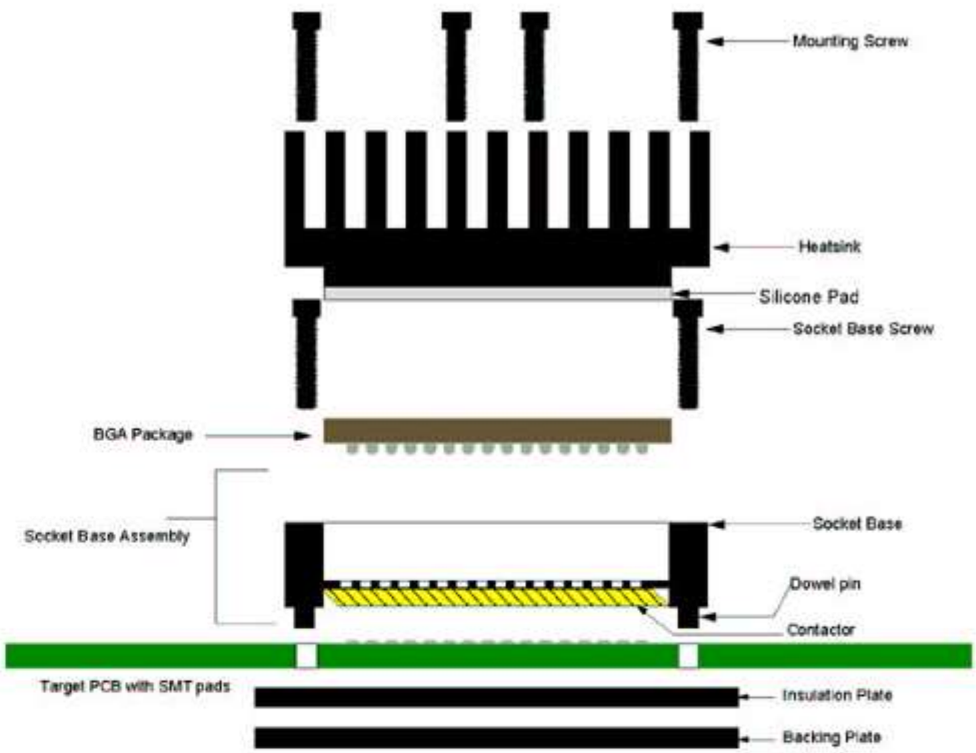
BGA Socket with Heatsink for High Power Devices

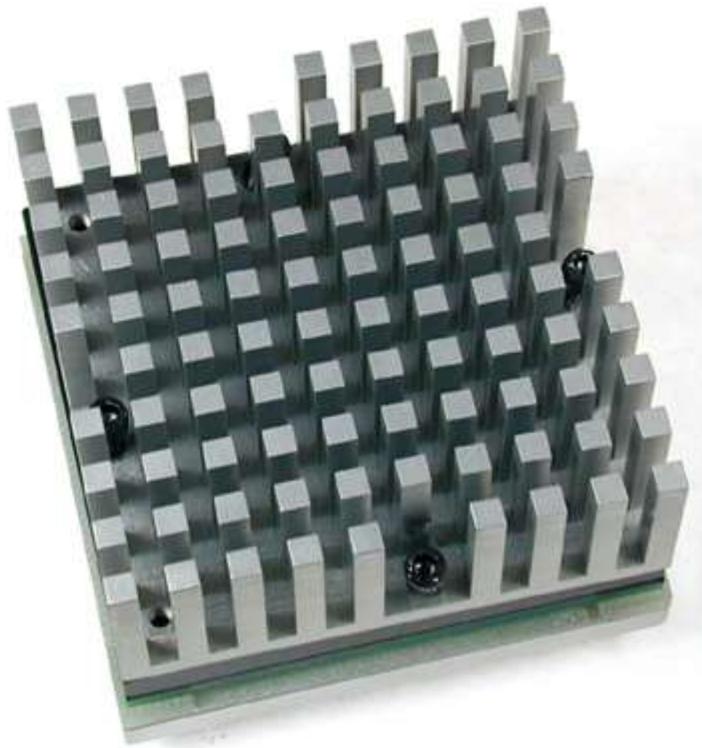
Introduction

The classic function of a socket is to provide a connection mechanism from the IC (Integrated Circuit) to the circuit board with as little electrical load as possible. This allows the IC to function as it is soldered into the PCB (printed circuit board) but can be replaced by another IC to upgrade or test multiple IC's. With the advent of "light bulb power" type IC's getting into the tens of watts perhaps even 40 to 50 watts, the socket needs to accommodate removal of the heat due to this power or the IC will self destruct or worse.

Socket Overview



Two of the most common high frequency contactors for a socket are elastomer and pogo pin with bandwidths of 6-20 GHz and 2-10 GHz respectively depending on the connection components selected. A functional drawing of a socket using these connection mechanisms is shown in Figure 1. The socket consists of the connection mechanism that interconnects BGA balls to the target PCB pads, socket body for precisely placing the IC over the connection mechanism, and a compression mechanism to apply the down force to compress the BGA's into the connection mechanism. In a high power application the compression mechanism needs to perform double duty acting as a heatsink pulling the heat out of the IC. A backing plate may be needed to provide the rigidity for the connection mechanism to work reliably. This is dependent on the size of the chip, flatness required, PCB material and PCB thickness. Figure 2 shows a picture of BGA socket with 30 watt heat sink.



