INTERFACING TO THE DIGITAL MICROMIRROR DEVICE FOR HOME ENTERTAINMENT APPLICATIONS

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ABSTRACT

The Digital Micromirror Device (DMD™) is a reflective light modulating MEMS device used as the heart for high quality digital projection systems. Traditionally, DMD’s™ have been used for conference room projectors, video walls, and large venue applications including digital cinema. In transitioning DMD™ based products into the home theater market, a key challenge has been ensuring a reliable system interface to the DMD™ for the life of the product, typically a minimum of 10 years. There are three primary interfaces to the DMD™ in any projection display system: electrical, opto-mechanical, and thermal. Due to the optical nature and functionality of the DMD™, there are very unique design constraints that must be taken into account when developing solutions for these interfaces. An overview of the designs incorporated for each of the key interfaces in a home theater application is provided. The primary issues associated with these solutions as related to DMD™ packaging and reliability are then identified. Finally, a discussion of the assessment testing performed for each of these cases is presented.

Keywords: DMD™, Digital Micromirror Device™, DLP™, Interface, cLGA™

INTRODUCTION

The DMD™ is an optical MEMS device that is used to modulate light in projection systems to create digital images of unsurpassed image quality. The DMD™ is actually constructed of an array of microscopic hinged mirrors, currently either 13.8 or 17 microns square, built on top of a CMOS understructure, as shown in Fig. 1. The mirrors can be tilted to ±10° to either an “on” or “off” position by electrostatic forces applied via the CMOS understructure.

![Figure 1 – DMD™ Pixel Stack Up](Image)

When the mirror is tilted on, light is reflected from an illumination lamp through a projection lens. In the off state, the light is reflected outside the pupil of the projection lens. By turning the mirrors on for varying amounts of time, gray scale colors can be created. The primary colors, red, green, and blue...
are generated by either having three separate DMD®-s and a color-separating prism, or by using a single DMD® and passing the illumination light through a spinning color-filter wheel. The so-called “three-chip” design is used for high-end, high-brightness large venue applications, such as digital cinema. The “one-chip” design is used smaller venue applications like conference room projectors and home entertainment applications.

Since the primary function of the DMD® is to project a digital image off of the active mirror array, most of one side of the package for the device must be an optical window. This dictates that the basic package structure be similar to that shown in Fig 2. For optimal overall system performance, the DMD® must also be very accurately aligned to the optical system. This results in several non-traditional constraints and requirements in designing the interfaces to the DMD®. There are three primary interfaces to the DMD® device for any projection system:

1) Electrical
2) Opto-mechanical
3) Thermal

**NOMENCLATURE**

- cLGATM: c-spring Land Grid Array
- DMD®: Digital Micromirror Device
- HD: High Definition
- IO: Input / Output
- LGA: Land Grid Array

**Electrical Interface**

**Design Overview**

Similar to other higher end electrical components, the DMD® is not soldered to an electronics board. This is due to the fact that if during assembly the board fails, the DMD® would have to be scrapped. The converse is also true. During the system assembly process, it is possible to scratch the window of the DMD® such that there is an objectionable blemish on a projected image. In this case, the entire electronics board would have to be replaced. This risk can be mitigated by mounting the DMD® to a board with minimal electronics that is in turn connected to the main formatting board. Adding the requirement that the device be very accurately aligned to the optical system, traditional soldering just is not practical. Thus, the electrical interface must be achieved by means of mechanically attaching the DMD® to the electronics board.

Historically, the electrical interface to the DMD® has been accomplished with a layered conductive elastomeric interconnect. The “elastomers” are compressible rubber strips that have alternating conductive and insulating layers. Those used for DMD®-s are composed of two long alternating conductive strips separated by a middle insulating foam barrier as shown in Fig. 3. The elastomers are aligned to the pads on the DMD® and board by a plastic housing. This plastic housing is also typically used to align the DMD® assembly to the optics.

