DLP® Series-310 DMD and System Mounting Concepts

Application Report

TEXAS INSTRUMENTS

Literature Number: DLPA041
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Application Report

DLPA041–October 2013

DLP® Series-310 DMD and System Mounting Concepts

1 Scope

This application report serves as an aid to the successful first-time utilization and implementation of the Series-310 DMD (DLP4500FQD) and addresses the following topics:

- Terminology
- Specification and design details of a Series-310 DMD
- System mounting concepts for a Series-310 DMD, including key attributes and important application design considerations
- Interposer (electrical interconnect) for use with a Series-310 DMD

2 Terminology

Mechanical ICD — The Mechanical Interface Control Drawing (ICD) describes the geometric characteristics of the DMD. This is also referred to as the Package Mechanical Characteristics.

BTB — Board-to-Board (BTB) connector; refers to a type of electrical connector that is typically used to provide an electrical connection between two PCBs, or a PCB and an FPCB

Dark Metal — The area just outside the active array but within the same plane as the active array, see Figure 5

DMD Features— The primary features of the Series-310 DMD are described in the following list and illustrated in Figure 1 and Figure 2

- Bond wires – the wires which electrically connect the WLP DMD chip to the ceramic substrate
- Ceramic Substrate – the structures which form the mechanical, optical, thermal, and electrical interfaces between the WLP DMD chip and the end-application optical assembly
- C-notch – outline feature of the ceramic substrate that is the shape of the letter 'C' (rectangular cutout with filleted corners)
- DMD active array – the two-dimensional array of active DMD mirrors which reflect light
- DMD Chip (or just DMD) – The aggregate of the WLP chip, ceramic substrate, bond wires, encapsulation, and electrical pins
- Encapsulation – the material used to mechanically and environmentally protect the wire bond wires
- Symbolization pad – the area on the ceramic substrate that is used for marking the part
- System electrical interface – the electrical interface between the ceramic substrate and the end-application electronics
- Thermal interface area – the area on the ceramic substrate which allows direct contact of a heat sink or other thermal cooling device
- TI test interface – LGA pads used by TI to electrically test the DMD during the manufacturing process (do not connect these pads in the system application)
- V-notch – outline feature of the ceramic substrate that is the shape of the letter 'V' (cutout)
- Window glass – the clear glass cover which protects the DMD active area (mirrors)
- Window aperture – the dark coating on the inside surface of the window glass around the perimeter of the active array

- WLP chip – Wafer-Level Package (WLP) DMD chip that contains the DMD active array, window glass, and window aperture

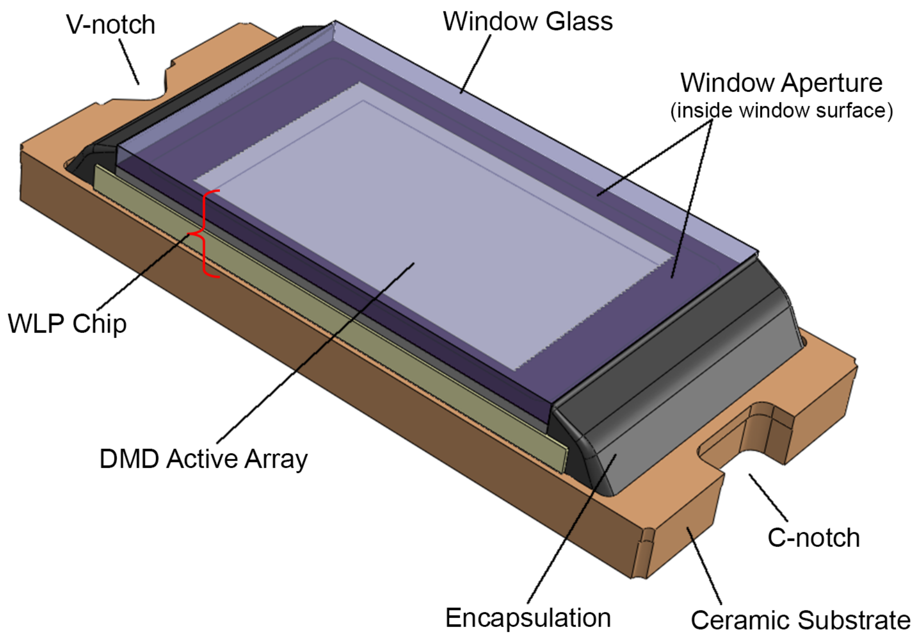

Figure 1. DMD Features – Window Side

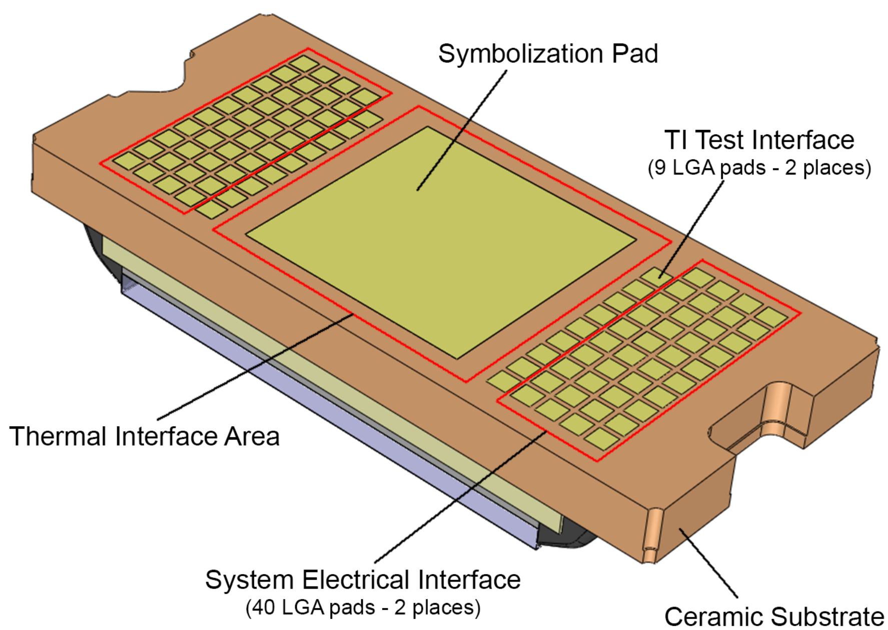

Figure 2. DMD Features – Electrical Side

FPCB— Flex Printed Circuit Board

Illumination Light Bundle— The illumination cross-section area (size) at any location along the illumination light path but specifically at the DMD active array and within the same plane as the active array

Interposer— Component that provides electrical connection to a DMD which utilizes a land grid array for the system electrical connection (similar to a socket or connector)

LGA— Land Grid Array (refers to a two-dimensional array of electrical contact pads)

Optical Assembly— The sub-assembly of the end product which consists of optical components and the mechanical parts that support those optical components

Optical Chassis— The main mechanical part used in the optical assembly to mount the optical components (DMD, lens, prism, and so forth)

Optical Illumination Overfill — The optical energy that falls outside the active area, and which does not contribute to the projected image

Optical Interface— Refers to the features on the optical chassis used to align and mount the DMD

PCB— Printed-Circuit Board

PGA— Pin Grid Array (refers to a two-dimensional array of electrical contact pins)

RSS — Root Sum Square method of characterizing part tolerance stack-ups. This is the square root of the sum of each part tolerance squared.

SUM — Sum method of characterizing part tolerance stack-ups. This is the sum of each part tolerance.

TP — Thermal test point

3 DMD Specifications

The key mechanical and thermal parameters of the DMD are described in this application note. The actual parameter values are specified in the DMD data sheet (DLPS028). A 3D-CAD file of the DMD nominal geometry of STEP format is available for download. See Section 6.

3.1 Optical Interface Features

To facilitate the physical orientation of the DMD active array, relative to other optical components in the optical assembly, the Series-310 DMD incorporates three principle datum features (Datum ‘A’, Datum ‘B’, and Datum ‘C’). The dimensions and sizes of the datum features are defined in the Mechanical ICD drawing at the end of the data sheet. The three datum features are shown in Figure 3 and described as follows:

Datum ‘A’ – Primary Datum

Datum ‘A’ is a plane specified by 3 areas on the surface of the ceramic substrate. The plane of the DMD active array is parallel to the plane formed by the three Datum ‘A’ areas. The DMD active array has a controlled distance and parallelism from Datum ‘A’, as defined in the Mechanical ICD. Datum ‘A’ allows the plane of the active array to be precisely (and repeatedly) oriented along the system optical axis. The Datum ‘A’ areas are a part of a surface and not a raised separate feature.

Datum ‘B’ – Secondary Datum

Datum ‘B’ is not a feature on the ceramic substrate but rather the center of a theoretically perfect 1.50-mm diameter that contacts tangent points on the edge of the V-notch cutout of the ceramic substrate. The flat sides of the V-notch make a line contact with the theoretical 1.50-mm diameter. While Datum ‘A’ defines the reference location of the active array plane axially along the system optical axis, Datum ‘B’ establishes the reference for the X and Y position of the active array within the Datum ‘A’ plane. Datum ‘B’ is not the entire depth of the V-notch in the ceramic but rather the top region closest to the Datum ‘A’ areas, see Figure 3.

Datum ‘C’ – Tertiary Datum

Datum ‘C’ is the one edge of a 3.0-mm wide C-shaped cutout on the edge of the ceramic substrate. The Datum ‘C’ edge is specified in the Mechanical ICD. Datum ‘C’ establishes the reference rotation of the active array within the Datum ‘A’ plane and about the Datum ‘B’ X-Y reference position. The Datum ‘C’ is not the entire depth of the C-shaped notch in the ceramic but rather the top region closest to the Datum ‘A’ areas, see Figure 3. **Note that Datum ‘C’ is not the center of the C-shaped notch.**

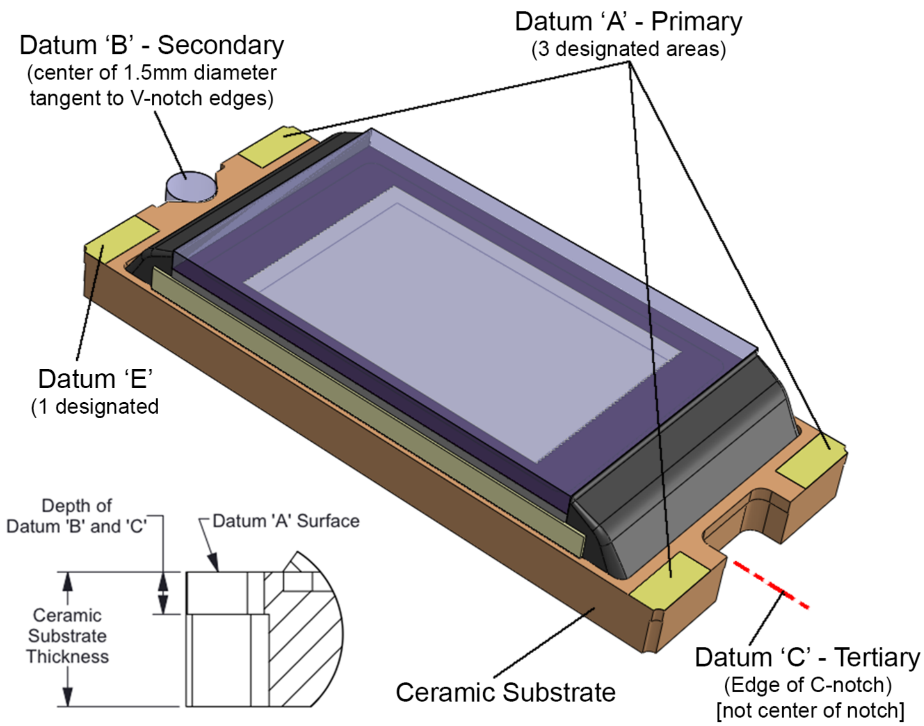

Figure 3. DMD Datum Features

3.2 DMD Cross-Section Features

Figure 4 illustrates the features of the DMD in cross-section. Shown are the window thickness, distance from active array to the window, window aperture location, ceramic substrate thickness, Datum ‘A’ plane location, active array plane, and encapsulation. The nominal distance and tolerance between these features are defined in the DMD Mechanical ICD.