Modes of Heat Transfer
Heat transfer can be defined as the transmission of energy from one region to another as a result of temperature difference. Heat conduction is due to the property of matter which causes heat energy to flow through the matter. Heat convection is due to the property of moving matter (naturally or under force) to carry heat energy from higher temperature region to low temperature region. Heat radiation is due to the property of matter to emit and absorb different kinds of electro-magnetic radiation.

Heat Sink Function
A common heat sink system consists of a finned metal part forced down onto the IC and pulling the heat from the IC through conduction and radiating the energy into the air. A fan is added to blow air over the heat sink to remove heat through convection which greatly lowers the temperature of the heat sink. Higher the velocity of the airflow, lower the heat sink temperature – as you would expect.

Parameter Consideration
When designing a heat sink, following are the characteristics of the IC to be considered:
- Thermal resistance from die to IC heat spreader (case)
- Size and material of the heat spreader on the IC.

Heat sink is designed to transport the heat from the heat spreader on the IC to ambient air. The

other characteristics to be considered for the heatsink include the following.
- Thermal resistance from IC heat spreader (case) to heat sink
- XY area of heatsink
- Whether heatsink is finned or pin design, height of pins or fins
- Whether a fan is used and its air flow rate
- Mounting relationship of fan to heatsink – vertical or horizontal
- Heatsink material (aluminum or copper typically for machined parts)
- Maximum temperature to be allowed at die
- Ambient conditions of air and wall temperature and pressure (altitude)
- Heatsink color (Black can be significantly more efficient than white)

Thermal Resistance

Thermal resistance is the critical parameter of heat sink design. The thermal resistance between a silicon-die junction and the ambient air determines whether a heat sink is adequate. Total thermal resistance can be calculated as:

_ja = _jc + _ch + _ha

Where:

_ja (junction to ambient thermal resistance) = (Tj - Ta) / P

_jc (junction to case thermal resistance) = (Tj - Tc) / P

_ch (case to heat sink thermal resistance) = (Tc - Ti) / P

_ha (heat sink to ambient thermal resistance) = (Ti - Ta) / P

Ti = Heat sink temperature

Tj = Junction temperature

Tc = Case temperature

Ta = Ambient temperature

P = Power dissipation

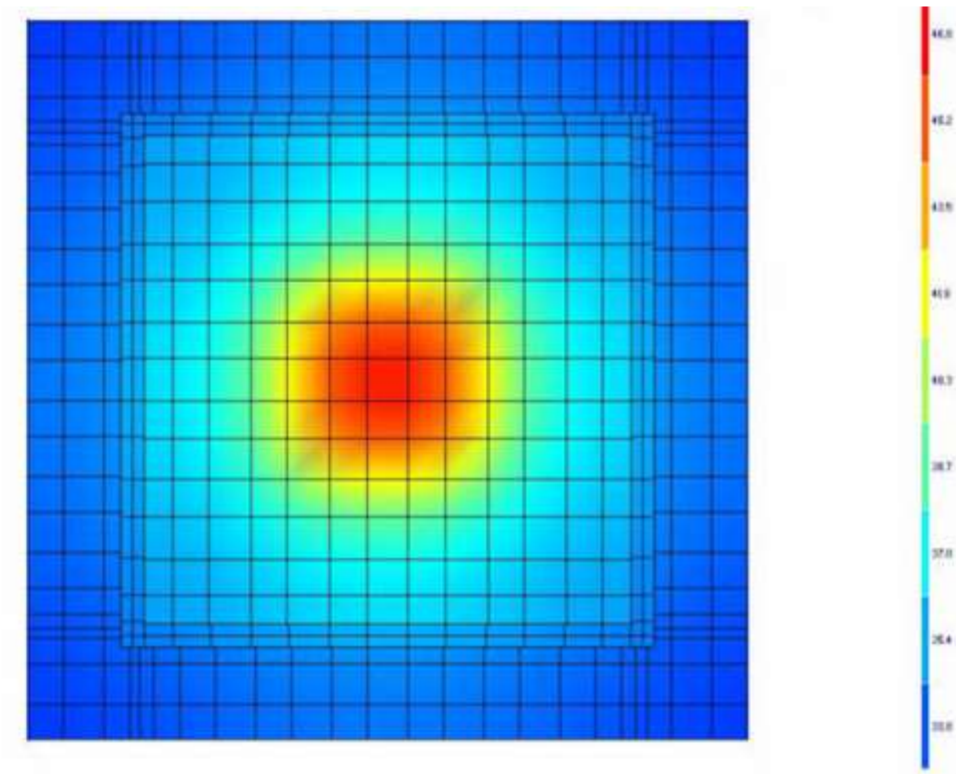
Thermal resistance is directly proportional to thickness of the material and inversely proportional to thermal conductivity of the material and surface area of heat flow. A heat sink design can be a complex task requiring extensive math – finite element analysis, fluid dynamics, etc. Luckily there are tools to be used that can quickly give you a fairly accurate thermal model. To design a 30 watt heat sink, off-the-shelf heat sink design software – QFin was used. Designing the heat sink is an iterative process with the possibility of changing a number of the heat sink parameters as listed above. It should be noted that part of the design is to make sure that the heat sink is manufacturable. For instance, changing the length and spacing of the pins on the heatsink can reduce the cost of the heatsink substantially and sometimes even producible. Several variables (surface area of heat sink base, reduced mass, structural rigidity for ease of manufacturing, fin geometry, cross-cut pins for efficient air flow, etc.) can be modified for optimal thermal design.