![Figure 3 – Elastomeric Interconnect Design](image)

There are two primary issues with this style of electrical interface to the DMD®. The first issue is that as the interface to the DMD® operates at higher and higher speeds, the impedance of the elastomers becomes unacceptable. The first generation HD1 device design for Home Entertainment can accommodate the elastomer’s impedance. However, future generations DMD®-s will operate at speeds incompatible with the elastomeric interface.

The second major issue is ensuring proper alignment of the pads on the DMD® with those on the electronics board. Even thought the plastic housing references the DMD® datum’s and has alignment pins to the board, there is the possibility of having electrical opens and shorts due to mechanical tolerances. When this occurs during assembly, the DMD®/board assembly must be taken apart, re-aligned and then reassembled. There exists the potential to have an intermittent failure if the DMD® to board pad misalignment is just right. This entire issue could be solved by widening the spacing between adjacent pads; however, by doing so limits the number of IO pins to the DMD® too much.

The HD1 device required a larger number of IO pins than previous packages of the same size. It also had to be able to be assembled in a very reliable method that ensured good electrical contact alignment. After investigating several different interconnect technologies, the solution chosen was the cLGATM.
The cLGA™ is a grid of c-shaped springs that are held in place by a plastic contact holder as shown in Fig 4. Since each individual contact is unique, their location can be explicitly specified. This results in the system being able to tolerate looser tolerances without the risk of electrical opens or shorts. It also allows for the pad arrangement on the back of the DMD™ to be arranged in a tight packed offset row formation that yields a higher total IO. This pad pattern also allows for other alternate interconnect technologies whereas the elastomeric interconnect pattern does not.

In almost all DLP™ products, the DMD™ is held firmly to the electronics board by clamping it between the optical interface and the board. In this case however, a clamp was used to hold the DMD™ firmly to the formatter as shown in Fig 5. This allows for proper operation to be verified during assembly and for that alignment to be maintained during shipping to the customer for final assembly.

**Issues with the Design**

Very seldom is any solution perfect. While the cLGA™ interface solved the primary problem of misalignment of the DMD™ to the board, it is not without its own drawbacks. One of these is that careful handling of the cLGA™ interposer is required during assembly. Due to the extremely small size of the springs, they can be very easily damaged or dislodged if something is slid across the tops of them. There also exists the potential to scrape off tiny plastic shavings when inserting the DMD™ into the cLGA™ housing. These plastic shavings can then prevent one or more of the springs from making good electrical contact. Through use of an assembly fixture to open up the retaining spring arms of the contact housing, and by providing proper training for the assembly personnel, this issue is easily managed.

Another issue is the distributed force exerted by the springs, approximately 35 pounds. While this is much less than what the traditional elastomers typically required, a total force of around 50 pounds, the c-springs do not have as much working travel. For previous designs for the same package size, the elastomers were compressed .020 inches or 12.5%. The c-springs, however, only have a total compression of .012 inches. This makes any bending in the board from the 35 pounds a concern. Thus, an aluminum stiffener plate is used on the back of the board to prevent bending and ensure full compression of all the springs.

The stresses put on the DMD™ ceramic base are also of key concern. With most of the front of the DMD™ package being a window, the clamp can only act on the outer edges of the ceramic. The stiffener plate, on the other hand, applies a distributed load across the back of the package. This results in bending stresses being applied the ceramic. This is not only a concern due to internal stresses in the ceramic, but also because of a new package design under development. The new Type C package design incorporates a flat window bonded directly to the ceramic package. This is significantly different from the current Type A package with a fused glass to Kovar window that is welded to another Kovar ring brazed onto the ceramic base. Figure 6 shows a cross-sectional view of both a package designs. Any stresses acting on the Type C window epoxy joint are of concern and need to be minimized to help prevent any long term reliability issues.

The final issue encountered with the cLGA™ interconnect, is possible corrosion on the board pads. Unlike elastomers, the
c-springs do not form an environmental seal. There is the potential for moisture and air to slowly seep between the cLGA™ contact housing and the DMD™ and/or the electronics board. Thus, as the results of several phases of testing described below, the decision was made to use electroplated gold for the board pads. Electroplated gold was already used for the DMD™ pads and the c-springs themselves.