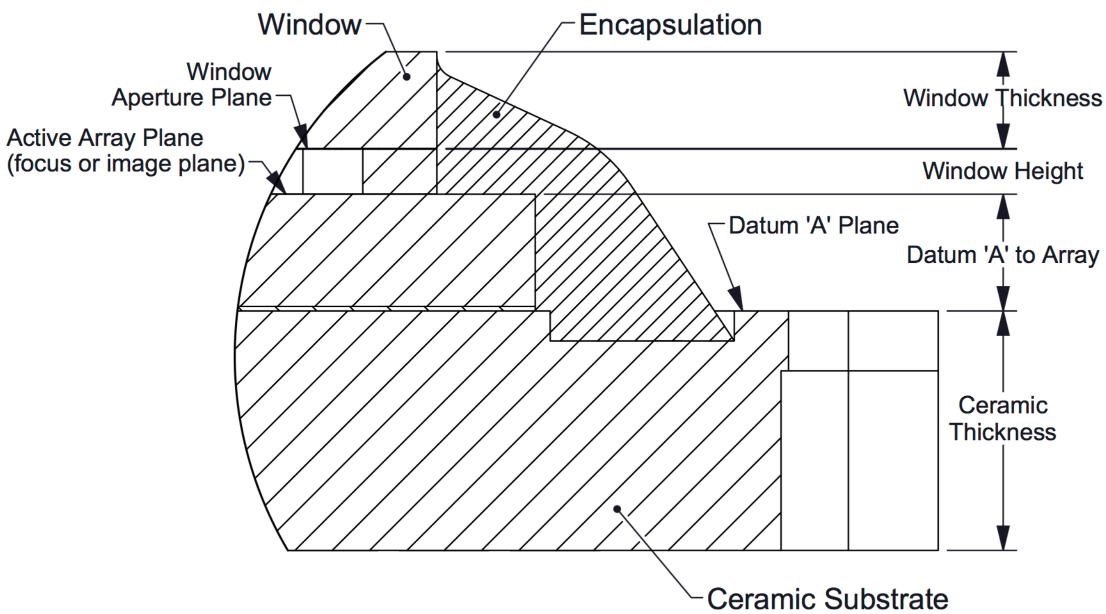

Figure 4. DMD Cross-Section View Features

3.3 Optical Illumination Overfill

Optical illumination overfill is defined as the optical energy that falls outside the active area. The overfill is wasted light that is not reflected by the mirrors and does not contribute to the brightness of a projected image. The shape and spatial distribution of the optical energy in the overfill region is determined by the system optical design. The overfill which results from an example illumination profile is illustrated in Figure 5.

Typical attributes that result in different overfill profiles include (but are not limited to) integrator size, illumination source, and optical aberrations (such as distortion, or color separation, or both).

Excess optical illumination overfill can result in higher thermal loads on the DMD (which must be cooled by the system), or various types of image artifacts (for example, stray light), or both.

The magnitude of these effects depends upon several factors which include (but are not limited to):

- The total amount of energy being reflected from the DMD active array
- The total amount of energy within the overfill area
- The spatial distribution of energy within the overfill area
- The specific DMD feature upon which overfill is incident (window aperture, dark metal area around the active array which is in the plane of the array plane, and so forth)
- The thermal management system used to cool the DMD
- The type of end-application (for example, front projection display, rear projection display, lithography, measurement, printing, and so forth)

The amount of energy outside the active array should be minimized to improve system optical efficiency, reduce the thermal cooling load, and reduce any possible optical artifacts.

Avoid optical overfill energy on the window aperture (if present). The heat absorbed by the window aperture (due to overfill that is incident upon the window aperture) is more difficult to remove (more resistive thermal path) than heat absorbed in the dark metal area surrounding the active array.

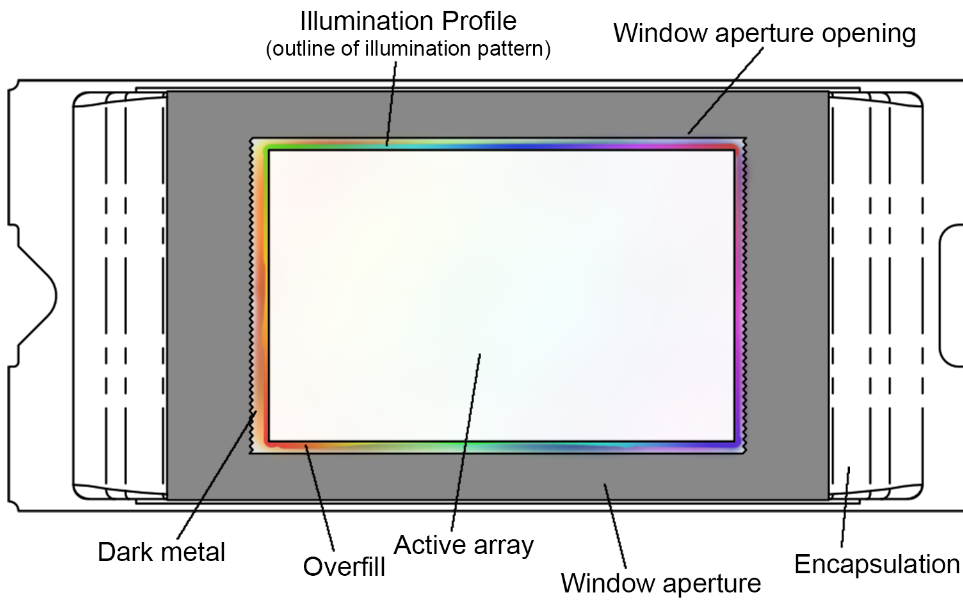

Figure 5. Optical Illumination Overfill

3.4 System Dust Gasket and System Aperture

The exterior surface of the DMD window is relatively close to the imaging plane of the DMD active array, as shown in Figure 4. Since the DMD active array is the optical focus plane, there is a risk of dust particles on the outside window surface being re-imaged and appearing in the projected image. To prevent this from occurring it is best to prevent dust from getting onto the outside surface of the DMD window. This can be accomplished by:

- Not having any openings in the optics assembly (close openings, use of gaskets, tape, and so forth)
- Maintaining optical cleanliness for all components used in the optical assembly, including the mechanical parts
- Assembly of optical engine in a clean-room environment

It is important that any gasket be flexible (compressive) enough that it does not interfere with the contact between the DMD Datum 'A' features, and the associated features on the optical chassis. Such interference could result in optical focus uniformity issues.

3.5 Active Array Size and Location

The active array size and location is specified in the DMD data sheet The active array is located relative to the specified DMD Datum 'A', Datum 'B' (1.50 diameter), and Datum 'C' (edge of C-notch) features.

The active array center is not at the center point between Datum 'B', and Datum 'C', but rather offset top-to-bottom. The offset is illustrated in Figure 6.

Also, the active array center is not centered between the 0.6-mm radius of the V-notch and the edge of the C-notch, nor is it centered between the Datum 'B' and the C-notch edge. This is illustrated in Figure 6 and Figure 7. Note the center of the V-notch radius and center of Datum 'B' are not coincident, see Figure 7.

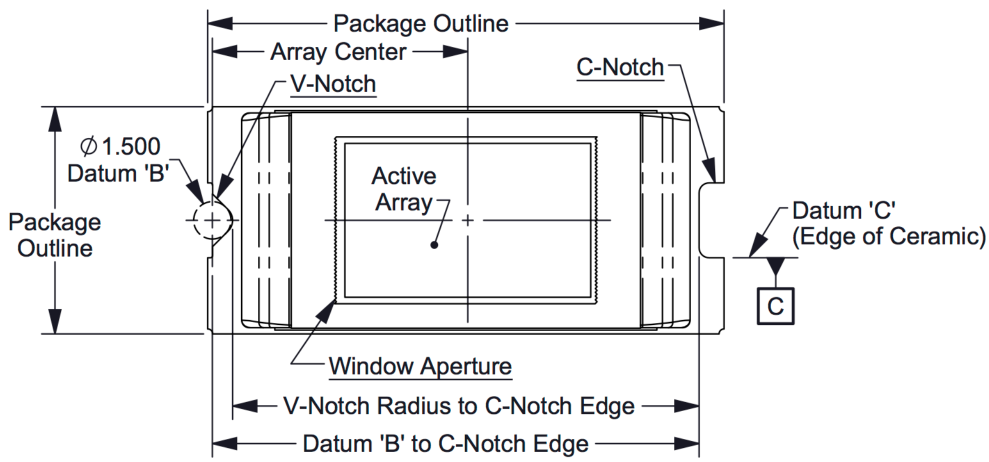

Figure 6. Active Array Location

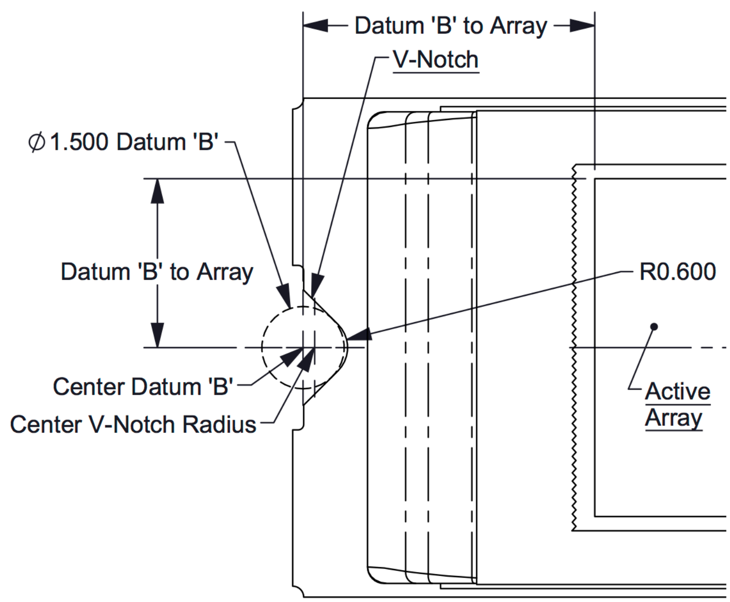

Figure 7. Active Array Location and V-Notch Detail

3.6 Electrical Interface Features

The electrical interface to the Series-310 DMD consists of two groups of LGA pads. Each group has an array of 10x4 pads for system connection and an array of 9x1 pads for TI testing. The pitch of the pads within each group is 0.7424 mm. The LGA pads are located relative to the same DMD optical interface features Datum 'B' and 'C' described in section Section 3.1. Utilizing the DMD Datums 'A', 'B', and 'C' is critical to achieving a good electrical connection between the DMD LGA pads and the system DMD PCB (FPCB). The location is illustrated in Figure 8.

