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Coaxial IC Socket for PAM4 & High Power Specification Requirement

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Abstract

Significant signal integrity improvement is required for IC socket in application of Gbps transmission and receiving IC. PAM “Pulse Amplitude Modulation” especially PAM4 : 52 Gbps transmission performance is configured with base band : 13 GHz, and differential signal transmission channel. For system performance achievement with signal integrity, the IC socket must keep up its own specification for Cross-talk performance between channel to channel under -50dB by signal transmission of PAM4 (52 Gbps). LSI Circuit needs large number of differential SerDes channel resulting in huge power consumption such as 400 watts or over per IC package. The IC socket has been given two different duties to solve all at once. The solution was simple, return to engineering base. And answers were “keep transmission line Zo = 50 Ω without signal leakage” and “keep pure thermal transfer path on the top of IC package” .

Summary

1. Differential transmission channel matrix & Cross-talk performance

The subject of differential channel matrix is staggered array and 1mm pitch contact with 4300+ contacts per package. Staggered matrix array example is shown in Fig 1. Fig 2 shows Cross-talk performance result achieving -50dB @ 13 GHz and also -50dB @ 20 GHz as per our original performance target spec requirement.

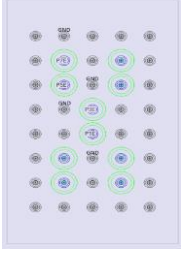

Fig 1 : Stagger differential transmission channel matrix example

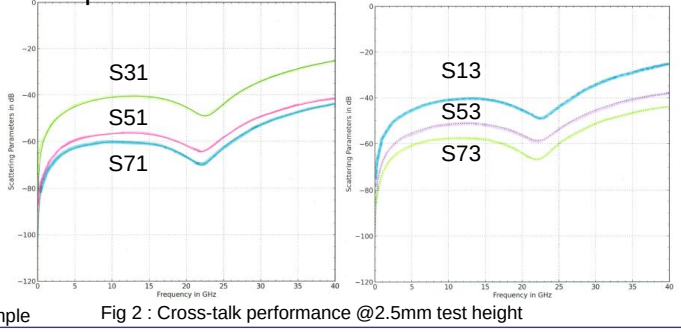

Fig 2 : Cross-talk performance @2.5mm test height

2. Base socket height design vs 1/4 wave length at 52 Gbps

Due to 13 GHz base band frequency, performance verification was extended up to 20 GHz for design allowance. The wave length corresponding to transmission line in base socket is 15.0 mm. 1/4 wave length is 3.75 mm at 20 GHz. In case of 52 Gbps, base band is 26 GHz. 30 GHz is chosen for design allowance. Wavelength is 10 mm, and 1/4 wave length is 2.5 mm. Based on this reason, transmission line length in IC socket (test height) was decided to be 2.5 mm.

Fig 3 is Cross-talk performance of 3.8 mm transmission line length by same design concept for IC socket, but cross talk performance was -30dB @ 20 GHz. Result did not meet the requirement.

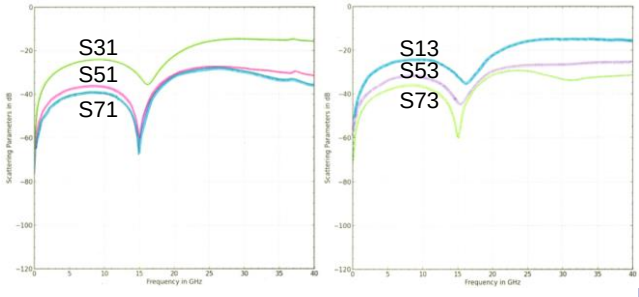

Fig 3 : Cross-talk performance @3.8mm test height

3. Characteristic impedance control for transmission line in IC socket base

Signal contact probe and connection must be pure transmission line as Zo = 50 Ω. So, complete coaxial contact technology was chosen, and transmission connection was from surface pad of mother board to IC terminal. Probe and coaxial line ground hole was designed simply as $Zo=138*\log(D/d)/\sqrt{\varepsilon}$, which means coaxial line everywhere in socket.