**Assessment Testing**

Several phases of testing were done on the cLGA™ design to prove out the long term reliability of this new interconnect technology. The test plan developed was based off of EIA-701. Two sequences were designed that the test parts were divided between. The first sequence started with a 24-hour 85°C preconditioning. Then the parts were continuously monitored during a 50G 6-axis mechanical shock test followed by a 7.3Grms, 45 minute, 3-axis random vibration test. Finally, this sequence finished with an accelerated temperature cycling of 0 to 75°C for 1000 cycles with checks every 250 cycles.

The second sequence of testing started with a 20 mates and un-mates durability test. Then a continuously monitored thermal cycling test from ~40 to +70°C for 10 cycles was done. This was followed by a continuously monitored temperature-humidity test of 168 hours of 25 to 85°C at 80% humidity. The last step in this sequence was a 1000-hour humidity life test at 85°C and 85% humidity with checkpoints every 250 hours.

After several initial phases of testing used to refine the c-spring design, the cLGA housing and other design aspects, the testing focused on the integrity of the electrical circuit. The first phase of testing using production-tooled samples was performed with boards having a minimum of 5 microinches of immersion gold plating over 150 microinches of electroplated nickel on the contact pads. All of the parts passed each step of testing until the 85°C at 85% humidity life testing. Initial investigation showed a small amount of corrosion on the board pads. Later analysis of the corrosion would show that it was organic in nature, most likely resulting from improper cleanup of active solder flux during assembly of the test boards.

With the development schedule getting short, another phase of testing was performed this time using 30 microinches of electroplated gold over the nickel on the board pads. In this phase of testing, the parts were run through a single modified sequence of tests. This new test sequence was composed of the 24 hours at 85°C preconditioning followed by the 20 mates and un-mates durability test. The parts were then continuously monitored during a 50G, 6-axis shock; a 7.3Grms, 45-minute, 3-axis random vibration; and finally a ~40 to +70°C thermal cycling for 100 cycles. At the end of this step was the decision point to use the electroplated gold for production. However, the parts were still temperature humidity tested from 25 to 85°C and 80% humidity until failure. This was done to gain information about the potential life of the cLGA interconnect. The results showed initial fails, due to board corrosion, at the 1000-hour point but with most samples surviving past 2500 hours.

While results of the testing done with the cheaper immersion gold were somewhat suspect, the quality risk outweighed the cost and the decision was made to use electroplated gold in production and stop further testing. Additional tests might still prove that either a thinner layer of electroplated gold or even immersion gold could give acceptable performance. It should also be noted that since the DMD™ pads on the board had to be electroplated gold, the entire board was electroplated with 15 microinches of gold instead of the traditional immersion gold. By using a single plating process, the overall board cost was less than having to have the additional immersion gold step. This also gave the added benefit of eliminating the reliability problem of black nickel oxide that can occur when soldering ball grid array parts to a board.

**Opto-mechanical Interface**

**Design Overview**

Since the key function of the DMD™ is to modulate light, the optical-mechanical interface to the device is extremely critical. Since the front of the DMD™ package must be an optical window, only the outer edges of the front and sides are available for referencing to the opto-mechanical interface. Since all of the loading has to be applied to the perimeter of the package, unique bending stresses are imparted onto the package that must also be considered in designing the interface.

There are three primary alignments of the DMD™ to the optics:

1) Rotation about the projection axis
2) x-y alignment normal to the projection axis
3) Parallelism of the die to the projection axis normal

Rotation about the projection axis is important in aligning the optical engine to the projection screen. Since the HD1 device was intended for rear projection, this is especially important since the projected image is framed, thus providing a visual reference.

