# Ceramic and Plastic PGA Package Comparison for IBM x86 Microprocessors

## *Application Note*

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| Revision Summary: This is the initial release of this Application Note. |

X86 applications notes and databooks can be found on the website at ***http://www.chips.ibm.com/products/x86***

# Introduction

The plastic pin grid array packages are relatively new compared with traditional ceramic pin grid array packages. The 296 pin ceramic pin grid array with integrated copper-tungsten heat slug and spreader package has been used for IBM 6x86 and 6x86L microprocessors[1]. The introduction of new plastic package for IBM 6x86L and future products might be new to many of users. In light of above, this application note will discuss key differences and similarities between these packages.

## Mechanical, Thermal and Electrical

| Parameter | 296 Pin Ceramic PGA | 296 Pin Plastic PGA |
|---|---|---|
| **Device attach to** | Cu-W (10Cu90W) heatslug | Cu heatslug |
| **Device protection** | Ceramic or metallic lid | Epoxy filling |
| **Package Insulator material** | Ceramic | BT Laminate |
| **Package Conductor material** | Tungsten or Molybdenum | Copper |
| **Package Thermal Enhancement Material** | Au plated Cu-W Heat slug and Spreader | Ni plated Cu Heat slug and Spreader |
| **Thermal Solution Attachment Area** | 31.75 mm X 31.75 mm | 21 mm X 21 mm |
| **Thermal Conductivity of Heat slug and Spreader** | ~ 200 W/m-K | ~ 400 W/m-K |
| **Heat slug and Spreader attach** | Au/Sn Brazing | Sn/Pb Soldered |
| **Pin Material** | Kovar | Kovar |
| **Pin Attach to the Package** | Au/Sn Brazing on bottom surface | Press fit into plated thru hole and 90/10 Pb/Sn dip |
| **Weight** | > 30 gms. | < 20 gms. |
| **Internal Thermal Resistance of Package with Heatsink** | 0.4 C/W | 0.5 C/W |
| **Socket Compatibility** | Plugs into Socket 7 | Plugs into Socket 7 |

***Table 1. Mechanical, Thermal and Electrical Comparison between 296 Pin CPGA and PPGA Packages.***

[1] The IBM 6x86 and 6x86L Microprocessors are designed by Cyrix Corp., and manufactured by IBM Microelectronics.

## Mechanical

The electronic device, such as microprocessor die, used for both ceramic pin grid array and plastic pin grid array packages is exactly the same from the mechanical and electrical points of view. The device or die is attached to the integrated heatslug and spreader in both packages. However, the die is attached to the Au plated Cu-W heatslug in the case of the ceramic PGA package while for the plastic PGA package the die is attached to the Ni plated Cu heatslug. A wide variety of die attach materials can be employed for both packages. The die is electrically attached to the package with wire bond technology in both packages. In order to protect the die from the harsh environment, a ceramic or metallic lid is used as a cover in CPGA while an epoxy is dispensed over the die after mechanical and electrical attachment of die to the package in the case of PPGA. The epoxy is then cured at elevated temperatures.

The coefficient of thermal expansion of silicon die is roughly 7 times lower than the copper heatslug and hence the selection of die attach epoxy and processes are carefully chosen to compensate the mismatch in the coefficients of thermal expansion between them in the PPGA package. The coefficient of thermal expansion of silicon die is about 2 times lower than the copper-tungsten alloy in a CPGA package.

The pins for both packages is made of Au/Ni plated Kovar and are of the same dimensions. Since the coefficients of thermal expansion of Kovar and ceramic are in the same range, the Kovar pins are brazed to the surface of the CPGA package with Au/Sn alloy. While the coefficient of thermal expansion of Kovar is about 4 times less than the coefficient of thermal expansion of plastic laminate, the Kovar pins are pressed fit into the plated through holes and then the tip of the pin is solder dipped in the PPGA package. As one can expect, the density of the ceramic material is high compared with the density of the plastic material, the PPGA package weighs less than the CPGA package. However, both CPGA and PPGA packages are identical in dimensions and can be plugged into socket 7.

## Thermal

Although the impact of variations in die attach material can be on the internal thermal resistance of the package, the material alone does not impact the internal thermal resistance of the package but the several other parameters such as die attach thickness, the amount of bond coverage, void and the size of the die also have significant influence on the internal thermal resistance of the package.

Both CPGA and PPGA packages are thermally enhanced with integrated heatslug and spreader. The difference is in the packaging is that the PPGA is enhanced with Ni plated copper heatslug and spreader because the coefficient of thermal expansion from the package material expands in heat at the same rate as the coefficient of thermal expansion of the plastic laminate insulator. The CPGA package is enhanced with copper-tungsten alloy heatslug and spreader because it has a lower coefficient of thermal expansion that is proportional in rate with the coefficient of thermal expansion of ceramic insulator.

The bulk thermal conductivity of copper heatslug and spreader in PPGA package is almost twice the thermal conductivity of the copper-tungsten heatslug and spreader in CPGA. This enhanced thermal conductivity improves the heat transfer effectively. However, the size of the copper heatslug and spreader is smaller than the size of copper-tungsten heatslug and spreader in CPGA package. The thermal conductivity of the plastic is low in the x-y plane compared with the ceramic. Hence, the overall package internal thermal resistance of the PPGA package is slightly lower than the CPGA package's internal thermal resistance.

Although an external heatsinking device such as heatsink or fan/heatsink is secured with a mechanical retention mechanism such as a spring loaded clip which can be attached to either the package body or the tabs of socket 7, it is strongly recommended that the external heatsinking device be secured with a mechanical retention mechanism that attaches to the tabs of socket 7 in case of PPGA package. The clip force does not only secure the heatsinking device but also helps remove the micro air voids between the heat spreader and heatsinking device's bottom surface. This, in turn, improves the thermal conduction path between the package and heatsinking device. A minimum of 5 lbs of clip force is recommended. A clip force higher than 5 lbs does not improve the thermal conduction significantly.

Since the thermal conduction interface area of the Cu heatslug is lower than the Cu-W heatslug, it is recommended that the interface material used for heatsink attachment, such as thermally conductive grease, be of higher thermal conductivity, such as 1.0 W/m-K, used for PPGA package. Since the thermal conduction interface area is reduced in the case of the PPGA package, the flatness of the interface surfaces would obviously be improved and hence the interface attach material thickness can also be reduced to achieve a better thermal conduction path. It is also imperative that the interface attach material be thermally conductive but electrically insulated to avoid the shorting of the components on the top of the package.

## Electrical

The relative dielectric constant of ceramic material is more than twice the dielectric constant of plastic material. The advantage of low dielectric constant can be realized in propagation delay of a signal trace. The low dielectric material also reduces cross talk and therefore the traces can be finer brining about a higher packaging density in the PPGA package. The conductor in a CPGA package is usually tungsten while in the PPGA package it is copper. The resistibility of tungsten is roughly 3 times higher than the resistibility of copper. The resistance of the copper traces in the PPGA package is less than the tungsten in CPGA. This reduced resistance provides better voltage distribution in the processor and thus improves the performance.

## Summary

The PPGA package is an alternative to the CPGA package. The PPGA package improves the electrical performance without impacting mechanical and thermal performance. Both CPGA and PPGA packages are subjected to the reliability qualification tests to ensure a reliable product.