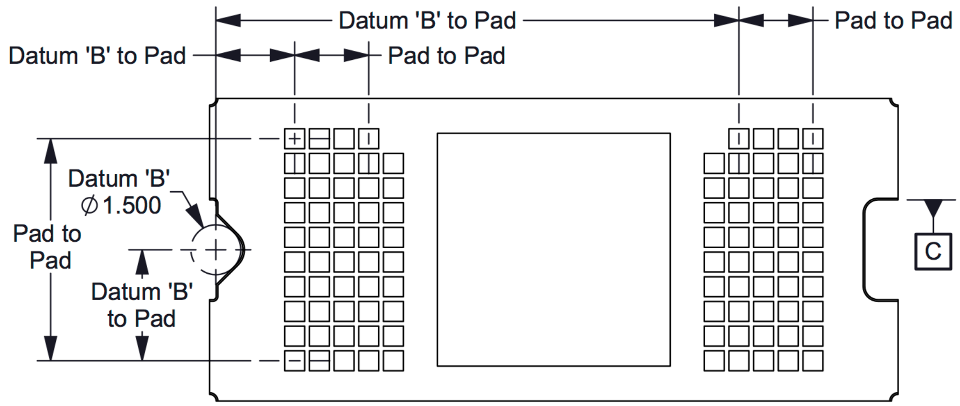

Figure 8. LGA Pad Locations

The pin numbering scheme for the LGA pads used on Series-310 DMDs is illustrated in Figure 9. The signal names for each pad A1 – K4 and A19 – K22 are identified in the DMD data sheet.

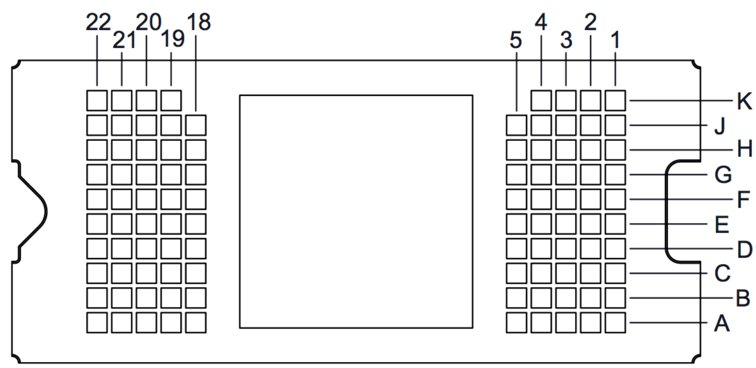

Figure 9. Pin Numbering Scheme

The LGA pads A5 – J5 and A18 – J18, adjacent to the symbolization pad, are used for TI testing during the manufacture of the DMD and are not to be electrically connected in the system. Care should be taken when mounting the DMD to ensure these test LGA pads are not electrically shorted together as this will cause the DMD to not function properly or be damaged.

3.7 Thermal Characteristics

The Series-310 DMD has a dedicated thermal interface area on the LGA pad side of the DMD which allows for conductive cooling of the DMD. The thermal interface area includes the area of the symbolization pad and the adjacent ceramic areas, as illustrated in Figure 2. The dedicated thermal interface area enables the DMD to be used in higher illumination applications. The thermal specifications provided in the DMD data sheet (DLPS028) include both recommended operating conditions and absolute maximum ratings.

The thermal specifications provided in the DMD data sheets are based upon characterizations done with illumination loads which are evenly distributed across the active array with less than 16 percent overfill (by energy). **Applications utilizing illumination profiles which have regions of high energy density (for example, highly collimated laser beams) have not been characterized and require special consideration on the part of the product designer.**

The primary thermal load on the DMD originates from the dissipated electrical load that drives the mirrors and the absorbed optical load. Secondary heating from other components near the DMD can exist, but their significance depends upon the magnitude and location relative to the DMD. Secondary heating sources could be electrical components near the DMD (convective transfer of heat) or mounted to the same optical chassis as the DMD (conductive transfer of heat). The transfer of heat from secondary heating sources to the DMD should be eliminated or at least minimized as this can affect the cooling of the DMD.

The thermal load on the active array has a low resistance direct conduction path to the thermal interface area on the LGA pad side of the ceramic substrate. The primary thermal dissipation path for the energy on the window aperture is the same thermal interface area of the LGA pad side of the ceramic substrate. The conduction path from the window aperture to the thermal interface area is much higher than for the active array. The energy on the window aperture is the most challenging to dissipate from the DMD and should be eliminated or reduced, as much as possible.

Note that optical energy that falls on the window aperture is wasted energy that must be cooled, but does not contribute to the optical efficiency of the DMD.

Please see the DMD data sheet for additional thermal information, including location of the thermal test points and how to calculate the active array temperature. Additionally, the data sheet specifies the maximum UV power density that can be incident upon the active array, or overfull areas, or both. A UV filter may be required, depending on the spectral content of the illumination source. To ensure the longest possible reliability, the DMD should not be exposed to the maximum operating temperature and maximum UV level at the same time.

3.8 Mechanical Loading Considerations

Installing a DMD into an end-application environment will involve placing a mechanical load on the DMD, and more specifically, upon the ceramic substrate. The maximum mechanical load which can be applied to the DMD is specified in the DMD data sheet (DLPS028). The areas the loads are to be distributed are shown in Figure 10. The load is the maximum to be applied during the installation process, or the continuous load after the DMD has been installed. The DMD has three main areas to accommodate a mechanical load:

Electrical Interface Area

The Series-310 DMD is designed to accommodate mechanical loads evenly distributed across the two electrical interface areas shown in Figure 10. The interposer available for use with the DMD has compressive spring contacts on the DMD side which require a constantly-applied load to ensure an electrical connection is maintained. The load applied to the electrical interface areas are those required to compress the contacts and which result from mounting the DMD PCB.

Thermal Interface Area

The Series-310 DMD is designed to accommodate mechanical loads evenly distributed across the thermal area shown in Figure 10. This load is for contact with a heat sink (or other thermal hardware) in order to facilitate optimal thermal performance. A thermal pad is typically used to facilitate the transfer of heat from the DMD to the heat sink. A minimum force (or pressure) on the thermal pad is needed for good thermal impedance, but increasing the pressure does not improve the thermal performance substantially and may result in damage to the DMD. The minimum mechanical load applied to this area is that which is needed to ensure good thermal performance. Items to consider when determining the range of mechanical loads that could result on this area include:

- manufacturing tolerances of all parts
- minimum force required for thermal pad performance
- thermal pad pressure versus deflection
- pressure versus thermal impedance

- worst-case mechanical shock loads expected

Datum ‘A’ Area

The Series-310 DMD will accommodate a mechanical load evenly distributed across the three Datum ‘A’ areas shown in Figure 10. This load functions to counteract the combined loads from the thermal and the electrical interface areas. The Mechanical ICD defines the location and size of the Datum 'A' areas.

The data sheet specifies three Datum ‘A’ areas based on the fact that three points define a plane. These three points are what the active array plane is referenced. From a practical standpoint the mounting and securing of the DMD is simpler and more consistent if four areas are contacted rather than three. This reduces the chance of tilting the DMD during mounting when a non-uniform clamping load is applied. In the case where four areas are used, the maximum load for the ‘DMD mounting area’ should be uniformly distributed across the four areas. The four mounting areas shown in Figure 10 are those on the opposite side of the ceramic from the Datum ‘A’ areas and Datum ‘E’ area.

Loads in excess of the specified limits can result in mechanical failure of the DMD package. A failure may not be catastrophic such that it can be initially identified but rather a more subtle failure, which could result in reduced lifetime of the DMD.

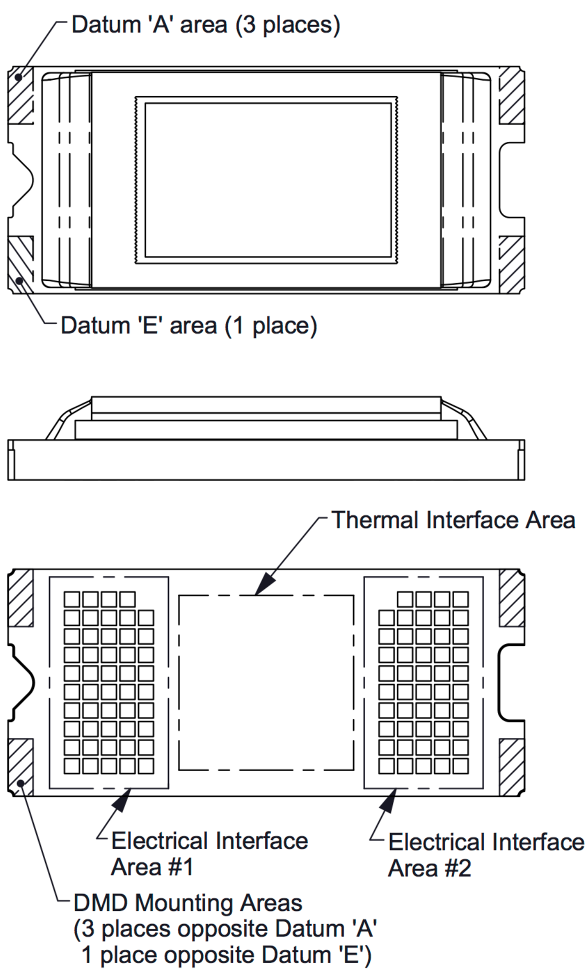

Figure 10. DMD Mechanical Loads

4 System DMD Mounting

4.1 Critical Considerations for Mounting and Utilizing the DMD

The method used to mount the DMD into the end-application system needs to meet the functional design objectives of the application, while also ensuring that the DMD thermal and mechanical specifications are not exceeded.