The x-y alignment of the die to the optics is important for two different reasons. The first is that the die must be properly located in the projection lens aperture. If the mirror array to projection lens aperture alignment is off, the corners of the image will be shaded. The other is that the illumination light on the DMD™ must be properly centered. The better that the DMD™ can be located to a particular reference both in x-y and rotation, the smaller the illumination light patch can be. This in turn allows more of the light to be concentrated on the active mirror array resulting in higher brightness and less heating of the DMD™. The lower heating is due to more light being reflected instead of being absorbed by the dark border around the active array that is used to reduce stray light and increase contrast.

When the DMD™ die is bonded to the ceramic substrate, its location is controlled to the datums on the edges of the ceramic package shown in Fig 7. Since the front edge of the ceramic is the primary datum, only two datum areas on one edge and then a single datum area centered on the adjacent edge are required. The double datum edge is used to control rotation and location in x-dimension. The single datum area on the other edge is required to control only the y-dimension location.
To properly align the c-springs to the DMD™ pads, the contact holder must already reference the sides of the package. Thus system level rotation about the projection axis and the x-y alignment normal to the projection axis can also be accomplished with the cLGA™ contact holder. The holder has datum pads that interface to the datum’s on the sides of the DMD™. To interface to the optics, the contact holder also has two locating pins along the array diagonal. The pads that interface to the DMD™ are tightly tolerated to these two pins. This allows for the active array of the DMD™ to be located relative to the optical housing very accurately.

For good focus, especially from one corner to the opposite corner, the parallelism of the active mirror array to the projection lens normal is a crucial factor. There are numerous elements in the projection lens and the parallelism of the datums to system focus from tolerances in the DMD™ is about 25%. The remaining 75% is due to tolerances in the rest of the optical system. These include how the projection lens is mounted to the optical housing, the tolerances of the lens elements in the projection lens and the parallelism of the datums for referencing the DMD™ and projection lens.

The DMD™ ceramic substrate is made up of several different layers of aluminum oxide with electrical wiring between. During the assembly process, the DMD™ die is bonded directly to the same layer of the ceramic that is used as the opto/mechanical interface datum. Doing so helps to minimize the number of interfaces between the die and the package datum.

Geometrically, only three points are needed to define a plane in space. Therefore, three specific areas on the front lip of the ceramic package are used to define the primary datum of the package. These three datum pads are used to specify the parallelism of the die. They are also used as the defined interfacing points in attaching the DMD™ to the optical housing.

Issues with the Design

The primary issue with the opto-mechanical interface design is the stresses applied to the DMD™ package. This is particularly true since the new Type C package design has an epoxyed on window. Unlike the welded Type A package, the Type C package is not a truly hermetic seal. Changes in the internal gases in the package can cause the mirrors to fail. Therefore the permeation of the epoxy joint is very crucial. Stresses on the epoxy can act to degrade this joint and potentially decrease the overall bondline thickness.

There are general bending stresses on the package due to all frontal loading having to be applied to the outer edges due to the window. These bending stresses result from the cLGA system clamp and the optical interface. There are also bending stresses resulting from the center loading on the back of the package by the mechanically attached heatsink discussed in the next section. Also, since there are only three datum bosses on the optical interface, the resulting bending stresses are not symmetrical about both longitudinal axes.

For good focus, the DMD™ must always contact the three reference datum pads on the optical interface. Thus there must be a space between the cLGA™ clamp and the optics housing before tightening the mounting screws. Since the mounting screws cannot pass through the three mounting datums, they are located just outside of the datum bosses. This results in large moments acting on the edges of the ceramic. If the screws are torqued too high, the edges of the ceramic package where it contact the mounting can be broken out. This requires that the initial gap between the optical interface and the cLGA clamp be just large enough to accommodate the tolerance stack up. With the asymmetrical location of the three areas, the largest stresses exist at the unbalanced pad.

The bending moment not only acts on the edge of the DMD™ package but also on the optical housing. By keeping the torque on the screws low, warping in the mount that could affect focus is also minimized. Through testing described in the next section, a torque specification of 4 inch-pounds was set on the mounting screws.

Assessment Testing

Due to the stresses on the package from the opto-mechanical interface, there was a large battery of tests performed to determine the impact to the new Type C DMD™ package design. The testing done was composed of three main phases.

