3 sec.

6.3 Solder Joint Reliability

Solder joint strength of the Lead(Pb)-Free packages is similar to that of packages that are not Lead(Pb)-Free. Figure 6-3 shows the method of the lead joint strength test, and Figure 6-4 shows lead joint strength in various combinations with solder plating and solder paste for TSOP I 48-P-1220-0.5. Repetitive bending tests, and package pull/strength tests have also been conducted to compare the soldering strength of Lead(Pb)-Free packages to packages that are not Lead(Pb)-Free. The results show that the Lead(Pb)-Free packages are equivalent in terms of solder strength and reliability to packages that are not Lead(Pb)-Free.

Figure 6-3 Solder Joint Strength Test

Solder Joint Reliability	Evaluation Conditions
Temperature cycle conditions	
TCT conditions Cycle	-40°C 30min 125°C 30min
Read out points	Initial, 100, 300, and 500 Cycles
Measuring method of solder joint strength	
Lead pull speed	20mm/min
Tool	Load cell
Judgment criteria	More than 5N

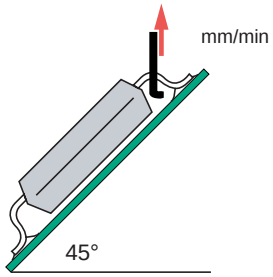
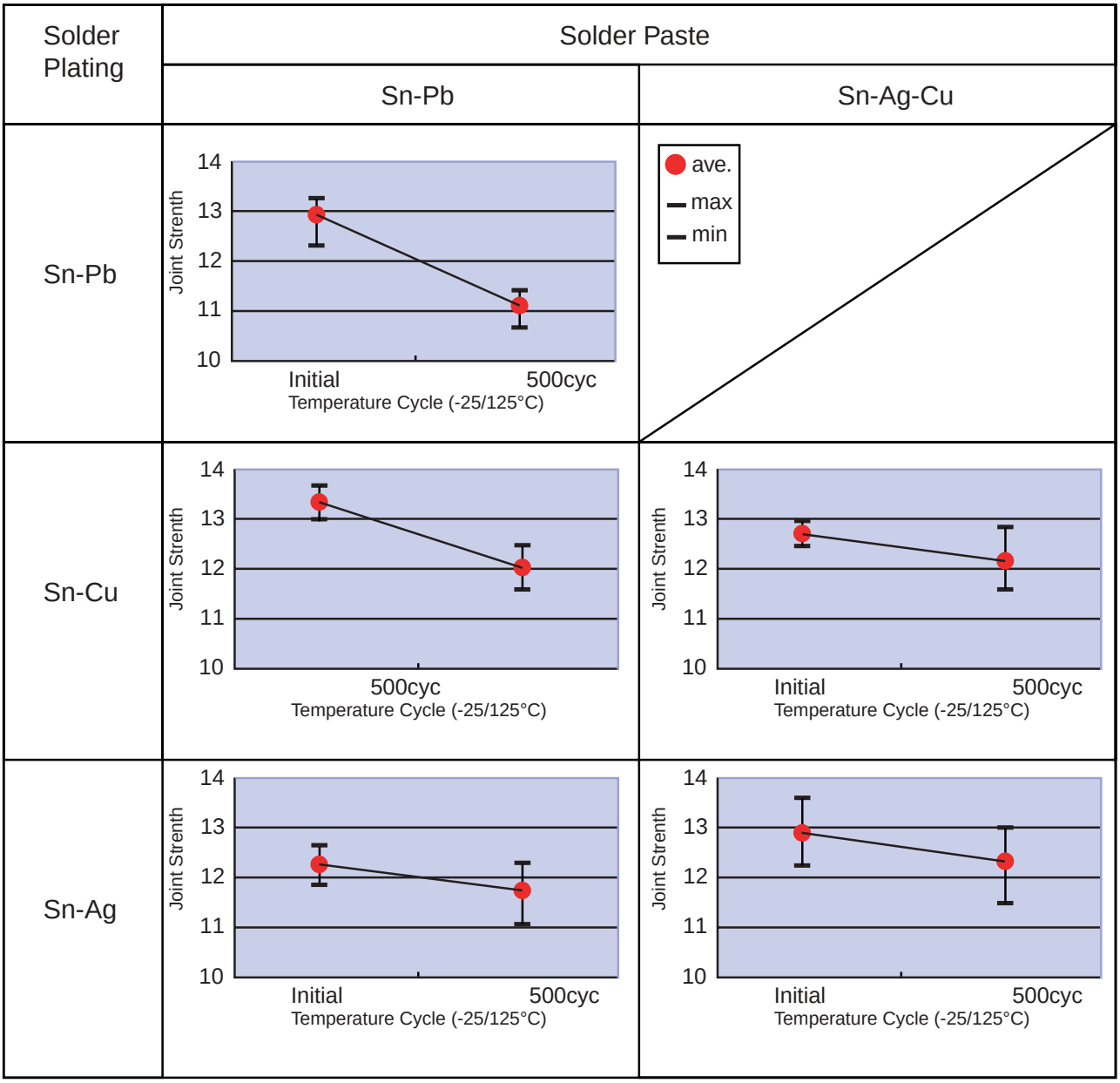