The functional design objectives of the mounting system include:

- Establish (and maintain) the physical placement of the DMD's active array relative to the optical axis of the applications optical assembly
- Establish (and maintain) a proper electrical connection between the DMD's electrical interface and the system interposer (connector)
- Establish (and maintain) a dust-proof seal between the DMD and the chassis of the optical assembly
- Establish (and maintain) a proper thermal connection between the DMD's thermal interface area and the system's thermal solution. Systems with low thermal loads on the DMD will generally not need a dedicated thermal connector.

To meet these functional design objectives requires that some minimum mechanical load be applied to the DMD. The DMD mounting concepts presented in this application note achieve the minimum mechanical load to meet the functional objectives while illustrating various concepts for controlling the maximum mechanical loads being applied to the DMD.

The ideal mounting design is one which:

- does not rely upon strict assembly techniques or processes to control the loads
- is tolerant of manufacturing variations of piece parts
- minimizes the variations in mechanical loads applied to the DMD

If not understood and minimized, the variations can easily result in lower forces than what is needed to hold the DMD in place, or higher forces which could result in damage to the DMD. Variations in load to the electrical interface area can result in not having electrical connection, or damage to the DMD, or electrical interposer (connector).

4.2 Basic System DMD Mounting Concept

The DMD mounting concepts described in this application note represent *drop-in-place* designs. The *drop-in-place* name indicates that the DMD is placed onto the optical chassis mounting features and secured into place without any adjustment of the DMD for optical alignment. A *drop-in-place* design is desirable because it simplifies the assembly process of the DMD and enables replacement of the DMD without needing to re-adjust optical components or DMD position. Achieving a *drop-in-place* design is realistic for a single-chip DMD system. Achieving a *drop-in-place* design for a multi-DMD system is more challenging, due to the need to align the individual DMDs to each other in order to form a single combined image.

Alignment of the illumination light bundle to the active array is closely related to the amount of overfill, shape of the light bundle, and dimensional tolerance of the piece parts. Adjustment of the illumination is usually still required with *drop-in-place* mounting unless an excessive amount of overfill is used to compensate for the many part tolerances. It should be noted that excessive overfill increases the amount of DMD cooling required and reduces the efficiency of the system (both optical efficiency and electrical power efficiency). For these considerations it is nearly always best to minimize the amount of overfill, and to design the system and assembly process with adjustment in mind. A convenient way to perform this adjustment is by adjusting an integrator element or fold mirror. Generally the illumination light bundle is adjusted after the DMD is installed into the system.

A key characteristic of the *drop-in-place* mounting concept is that the DMD does not need to be adjusted in order to achieve acceptable focus across the entire active array. Acceptable focus is achieved by establishing perpendicularity between the active array and the projection lens axis. The variation in the optical components and mechanical mounting features will likely require that an adjustment be done to establish this relationship (dependent on the specific optical design). An optical sensitivity analysis of the optical design will identify the components that are the greatest contributors and likely candidates for adjustment. It is thought best to adjust an optical component (like a prism) rather than the DMD so as to avoid conflicts with the electrical connection and also allows for replacement of the DMD without readjusting the DMD.

A *drop-in-place* style of mounting simplifies the assembly of the DMD into the optical assembly, but requires adequate tolerances on the DMD interface features of the optical chassis (see Section 4.2.1 and Section 4.2.2). The specific tolerance requirements vary for each system design. Key areas of consideration include:

- size and shape of the illumination overfill
- alignment of the illumination light bundle to the active array (X-axis, Y-axis, and rotation)
- variation in size and location of optical components and of the DMD mounting features on the optical chassis (this is less critical if DMD interchangeability is not important)
- variation in the location (and rotation) of the active array within the DMD package due to size and location tolerances of the DMD datum features, and the placement of the active array relative to the datum features (this is less critical if interchangeability of DMDs is not important)
- identifying optical components that contribute to uniform focus across the entire active array, and which ones need to be adjusted (or simplest to adjust) to achieve uniform focus (that is, right angle prism)
- variation in the location of the DMD electrical pads relative to features that are utilized to align the electrical interconnect alignment pins for the PCB

4.2.1 Optical-Mechanical Alignment Features

The DMD Optical-Mechanical Alignment Features (datums) are used to establish and maintain the physical placement of the DMD's active array relative to the illumination light bundle and the optical axis of the projection lens. Section 3.1 reviewed the Optical Interface Features of the DMD. This section reviews the suggested corresponding features on the optical chassis. The features shown in Figure 11 are summarized as follows:

- Datum 'A' and 'E' tabs – four coplanar areas that contact the DMD Datum 'A' areas and Datum 'E' area. These establish the relationship for the position of the active array relative to the projection lens axis and other optical components
- Datum 'B' Ø 1.5-mm round pin – contacts with the DMD Datum 'B' (V-notch feature) providing two contact areas (line) on the edge of the ceramic
- Datum 'C' Post Edge – mates with the DMD Datum 'C' (C-notch feature)
- Screw holes to mount a clamp and secure the DMD against the Datum 'A' and 'E' features of the system optical chassis

The alignment features on the optical chassis are commonly referred to as the optical interface

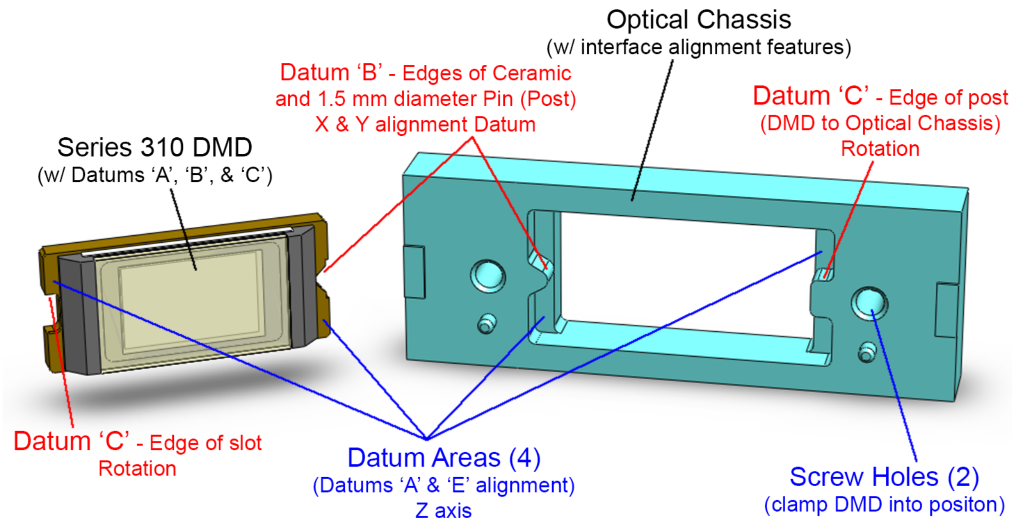

Figure 11. Optical Interface (Alignment) Features

The following characteristics of the Series-310 Optical-Mechanical alignment features should be noted:

- The simplest form for the Datum 'B' interface feature is a precision Ø 1.5-mm diameter pin. This works fine; however, other shapes could be used to create a more robust feature that would be easier to manufacture. An example of such a feature is shown in Figure 11.
- The three Datum 'A' tabs and Datum 'E' tab on the optical chassis must be coplanar to ensure uniform focus of the active array, and focus repeatability between systems. The coplanarity of these features, the DMD parallelism, optical design depth of focus, and optical component sensitivity combine to determine the uniform focus of all four corners of the image.
- The outline shape of the features on the optical chassis that correspond and contact the DMD Datum 'A' features should be slightly smaller than the defined DMD Datum 'A' features to ensure the area outside the DMD Datum 'A' area is not contacted. Contact outside of the DMD Datum 'A' area could result in focus variations or non-uniform focus.
- To avoid bending and damaging the DMD, the mounting forces should be applied perpendicular to the substrate and directly opposite the ceramic Datum 'A' and 'E' areas.
- The system gasket or aperture (if used) should be designed to not interfere with the proper mating of the DMD Datums and corresponding Datum 'A' features on the optical chassis. Any gasket or aperture material that overlaps the DMD Datum 'A' features could cause focus problems. Another issue that could result in focus problems is if the gasket material is not compliant enough to allow sufficient compression, thus prohibiting full contact of all the Datum 'A' features.
- Avoid sharp edges on the Datum 'A' tab features in order to prevent damage to the DMD ceramic substrate. The sharp contact point of a feature edge could result in a highly concentrated load (in a very small area), and potentially lead to damaging (cracking) the DMD's ceramic substrate.
- The **opening features in the optical chassis should accommodate the maximum encapsulation size** defined in the DMD mechanical ICD drawing. A 3D-CAD model of the DMD is available that has the maximum encapsulation size, see Section 6.
- When mounted, the DMD needs to be held firmly against the DMD Datum 'A' and 'E' areas. This will prevent the DMD from shifting or moving position. The clamping of the DMD should be done in a manner that does not apply excessive mechanical loads to the DMD. The maximum mechanical loads for the DMD are described in Section 3.8. It can be challenging to control the mechanical load on DMD by control of the torque of the DMD mounting screws. It is also beneficial to minimize the clearance gap between the optical chassis and PCB to prevent bending of the PCB (and clamp) when the screws are torqued. Reducing the bending reduces the variation of clamping force. The critical clearance gaps are identified in Figure 12 and Figure 13 for two mounting concepts. These mounting concepts will be described in more detail Section 4.3.

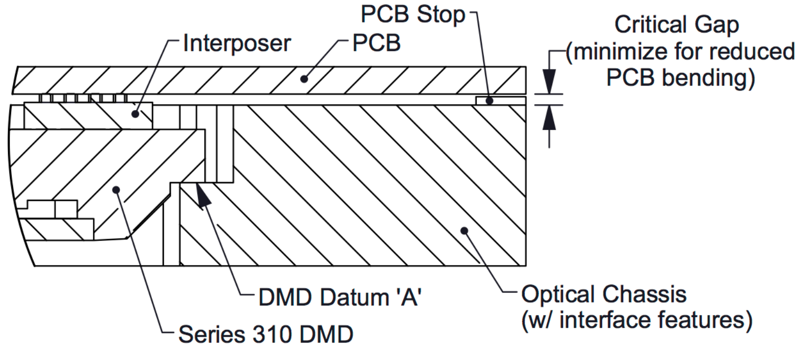

Figure 12. Mounting Clearance

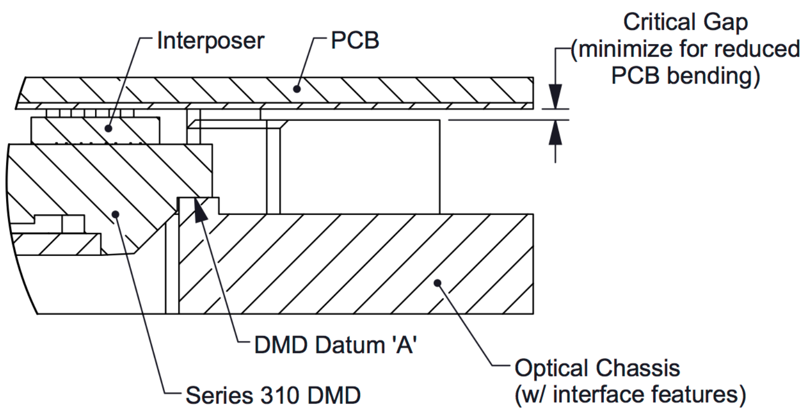

Figure 13. Mounting Clearance

- The DMD V-notch Datum ‘B’ is not a closed feature in the ceramic substrate. The intended use of Datum ‘B’ when mounting the DMD requires the DMD Datum ‘B’ contact the corresponding Datum ‘B’ post on the optical interface. To achieve this, the DMD must be pushed towards the Datum ‘B’ post in the direction illustrated in Figure 14.
- The DMD Datum ‘C’ is the edge of the C-shaped notch in the ceramic substrate. The datum is not the center of the C-shaped notch. The intended use of the Datum ‘C’ when mounting the DMD requires the DMD Datum ‘C’ contact a corresponding feature on the optical interface. To achieve this, the DMD must be pushed towards the interface Datum ‘C’ feature in the direction illustrated in Figure 14.