1) Mechanical tests (shock and vibration)
2) Temperature tests
3) Optical interface test

The mechanical and temperature tests were done on sample assemblies with the cLGA housing and clamp, the mechanical heatsink attachment parts and a plain FR4 fiberglass panel for an electronics board. The optical interface tests were done with similar assemblies excluding the heatsinks since the tests were to find an acute failure from the interface.

The mechanical phase of the testing included mechanical shock, random vibration and sine sweep vibration. These tests were done on fixtures that had a simulated customer optical interface to most accurately represent system loading. All of the tests were focused at making sure that the heatsink would stay firmly attached and that no damage was done to the DMD™. The shock testing was done starting at a 50 G impulse. The

Figure 7 – DMD™ Datums
parts were then inspected for any signs of damage. The three primary areas of concern were the locations that the package contacted the optical interface, the back of the package where the heatsink contacted and most importantly the epoxy joint between the window and ceramic base. The test was repeated at shock loads of 60 G, 70 G and finally to 80 G. After all of the tests, there was no evidence of damage to the package.

Similarly, the random vibration was initially started at a 4.1 Grms loading and was increased to 7.3 Grms and 10.0 Grms levels. A sine sweep vibration was also done to determine the effects of prolonged stressing at the natural frequency of the system. As with the shock testing, the parts were inspected after each test case with no evidence of damage to the package recorded.

The temperature testing consisted of three different parts, all intended to be test-to-failure. The first was a –40 to +85°C temperature cycling test. The second was a –40 to +85°C liquid-to-liquid thermal shock test. The last part was a humidity life test done at 85°C and 85% humidity. The first data point was after 250 cycles of thermal shock, which showed gross delamination of the Type C window epoxy. Testing being done simultaneously on the new package by itself showed similar results. Further investigation identified a material/process issue with the window attachment epoxy. Parts undergoing temperature cycling and humidity life did not show the same gross failure. However, the parts undergoing temperature cycling had condensation on the inside of the window indicating a breach in the package. These results were also consistent with the results from the packaging testing being performed simultaneously. This was really the first major battery of testing that had been performed on the new package design so the failures, while disappointing, were not totally unexpected. The decision was made to start production with the traditional Type A package design and then transition to the new Type C package on a future device once the design was more mature.

The optical interface tests that were done were to establish safe torque limits on the screws used to mount the DMD™ to the optics. During initial testing to define a safe torque limit, when the DMD™ was mounted to a reference design aluminum interface, it was noted that the interface would cup away from safe torque limits on the screws used to mount the DMD™ to package on a future device once the design was more mature. A package design and then transition to the new Type C interface designs. For each test, an initial torque value was determined and then the torque was incrementally increased until failure. Between torque values all of the screws were completely loosened and then reseated according to the specified sequence.

The original aluminum reference design interface and sample customer interface tests were started at 8 inch-pounds and incremented by 2 inch-pounds. The reference design interface tests showed that the edges of the DMD™ could be chipped or broken starting at 16 inch-pounds of torque. The customer interface tests were finally halted at 20 inch-pounds with no failures.

The “rigid” reference design interface tests were started at 2 inch-pounds and increased by 1 inch-pound until failure. For the RSS worst-case tolerance, the ceramic failed at 6 inch-pounds. The nominal tolerance parts failed between the 6 and 8 inch pounds. While the thick aluminum channel was by far a worst-case interface design, it most accurately represented the potential rigidity of a cast aluminum or magnesium optical housing. Therefore, the torque specification was set to 4 inch-pounds to provide a reasonable margin.

### Thermal Interface

#### Design Overview

The operating temperature of the DMD™ is a very critical factor in the life of the device. Thus, the thermal interface to the DMD™ is a very critical part of any DLP projection system. The HD1 device used for Home Entertainment applications has a maximum thermal specification of 65°C at any point on the package with no larger than a 15°C delta across any two points. With the majority of front side of the device being an optical window the thermal interface must also use the back of the package in addition to the electrical interface. This requires that a heat stud must be incorporated that passes through the PWB so that a heatsink can be applied on the opposite side of the electronics board.