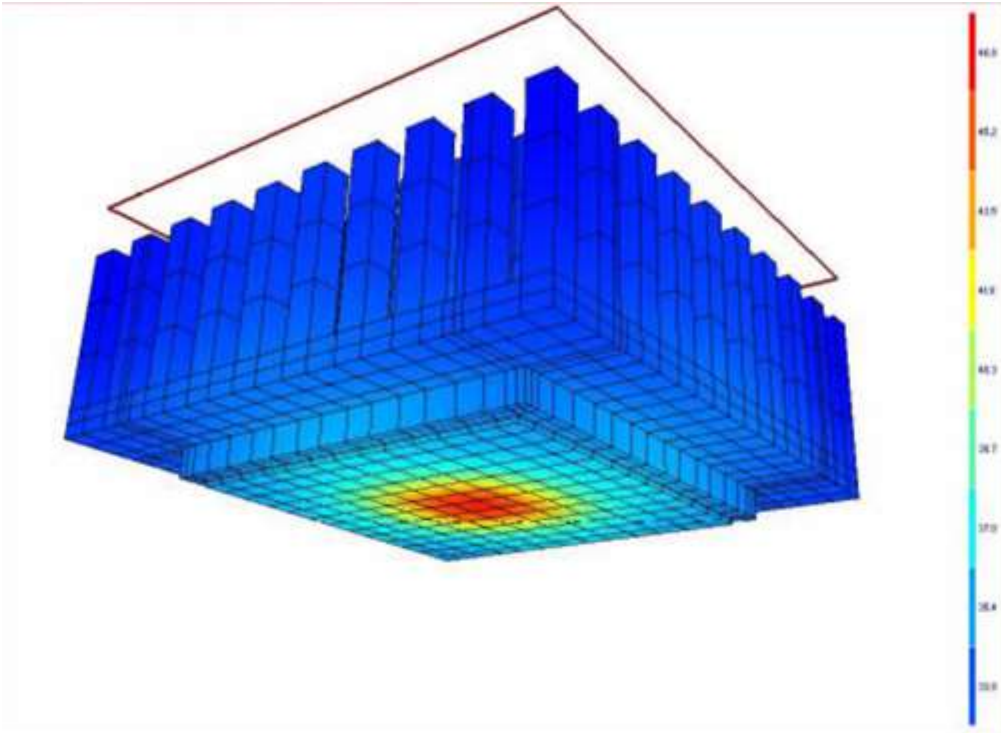
Thermal Interface Material

When two surfaces are interfaced, voids between the surfaces can cause poor heat transfer. This is normally solved with a thermal interface material that fills the gap between the surfaces (e.g. thermal grease, silicone pad, etc.). Depending upon the application and mating surface a thermal interface material can be selected. Thermal grease will spill over intricate parts and cause contamination which is especially dangerous in a very fine pitch, tight tolerance socket. It becomes necessary to have a solid silicone pad for high density interfaces even though thermal resistance is higher for the silicone pad than the thermal grease.

Heat Sink Design

The following example uses a top mounted heatsink for an IC with an encapsulated die 16X16 mm XY dimension. The IC has a copper heat spreader with dimensions of 39.6 X 39.6 mm. The aluminum finned heat sink presses down on the IC’s copper heat spreader with a 0.25mm thick thermally conductive filled polymer silicone laminate to fill possible voids between the two metal surfaces. This silicone laminate has a thermal resistance of 0.838708 C*sq cm/W. With a size of 39.6 mm2 the temperature rise across this interface pad is approximately 1 degree C or less. The heat sink is 60.5X60.5 mm with 100 square pins of 3 mm square and 18 mm tall. A top down fan is used with 8.67 liter/second capacity to convection cool the heatsink. Ambient air temperature of 25 C and ambient pressure of 101.325 KPa were used to solve for the heat sink solution. The result at a 30-watt load from the die, the junction temperature is predicted to be 72.97 C. Figure 3 and 4 show the expected heat distribution on the heatsink. The hottest spot on the heat sink is 46.27 C with the average temperature at 36.17 C.





Conclusion

Thermal management of BGA socket is an all-inclusive method involving the material selection, design, analysis, optimization and verification of a cooling system for the purpose of producing reliable socket for testing high power devices. Currently, the classical means of cooling components through conduction and convection is satisfactory solution to many problems. In the future, cold plates, cold water circulation pipe and other enhancement techniques can be applied to lower temperatures so that new goals may be achieved.

Author

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