- Utilizing the DMD Datums 'B' and 'C', as previously described and illustrated in Figure 14, when mounting the DMD will reduce X-Y movement and rotation variation of the DMD.

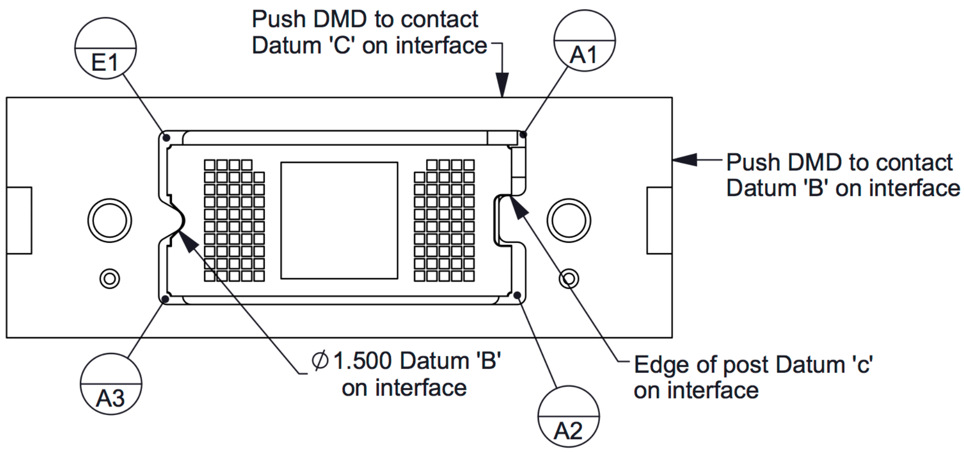

Figure 14. Mounting Datum 'B' and 'C' Contact

4.2.2 Electrical Connection Alignment Features

This section describes a concept for aligning the DMD and the interposer on the PCB to achieve electrical connection. The Series-310 DMD and electrical interposer (connector described in Section 5) do not have features for direct alignment between them. To achieve electrical alignment between the DMD and PCB, the DMD mounting concepts described herein utilize a combination of features on the DMD, optical engine, and PCB. The alignment concept is shown in Figure 15 and described in the following:

- The LGA pads on the DMD are located relative to the Datums 'B' and 'C'. The location of the LGA pads described in Section 3.6 utilizes the same DMD Datum 'B' and Datum 'C' features as the optical interface to the array.
- The DMD (when installed) is aligned to the optical engine using the DMD Datums 'B' (Ø 1.5 mm) and 'C' (slot edge), and the corresponding features on the optical engine.
- The optical engine incorporates precision align pins for alignment of the PCB. The PCB alignment pins are precisely located relative to the Datums 'B' and 'C' features used to align the DMD.
- The PCB incorporates a precision hole and slot. The interposers when soldered to the PCB are located precisely to the precision hole and slot.
- When the PCB is installed, the hole and slot are utilized to align the PCB with the pins on the optical engine.

The alignment needed for the electrical connection is best achieved by careful control of size and manufacturing tolerances for each of the features on the optical engine and PCB (described previously), proper use of the DMD Datums, and an assembly procedure which ensures uniform clamping of interposers.

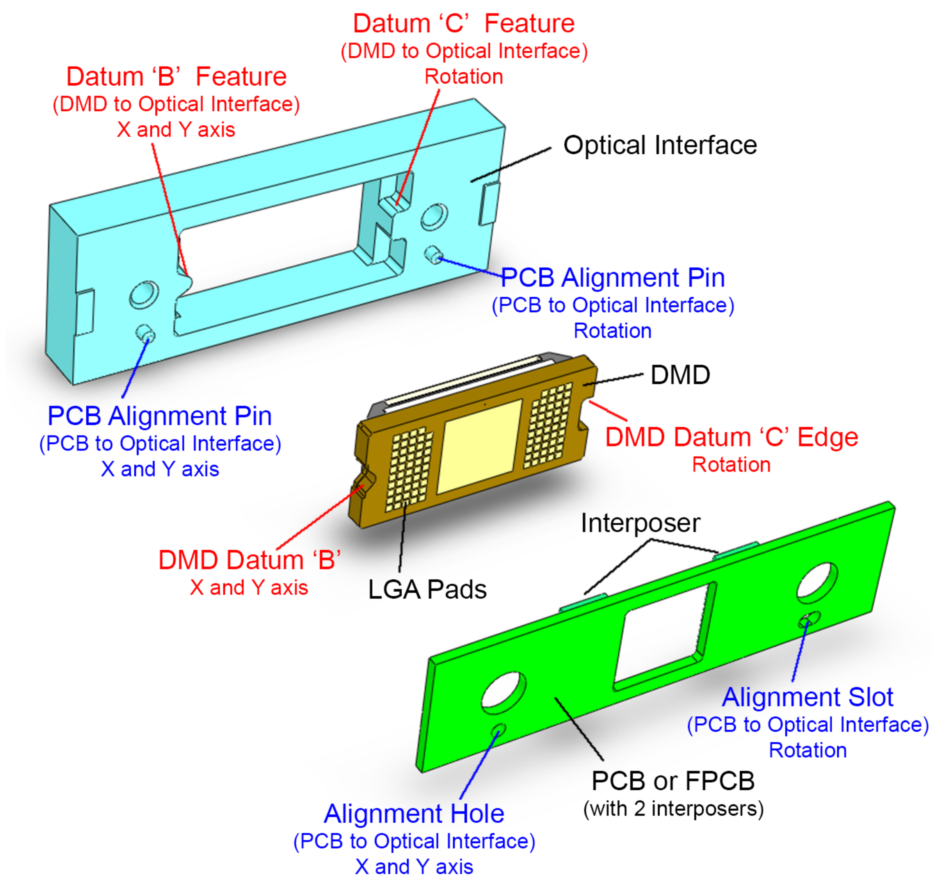

Figure 15. Electrical Alignment

4.2.3 Thermal Considerations

The Series-310 DMD has a dedicated thermal interface area which aids in cooling the DMD and allows for higher illumination applications. This dedicated thermal interface is intended to be contacted by a heat sink to allow direct conductive cooling of the DMD. The heat sink characteristics (surface area, fin spacing, fin size, length, and so on) need to be determined along with the airflow requirements to maintain the DMD temperatures for a specific application and environmental condition. The features and characteristics of heat sinks in the mounting concepts in this application note are to demonstrate the mounting features but are not representative of any specific thermal solution.

4.2.4 Mechanical Loads

The Series-310 DMD specification lists the maximum mechanical loads that can be applied to the 'Thermal' and 'Electrical' interface areas of the DMD. See Section 3.8. The DMD mounting options described in this application note include multiple springs to control the minimum and maximum loads for each area independently. The variations in the load applied to the thermal interface area does not change the load that is applied to the electrical interface area, and vice versa. The use of shoulder screws allows for the loads applied to each of the areas to be controlled by engineering design rather than assembly process and the amount of torque applied to the screws.

The minimum load required on the thermal interface area is that which is needed to provide good thermal performance for conduction of the heat from the DMD to the heat sink. The maximum load applied to the thermal interface area is that specified in the DMD data sheet. The mounting concepts described in this application note use a flat spring to control the force applied to the thermal interface area of the DMD. The flat spring contacts the heat sink and the underside of the shoulder screw head. Understanding the variation in the distance (or gap) between the heat sink and shoulder screw head is critical to understanding minimum and maximum loads applied to the DMD. This critical gap is shown in Figure 16. The maximum load on the DMD would occur when the gap was the smallest, and the minimum gap would occur when the gap was the largest. In addition to the critical gap size, the spring rate (N/mm deflection) of the flat spring has a role in the total load applied to the DMD. The spring rate is influenced by spring manufacturing tolerances and is typically characterized after manufacturing springs.

The minimum load required on the electrical interface area is that which is needed to compress the contacts on the electrical interposer (see Section 5) for electrical connection. The maximum load applied to the electrical interface area is that specified in the DMD data sheet. The mounting concepts described in this application note use two coil springs to control the force applied to the electrical interface area of the DMD. The coil springs contact the clamp and the face of the flat spring near the shoulder screw head. Understanding the variation in the distance (or gap) between the clamp and face of the flat spring is critical to understanding the minimum and maximum loads applied to the DMD. The critical gap is shown in Figure 16. The maximum load on the DMD would occur when the gap was the smallest, and the minimum load would occur when the gap was the largest. In addition to the critical gap size the spring rate (N/mm deflection) and free length of the coil spring have a role in the total load applied to the DMD. The variation in the spring rate and free length are typically understood by experienced spring manufacturers or could be characterized by testing springs.