Traditional DMD™ products incorporate an epoxy bonded aluminum stud onto the back of the device. During projector assembly, a heatsink is then attached with screws to the stud. While this design provides good thermal performance, it has had periodic quality issues on previous devices. Special handling of the thermal epoxy, aluminum stud and ceramic package are required prior to the bonding process. Improper handling or processing of the parts could potentially result in a weak bond. For the new HD1 Home Entertainment device, as well as future DMD™ devices, this problem needed to be resolved.

To eliminate the epoxied joint, the new heatsink attachment design had to be purely mechanical. Besides being mechanically attached, the new design required a comparable thermal performance to the traditional epoxy joint. Finally, any forces applied to the DMD™ package had to be minimized to prevent large internal stresses in the package.

A secondary benefit of going to a system level heatsink attachment was that the costly epoxy process could be eliminated from the DMD™ manufacturing process. This helps toward getting the fabrication process to a point to where it could be transitioned to numerous semiconductor facilities. Additionally, this also allows the OEM’s greater flexibility to
design thermal systems that best suit their unique mechanical situation.

There were two primary solutions that were considered. One used a custom spring clip screwed down to the back of the board as shown in Fig 8a. The other solution, shown in Fig 8b, incorporated an off-the-shelf heatsink spring clip in conjunction with some special hook features added to the cLGA backer plate previously discussed. This is the solution that was finally adopted for the Home Entertainment platform.

![Figure 8a – Screwed on Spring Heatsink Attach](image)

![Figure 8b – Clip on Spring Heatsink Attach](image)

The primary deciding factors were the ability to use an off-the-shelf spring clip, the design was very assembly friendly, and it offered a shorter overall development time and cost. The other solution has since been developed for Home Entertainment and other DMD devices due to a lower total heatsink profile and thus greater system design flexibility.

With the attachment solution defined, the next task was to find an acceptable thermal pad to use between the heatsink and DMD package. Due to the close proximity of the electrical contacts and sensitive optics, greases could not be used. After researching many different thermal pads, several were chosen for testing that had thermal conductivities generally above 2.5 W/m-K. A sample of each, along with the traditional epoxied stud and a raw joint, were then tested to measure the actual thermal resistance for this specific application.

The test fixture, shown in Fig. 9, consisted of a DMD ceramic with a bonded on heater to which a sample heatsink with stud could be applied at different forces. By monitoring the temperature change across the interface and the input power to the heater, the thermal resistance of the interface was measured. After testing numerous samples, only the .025 inch thick had comparable performance to the epoxied joint. Eventually a more economical alternate pad of the same basic material composition and thickness was chosen. Even though these pads had higher published thermal resistances than the thinner .003 to .005 inch thick pads, better performance resulted from the pad being more compliant and allowing for surface flatness irregularities. The data also showed that an axial loading of approximately 5 pounds was sufficient to achieve acceptable performance, and that above 10 pounds, there was little to no added performance.

The final part of the new heatsink attachment design was to choose a specific spring clip and design the heatsink height to match it. In evaluating spring clips, the overall size, cost and availability were evaluated. The spring clip chosen was a standard Socket 5 heatsink clip. With the spring determined, force deflection curves were generated by measuring the force applied by the spring with different thicknesses of shims. This was done using the apparatus shown in Fig 10.

![Figure 9 – Thermal Interface Test Apparatus](image)

![Figure 10 – Spring Loading Test Apparatus](image)
The electrical contact was monitored between the aluminum plate that acted like the package ceramic and the two offset brass inserts. When either contact was broken, the weight for a specific spring deflection was determined. The reason for testing in this manner was to be able to determine if the loading was symmetrical and to be able to get a loading without altering the actual spring deflection.

A dimensional tolerance analysis was then done to determine the required deflection range that needed to be accommodated. From this data, the minimum loading was set at approximately 10 lbs, to ensure optimal thermal performance. From the tolerance analysis, this in turn put the nominal load at approximately 12.5 pounds and the maximum at 15 pounds. The nominal loading was then used to determine the required height of the heatsink stud.