Figure 6-4 Representative Solder Joint Strength Test Results



7.0 How to Distinguish Toshiba Semiconductor Company's Lead(Pb)-Free Products

Toshiba Semiconductor Company's Lead(Pb)-Free parts can be identified by the part number and/or Lead(Pb)-Free designator that appears on the packing label affixed to the boxes and on the standard Enterprise Application Integration (EAI) barcode label on the outer box. Product naming conventions for Lead(Pb)-Free parts vary slightly by business unit. Examples for Memory products, Discrete products and System LSI products are shown below.

7.1 Part Number

7.1.1 Memory Products

For Memory products, a letter "G" is specified in the part number field of Lead(Pb)-Free packages to distinguish Lead(Pb)-Free products from conventional products that are not Lead(Pb)-Free, as shown in the examples in the table below. Exceptions may apply to some custom products; please contact your TAEC sales representatives for details.

Table 7-1 Distinguishing Lead(Pb)-Free Part Numbers—Memory Products

Representative Products	Part Number for Product that is not Lead(Pb)-Free	Lead(Pb)-Free Part Number
NAND 128Mb TSOP	TC58128AFT	TC58128ATG
PSRAM 32MbP-TFBGA	TC51WHM516AXBN	TC51WHM516AXGN

Note: Underlined letters show the package type

7.1.2 Discrete Semiconductor Products

Because Toshiba Discrete Semiconductor products may be Lead(Pb)-Free, have a Lead(Pb)-Free Finish, or be non-Lead(Pb)-Free, part numbers have been established to allow customers to distinguish between the three. Table 7-2 sets forth the part number scheme.

Table 7-2 Distinguishing Lead(Pb)-Free Part Numbers—Discrete Products

Product Category	Additional Code Displayed in Parenthesis After Product Name/Number	Label Indication on Package
Parts converted to Lead(Pb)-Free	Added F	Lead(Pb)-Free
Parts converted to Lead(Pb)-Free Finish only	Added Q	Lead(Pb)-Free Finish
Original Lead(Pb)-Free products*	No Change to product code	Lead(Pb)-Free
Originally only terminal finish is Lead(Pb)-Free*	No Change to product code	Lead(Pb)-Free Finish

*From mass production start.

7.1.3 System LSI Products

Because Toshiba Semiconductor Company System LSI products may be Lead(Pb)-Free, have a Lead(Pb)-Free Finish, or be non-Lead(Pb)-Free, part numbers have been established to allow customers to distinguish between the three. Table 7-2 sets forth the part number scheme.

Table 7-3 Distinguishing Lead (Pb)-Free Part Numbers—System LSI Products

Package Category	Additional Code Displayed in Parenthesis After Product Name/Number	Label Indication on Package
Parts converted to Lead(Pb)-Free	Add “G" to the end of full code	Lead(Pb)-Free
Parts converted to Lead(Pb)-Free Finish only	Add "Q" to the end of full code	Lead(Pb)-Free Finish
Original Lead(Pb)-Free products*	Not changed	Lead(Pb)-Free
Originally only terminal finish is Lead(Pb)-Free. *	Not changed	Lead(Pb)-Free Finish

*From mass production start

7.2 Packing Label

Lead(Pb)-Free marking is indicated on the outer box label as follows:
Lead(Pb)-Free products: [Lead(Pb)-Free]
Lead(Pb)-Free Finish products: [Lead(Pb)-Free Finish]