4. Full speed transmission signal process causes large power consumption in LSI

High speed and multi-channel SerDes function IC package like 65x65 mm and 52 Gbps operation causes high power consumption (400 watts or over). One of the design subject for this socket is thermal transfer and Tj control.

Fig 4 is High Pd IC socket design structure considered thermal transfer path and heatsink using heat pipe.

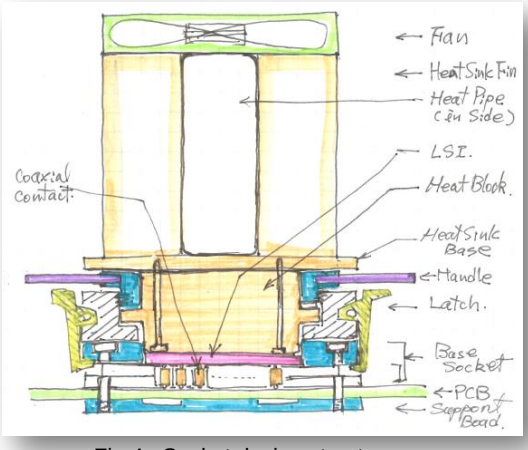

Fig 4 : Socket design structure

The socket was designed with handle operation cap, and thermal block (Cu) in the cap is on top of the package surface. Heat sink with fan has been set on top of the thermal block.
Thermal resistance (conductivity) of thermal block must be calculated by
(1) θch = Block height (m)/Area (m²)/Material thermal conductivity(W/m K).
Thermal equation must be
(2)Tj = Pd*θja+Ta = Pd*(θjc+θch+θha)+Ta
Here, Tj : Junction temperature of IC, may set to 110 ℃
Pd : Power dissipation of IC, 400 watts
θja : Thermal resistance from junction to air, 0.1913 ℃/W
θjc : Thermal resistance from junction to case, 0.055 ℃/W
θch : Thermal resistance of thermal block, 0.021318 ℃/W
θha : Thermal resistance of heatsink and fan, 0.115 ℃/W
Ta : Ambient temperature(air) 30 ℃
Tj(110℃)>Pd(400)*(θjc(0.055)+θch(0.0213)+θha(0.115))+Ta(30)=106.5 ℃

5. Fig 5 is simulation confirmation

Overheating confirmation for thermal transformation of 400 watts verified by Tj. Tj=107.3 ℃ is in the border safety line (assumption of 110 ℃ junction temperature).

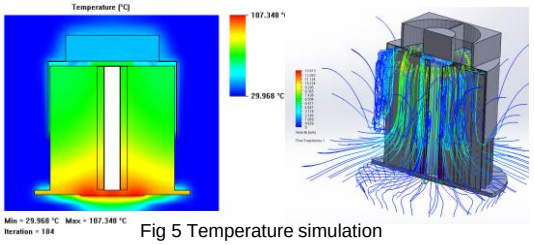

Fig 5 Temperature simulation

6. Fig 6 is for example of IC socket

IC Package : 67.5 x 67.5 mm, 4,356 balls,
Differential pair channel 132
IC Socket : 124 x 120 mm,
Handle cap operation with 400 watts IC

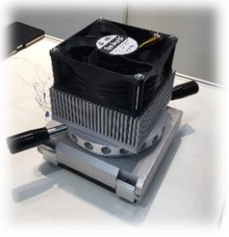
Fig 6 : Design example

Conclusion

Transmission line be 1/4 waveform length and complete coaxial Zo line for no signal leakage in connector are key factors to reach best Cross-talk performance for PAM signal transformation. For PAM4 results shown -50dB at 13 GHz, 52 Gbps or over.
Thermal control for very high power dissipation IC due to high speed and large number of multichannel transmission must be solved by careful design of thermal transfer path using best thermal conductivity and heatsink system design by heat pipe or similar application.