Issues with the Design

With the basic design defined, there were several issues that needed to be worked through. The first of these being that the thermal conductivity of the new design was slightly less than the epoxied joint. Since the search for a better performing thermal pad might end up as a wild-goose chase, the only way to improve the thermal performance was to increase surface area. Previously, since the epoxied stud was firmly bonded to the back of the package, there were several mechanical tolerances that had to be considered. These were tolerances locating the stud on the DMD™ during the epoxy process, locating the clearance hole in the PWB, and the ever-present machining tolerances. With the mechanical stud attach design, the only tolerances that truly needed to be accommodated were the machining tolerances of the PWB hole size and the stud itself. This is because the heatsink stud is not rigidly attached to the DMD™. Be eliminating the extra tolerances, the stud size was increased which compensated for the slightly lower thermal conductivity of the thermal pad. Therefore, similar overall system performance was maintained with the new mechanical attachment design.

The next issue was how would the force exerted by the new heatsink attachment solution affect the reliability of the electrical interface. The primary concern was if the cLGA clamp would be able to apply a sufficient amount of force to balance out both the 35 pounds exerted by the springs and the 15 pounds from the heatsink. When the DMD™ is mounted in the system, there is also additional retaining force applied by the optical interface. In fact, most current projector designs rely entirely upon the optical interface to apply the entire retaining force. Therefore, the clamp truly only needed to be able to withstand the full 50 pounds of force during the manufacturing and shipping process, not over the entire life of the product. Testing was later performed to prove out that this was actually the case.

The final issue with the mechanical stud attach solution was DMD™ package stress. As mentioned previously, any and all package stresses are always a concern. Since the heatsink applies force directly to the center of the package, additional bending stresses are placed on the package. Finite element analysis was used to evaluate the relative stress in the package due to the mechanical stud attach as compared to the epoxied stud. Modeling proved that the bending stresses resulting from the mechanical stud attach were actually significantly less that the epoxied joint. The reason is that over the required temperature ranges, the epoxied joint applies fairly large stresses to the ceramic package due to the thermal mismatch between the ceramic and the aluminum stud. The mechanical attachment solution, on the other hand, avoids this by allowing the heatsink to float on the back of the DMD™.

Assessment Testing

Most of the assessment testing of the mechanical stud attach design was done as part of the testing of the electrical and opto-mechanical design. To ensure that the force being applied by the heatsink did not degrade the electrical integrity of the cLGA™ interconnect, half of the parts tested in the electroplated gold phase of tests were tested with the mechanical stud attach. There was no significant difference in when each group of parts finally failed during the humidity life test to failure.

The mechanical shock, random vibration and sine vibration tests done as part of the opto-mechanical interface testing were also designed to assess the mechanical heatsink attachment robustness. The sine sweep was specifically geared at stressing the heatsink attachment at its natural frequency. These tests were focused at making sure that the heatsink would stay firmly attached and that no damage was done to the DMD™. After each step of testing, the thermal pads and back of the DMD™ were inspected for signs of damage. During all the testing, the heatsink attachment never failed and the only noticeable affect was that the thermal pad showed slight signs of compression in the corners.

As the final part of thermal testing to ensure that the DMD™ temperature requirements were met, assistance was provided to the OEM’s whenever possible. For one OEM, this included performing thermal evaluations of several different thermal/EMI shield cases and making design recommendations. For another, it involved evaluating their test results and also providing recommended design changes.

ACKNOWLEDGMENTS

I would like to express my deep appreciation for the following people who provided various parts used in this paper:

- Mark Miller of Texas Instruments, DLP™ for supporting information pertaining to the cLGA™ interconnect and mechanical stud attach.
- John McKinley of Texas Instruments, DLP™ who was part of the team for the HD1 mechanical design, including the mechanical stud attach.
- Gary Fenoli and Don Powell of Texas Instruments, DLP™ for many of the pictures

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