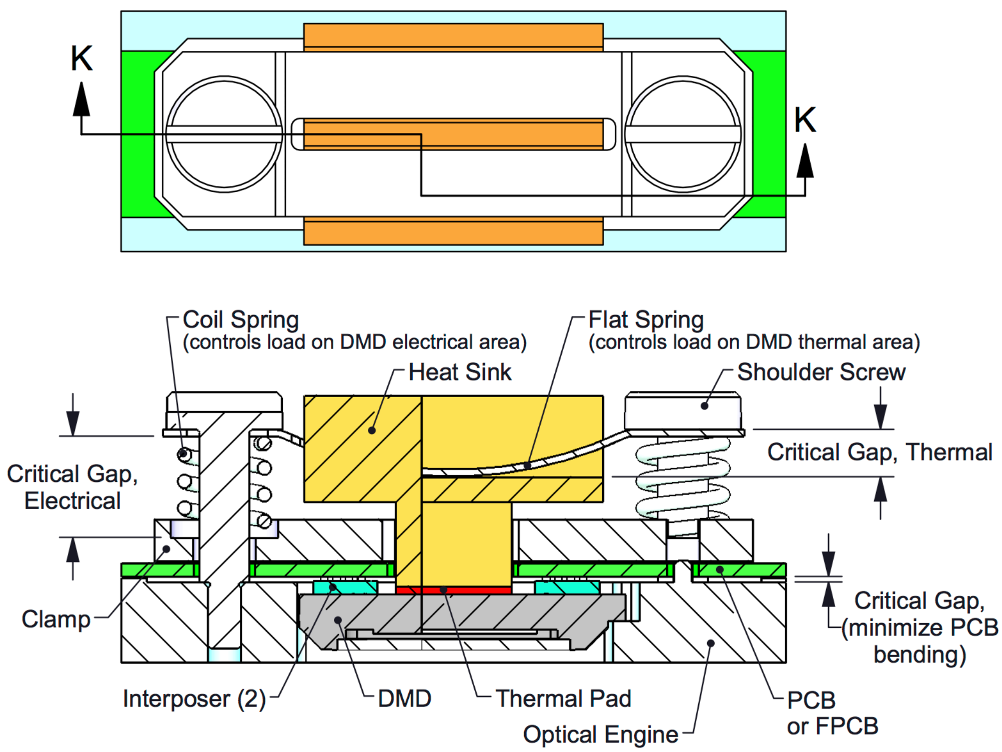

Figure 16. Critical Gaps

4.2.5 PCB Mounting

The PCB (or FPCB) needs to be mounted in a manner that it remains flat without bowing or bending. Bowing or bending of the PCB can result in no electrical connections on some or all the electrical interposer contacts. The compression range of the contacts is very small and a small amount of bending can result in no electrical connections. The purpose of the clamp is to provide the stiffness needed to prevent PCB bending from the loads applied by the coil springs. Tilting or bending of the PCB can also occur from the assembly process if one of the screws is tightened all the way before the other screw is partially tightened. An assembly fixture that holds the PCB flat while the screws are tightened can help to prevent bending during the assembly process.

The clamp should reduce the possible bending of the PCB but may not totally eliminate it when the maximum loads are applied. To simplify assembly, help assure uniform load on the electrical interposer, and reduce chances for PCB bending (or tilting), the distance between the PCB and optical engine shown as ‘Critical Gap’ in Figure 16 should be minimized.

4.2.6 Dust Gasket

The dust gasket (if incorporated) functions to provide a barrier to prevent ambient dust particles from accumulating on the DMD window glass. The outside window surface is relatively near the image plane (active array) of the DMD. The cross-section view of the DMD shown in Figure 4 illustrates this close proximity.

Dust particles on the DMD window, if large enough, could appear in the projected image as shadows or near shadows.

Characteristics of a dust gasket should include:

- creates no interference with the DMD mounting features (Datum ‘A’, ‘B’, and ‘C’) on the optical chassis when in either the compressed or non-compressed state
- has sufficient compliance to allow necessary compression without a significant mechanical mounting load on the DMD
- creates a sufficient seal against the surfaces it contacts to prevent dust particles from reaching the DMD window glass
- comprised of a material which does not create particles
- comprised of a material which does not allow dust particles to pass through its volume
- gasket should not interfere with assembly of the DMD into the optical assembly

4.3 Detailed DMD Mounting Concepts

Two concepts for mounting the DMD that will meet the needs stated earlier are described in this section.

It is expected that the parts and features represented in these concept designs will be adapted or modified to accommodate a specific application, part design requirements, part manufacture requirements, and other specific customer needs.

4.3.1 Shim Alignment Mounting Concept

The design concept for mounting the Series-310 DMD shown in Figure 17 is a *drop-in-place* concept which incorporates specific features to aid DMD alignment during the DMD installation process. This section describes the shim alignment features, details associated with control of mechanical loads applied to the electrical and thermal interface areas of the DMD, and interface features which aid in reducing PCB bending

The drawing number for the "Shim Mounting Concept" shown in Figure 17 is 2513122. The 3D-CAD models (in STEP format) and drawings (in pdf format) for each part shown are available for download. See Section 6.

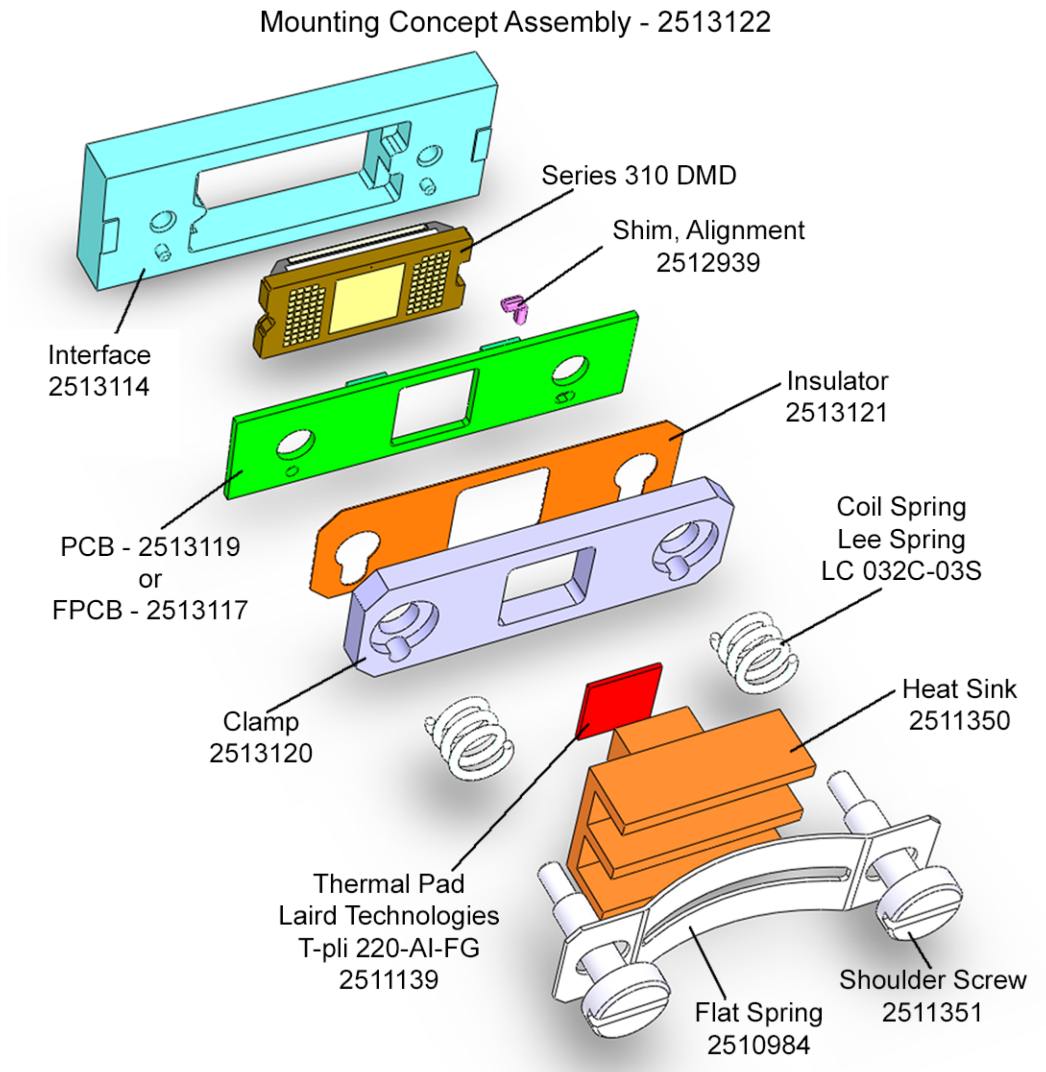

Figure 17. Shim Alignment Mounting Concept

4.3.1.1 DMD Shim Alignment Features

The location of the DMD is important for both optical (array position) and electrical (pad position) considerations. A consistent and repeatable DMD location requires the DMD be manually pushed into contact with the optical interface Datums ‘B’ and ‘C’ features, and then held in place while the mounting screws are tightened. To facilitate holding the DMD in position, this mounting concept utilizes two shims. The function of the shims is to keep the DMD from shifting locations while the bracket is secured. The shims are a compressible material that is placed between the optical interface and the DMD. The shims and Datum features are shown in Figure 18.

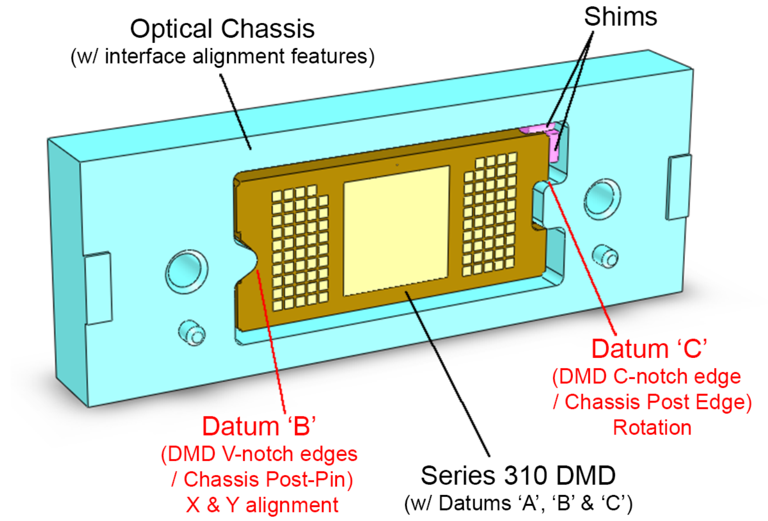

Figure 18. Alignment Shims

The gap between the optical interface and DMD varies with the interface and DMD size and manufacturing tolerances of the interface opening and DMD. The gaps and shim locations are shown in Figure 19. The size of the gap should be adjusted to accommodate:

- Optical interface opening size variations
- DMD size variation
- Size and shape of the shim part
- Compressibility of materials available for the shim part
- Forces needed to hold the DMD in position against Datums 'B' and 'C'

The shape of the shim in this concept is round but could be any shape. Round shapes seem readily available in many sizes and materials, and are easily installed. When compressed into the gap, the round shape of the shim increases size (height) in one direction, as illustrated in Figure 19. The shim material and gap size should be determined so the amount of increase does not interfere with the bracket or DMD installation.