Figure 7-1 Lead(Pb)-Free Packing Label

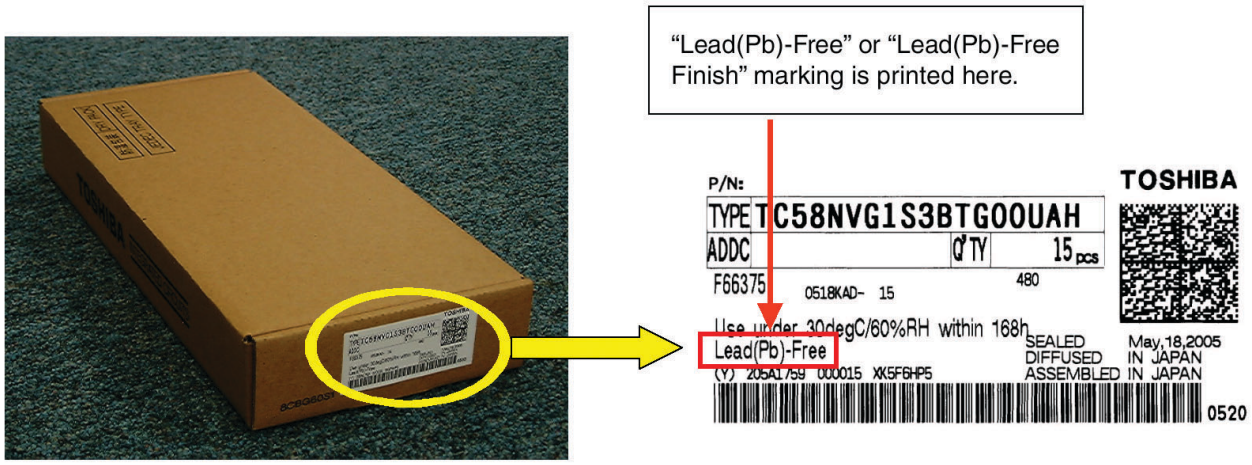
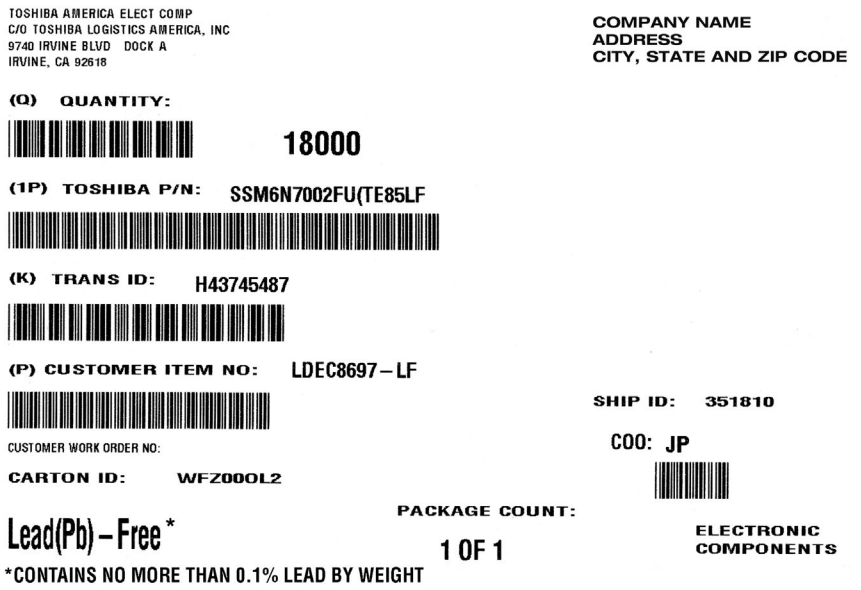


Figure 7-2 Lead(Pb)-Free Finish Standard EAI Packing Label (Bar Code)

Figure 7-3 Lead(Pb)-Free Standard EAI Packing Label (Bar Code)



8.0 Customer Qualification and Testing

Toshiba Semiconductor Company and TAEC are working closely with customers to match our roadmap for transitioning to Lead(Pb)-Free products to their Lead(Pb)-Free implementation plans. Some customers are already moving aggressively to Lead(Pb)-Free manufacturing. For customer qualification, some customers have submitted their requirements in writing, or have sent surveys regarding Toshiba Semiconductor Company's Lead(Pb)-Free implementation plans. Toshiba Semiconductor Company will provide samples for customer qualification and testing upon request. We also encourage customers to meet to discuss any specific requirements they may have.

NOTES

CORP 05 826
9/01/05

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INVENTOR OF FLASH MEMORY

TOSHIBA