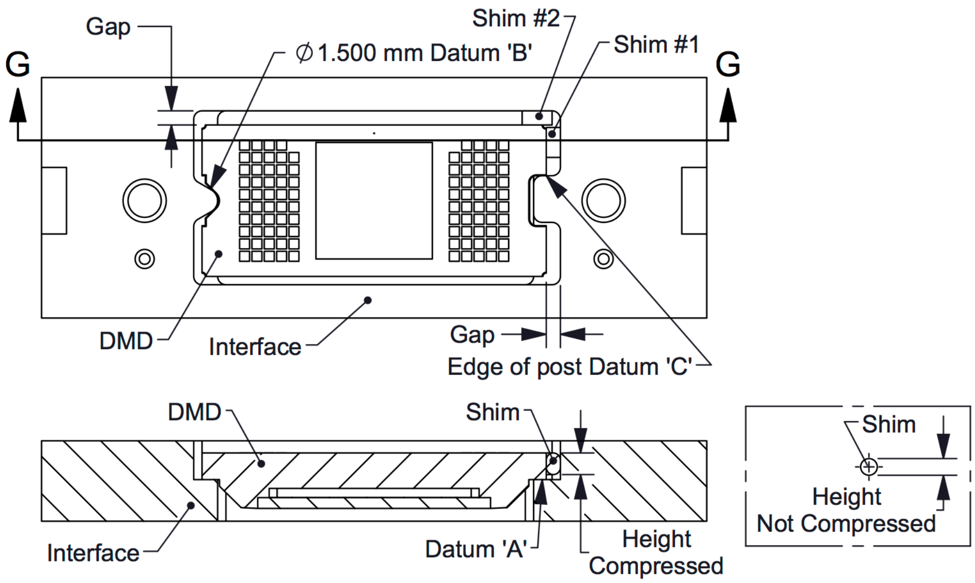

Figure 19. Gaps and Shim Shape

4.3.1.2 Thermal Mechanical Load Details

The method for mounting the heat sink shown in Figure 17 uses shoulder screws and a flat spring to control the forces applied to the DMD thermal interface area. The minimum load needed for good thermal performance and maximum load allowed on the DMD are described in Section 4.2.4. The flat spring is compressed between the heat sink and the head of the shoulder screw. The variation in the gap (identified as ‘Critical Gap’ in Figure 20) determines the range of loads applied to the DMD. Figure 20 illustrates a tolerance-analysis schematic used to determine the variation of the ‘Critical Gap’. The tolerance schematic starts at the top of the heat sink (right-hand side of Figure 20) where the flat spring contacts and continues to the head of the shoulder screw (left-hand side) where the flat spring contacts. The size of the ‘Critical Gap’ varies with the part manufacturing tolerances.

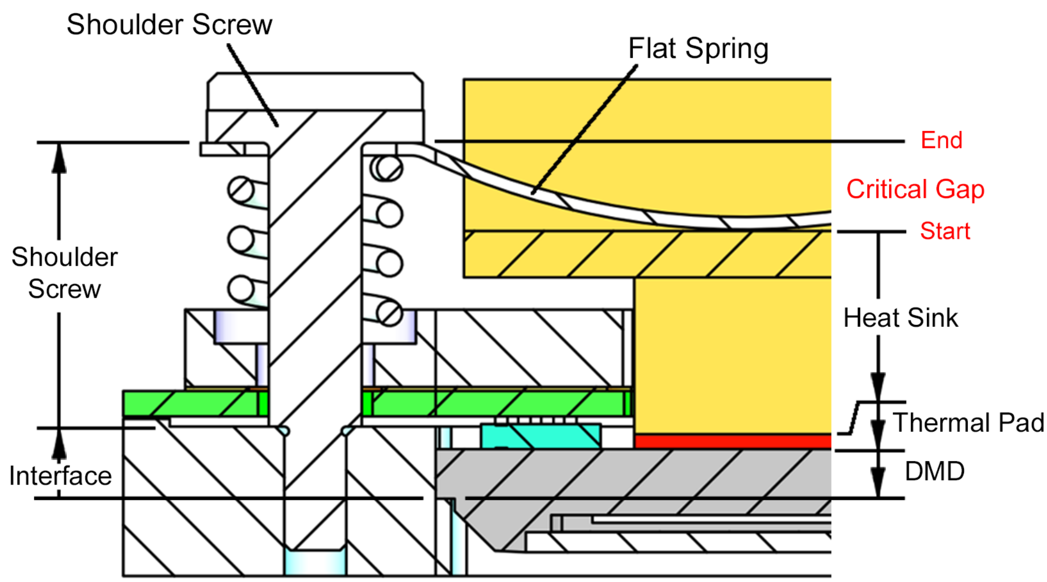

Figure 20. Flat Spring Gap Tolerance-Analysis Schematic (Shim)

Table 1 lists the nominal value and tolerance for each part feature in the tolerance-analysis schematic. The nominal values and tolerances used are those on the part drawings for the mounting concept shown in Figure 17. The parts are dimensioned in a manner to minimize variations in the 'Critical Gap'. The tolerance analysis indicates the nominal gap size is 2.846 mm. The simple (SUM) method of tolerance analysis (worst case) yields a tolerance of ±0.370 mm. This results in a (SUM) minimum gap of 2.476 mm, and a maximum gap of 3.216 mm. The root sum square (RSS) method of tolerance analysis yields a tolerance of ±0.173 mm. This results in an RSS minimum gap of 2.673 mm, and a maximum gap of 3.019 mm.

The design of the flat spring needs to comprehend:

- minimum and maximum gap ranges
- flat spring manufacturing tolerances
- spring constant variation of the flat spring

Table 1. Flat Spring Gap Analysis (Shim)

	Nominal (mm)	Direction Sign	Nominal (mm)	Tol (±) (mm)	Tolerance Method	Gap	
Heat Sink	6.5700	–1	–6.5700	0.100			
Thermal Pad	0.4836	–1	–0.4836	0.050			
DMD	1.6000	–1	–1.6000	0.100			
Interface	2.3300	1	2.3300	0.050			
Shoulder Screw	9.1700	1	9.1700	0.070			
						Max	**Min**
SUM			2.846	0.370	**SUM**	2.476	3.216
			(1)	0.173	**RSS**	2.673	3.019

(1) Nominal value must be positive to have a gap between heat sink and shoulder screw.

4.3.1.3 Electrical Mechanical Load Details

When mounting the PCB, a compressive load must be maintained on the spring contacts of the interposer to enable an electrical connection. The method for mounting the PCB shown in Figure 17 uses shoulder screws and coil springs to control the forces applied to the DMD electrical interface area. The minimum load needed for good electrical performance and maximum load allowed on the DMD are described in Section 4.2.4. The coil springs are compressed between the clamp and the flat spring (near head of the shoulder screw). The variation in the gap (identified as 'Critical Gap' in Figure 21) determines the range of loads applied to the DMD. Figure 21 illustrates a tolerance-analysis schematic used to determine the variation of the 'Critical Gap'. The tolerance schematic starts at the recessed area of the clamp (right-hand side) where the coil spring contacts and continues to the flat spring (near head of the shoulder screw – left-hand side) where the coil spring contacts the flat spring. The size of the 'Critical Gap' varies with the part manufacturing tolerances.

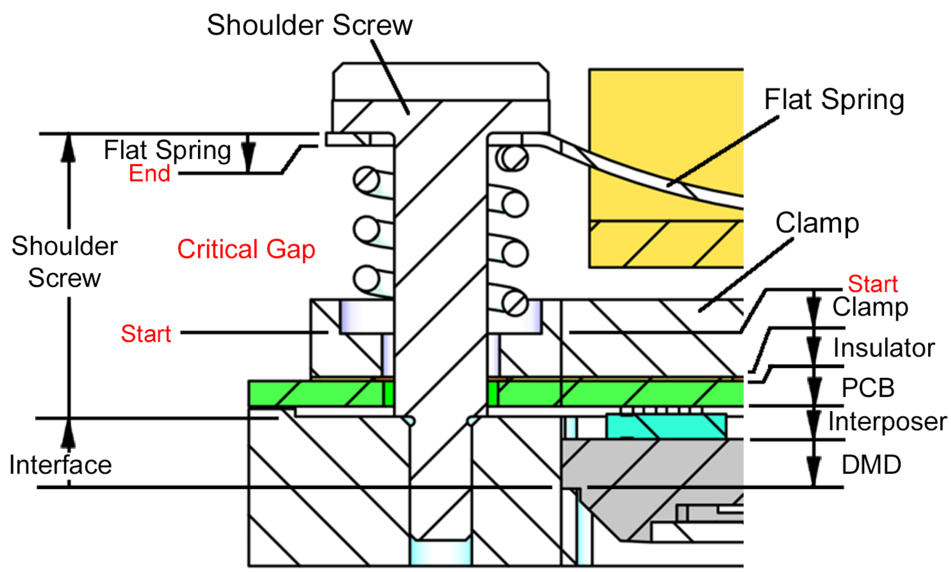

Figure 21. Coil Spring Gap Tolerance-Analysis Schematic (Shim)

Table 2 lists the nominal value and tolerance for each part feature in the tolerance-analysis schematic. The nominal values and tolerances used are those on the part drawings for the mounting concept shown in Figure 17. The parts are dimensioned in a manner to minimize variations in the ‘Critical Gap’. The tolerance analysis indicates the nominal gap size is 6.084 mm. The simple (SUM) method of tolerance analysis (worst case) yields a tolerance of ±0.600 mm. This results in a minimum (SUM) gap of 5.483 mm, and a maximum gap of 6.684 mm. The RSS method of tolerance analysis yields a tolerance of ±0.252 mm. This results in a minimum RSS gap of 5.832 mm, and a maximum gap of 6.335 mm.

Table 2. Coil Spring Gap Analysis (Shim)

	Nominal (mm)	Direction Sign	Nominal (mm)	Tol (±) (mm)	Tolerance Method	Gap	
Clamp	1.400	–1	–1.400	0.100			
Insulator	0.130	–1	–0.130	0.000			
PCB	0.820	–1	–0.820	0.100			
Interposer	1.060	–1	–1.060	0.160			
DMD	1.6000	–1	–1.6000	0.100			
Interface	2.3300	1	2.3300	0.050			
Shoulder Screw	9.1700	1	9.1700	0.070			
Flat Spring (mtl thk)	0.406	–1	–0.406	0.020			
						Max	**Min**
SUM			6.084	0.600	**SUM**	5.483	6.684
			(1)	0.252	**RSS**	5.832	6.335

(1) Nominal value must be positive to have a gap between clamp and flat spring.

The variation in the gap is used to design or select the coil springs used to apply the load to compress the contacts of the electrical interposer.

The design of the coil spring needs to comprehend:

- minimum and maximum gap range
- nominal free length of the coil spring
- nominal spring constant of the coil spring
- coil spring manufacturing tolerances for both free length and spring constant

The following is the basis for the coil spring analysis in Table 3:

- Coil spring rate tolerance of ±10% (see spring manufacturer for value)
- Coil spring free length of ±0.55 mm (see spring manufacturer for value)
- Nominal gap for spring of 6.084 mm (from Table 2)
- Minimum gap for SUM tolerance analysis of 5.483 mm (from Table 2)
- Maximum gap for SUM tolerance analysis of 6.684 mm (from Table 2)
- Minimum gap for RSS tolerance analysis of 5.832 mm (from Table 2)
- Maximum gap for RSS tolerance analysis of 6.335 mm (from Table 2)
- Minimum load of 15.7 N per spring (required to compress the 40 contacts in one interposer)
- Maximum load of 50 N (slightly less than maximum allowed on DMD electrical interface area)

The nominal force occurs when:

- the gap is 'as designed' (no tolerances associated with part manufacturing applied)
- the spring rate is the nominal specified value
- the free length is the 'as designed' length (no tolerances applied)

The maximum force occurs when:

- the gap is the smallest (using either SUM or RSS tolerance analysis)
- the spring rate is on the high side of tolerance
- the free length of the spring is on the high side of tolerances

The minimum force occurs when:

- the gap is the largest (using either SUM or RSS tolerance analysis)
- the spring rate is on the low side of tolerance
- the free length of the spring is on the low side of tolerances

Table 3 summarizes the loads on a single electrical interface area of the DMD for Nominal, SUM (worst case) and RSS tolerance analysis for several candidate coil springs (identified as A-G).

Table 3. Analysis Summary for Coil Springs (Shim)

Spring	Free Length (mm)	Spring Rate (N/mm)	DMD Electrical Area Load (Force)				
			Nominal	Worst-Case (SUM) Tolerance		RSS Case Tolerance	
			(N)	Min (N)	Max (N)	Min (N)	Max (N)
A	9.499	7.19	24.56	14.60	36.18	16.86	33.42
B	9.524	8.59	29.56	17.64	43.36	20.33	40.17
C	11.125	4.05	20.42	14.15	27.62	15.42	26.07
D	11.125	4.57	23.04	15.97	31.17	17.40	29.42
E	11.125	6.26	31.56	21.87	42.70	23.84	40.30
F	11.125	7.72	38.92	26.97	52.65	29.40	49.70
G	11.125	8.15	41.09	28.48	55.59	31.03	52.46

The results of the tolerance analysis in Table 3 indicates:

- all springs (A-G) have a nominal force that is between the minimum and maximum loads desired (15.7 – 50.0 N).
- springs A and C have loads less than the minimum (15.7 N) desired for the worst-case (SUM) tolerance analysis, spring C has a load less than the minimum desired for RSS tolerance analysis while spring A has a load greater than the minimum desired for RSS tolerance analysis
- springs F and G have loads greater than the maximum (50.0 N) desired for the worst-case (SUM) tolerance analysis, spring G has a load greater than the maximum desired for RSS tolerance analysis while spring F has a load less than the maximum desired for RSS tolerance analysis
- the candidate springs that meet the minimum and maximum loads allowed for nominal and all tolerance-analysis conditions (SUM and RSS) are B, D and E

A final selection between these spring candidates would be based on several factors, including but not limited to:

- what is the likelihood that the worst-case (SUM) conditions would occur?
- if the worst-case (SUM) conditions did occur what type of failure is likely to result? (Would the DMD be damaged? Would the electrical connection to the DMD be compromised?, and so forth)
- if a failure did result, could it be identified before the product was shipped to the final customer?
- if a failure did result, what would the impact on the final customer be?

4.3.1.4 PCB Mounting

Section 4.2.5 describes the importance of keeping the PCB (or FPCB) from bending to assure a good electrical connection. Bending that does occur can be minimized by reducing the distance (or gap) between the PCB and optical chassis. The variation in the gap determines the amount the PCB could bend. Figure 22 illustrates a tolerance-analysis schematic used to determine the variation of the ‘Critical Gap’. The tolerance schematic starts at the PCB and continues to the area of the optical engine where the PCB could contact and prevent any further bending.

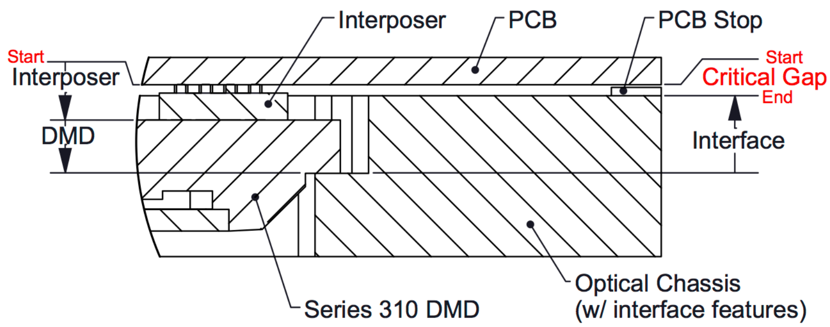

Figure 22. PCB Gap Tolerance-Analysis Schematic (Shim)

Table 4 lists the nominal value and tolerance for each part feature in the tolerance-analysis schematic. The nominal values and tolerances used are those on the part drawings for the mounting concept shown in Figure 17. The parts are dimensioned in a manner to minimize variations in the ‘Critical Gap’. The tolerance analysis indicates the nominal gap size is 0.33 mm. The simple (SUM) method of tolerance analysis (worst case) yields a tolerance of ±0.310 mm. This results in a (SUM) minimum gap of 0.020 mm, and a maximum gap of 0.640 mm. The RSS method of tolerance analysis yields a tolerance of ±0.195 mm. This results in a RSS minimum gap of 0.135 mm, and a maximum gap of 0.525 mm.

Table 4. PCB Gap Analysis (Shim)

	Nominal (mm)	Direction Sign	Nominal (mm)	Tol (±) (mm)	Tolerance Method	Gap(2)	
Interposer	1.060	–1	–1.060	0.160			
DMD	1.6000	–1	–1.6000	0.100			
Interface	2.3300	1	2.3300	0.050			
						Max	**Min**
SUM			–0.330	0.310	**SUM**	0.020	0.640
			(1)	0.195	**RSS**	0.135	0.525

(1) Nominal value must be negative to have a gap between interface and PCB

(2) The gap is the potential amount the PCB could bend if the clamp is not stiff enough for the selected coil spring, or PCB stop not used.

To fully guarantee the interposer contacts are fully compressed (for good electrical connection) there must always be a gap between the PCB and the optical engine. The worst-case maximum gap is much larger than the compression range of the interposer contacts. To help manage the maximum gap and reduce bending, a raised area has been added to the optical engine called the ‘PCB Stop’ (shown in Figure 22). The mounting load is applied to the PCB between the interposer and the ‘PCB Stop’ (by the shoulder screw and coil spring). As the mounting screw continues to be tightened, after the PCB contacts the ‘PCB Stop’, the PCB will deflect slightly and enable the PCB to contact the interposer contacts (making electrical connection). The ‘PCB Stop’ can be part of the optical chassis or a separate added part. A separate part would be easier to change if any of the manufacturing tolerances changed for the parts included in the gap analysis.

4.3.2 Clip Alignment Mounting Concept

The design concept for mounting the Series-310 DMD shown in Figure 23 is a *drop-in-place* concept which incorporates specific features to aid DMD alignment during the DMD installation process. This section describes the clip-alignment features and details associated with control of mechanical loads applied to the electrical and thermal interface areas of the DMD.

The drawing number for the "Clip Mounting Concept" shown in Figure 23 is 2511348. The 3D-CAD models (in STEP format) and drawings (in pdf format) for each part shown are available for download. See Section 6.

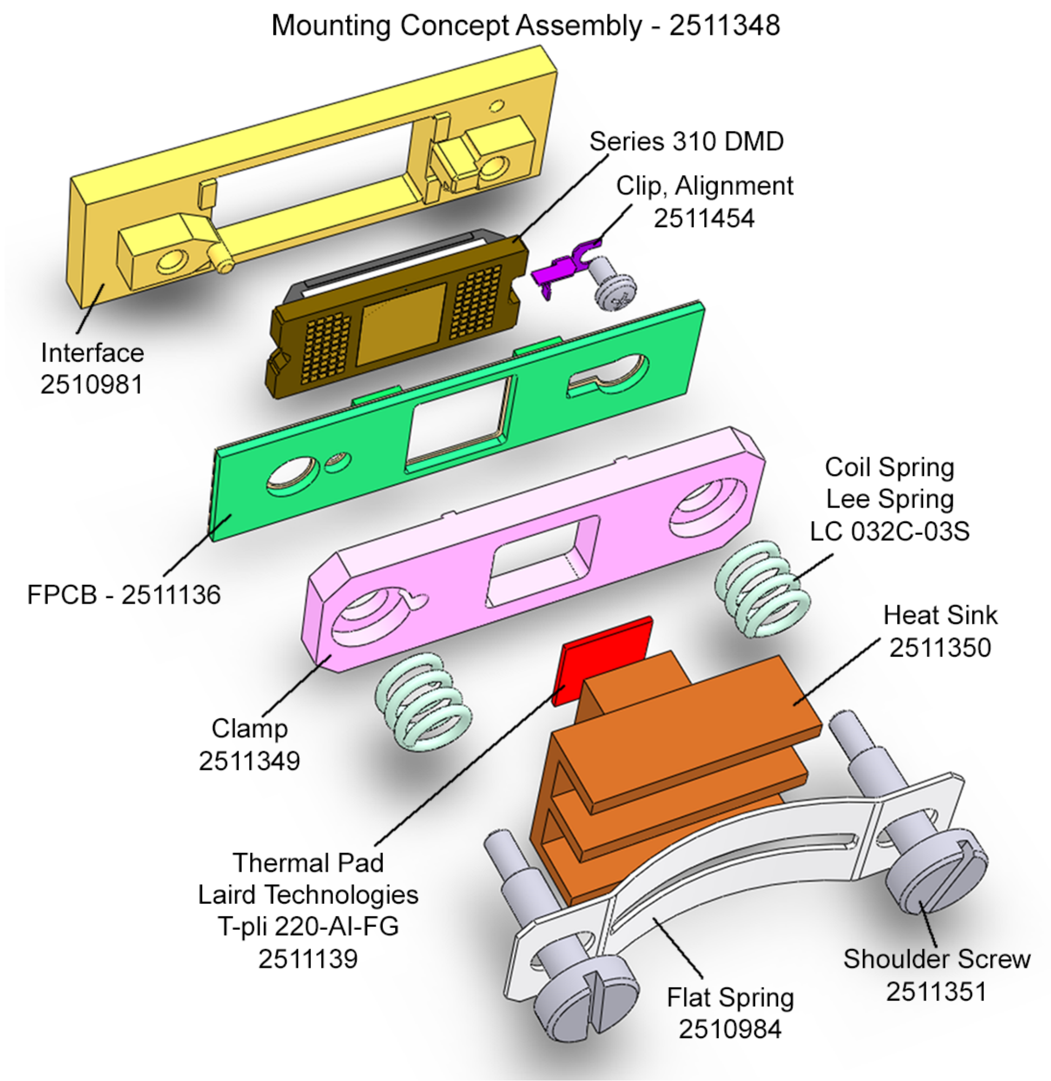

Figure 23. Clip Alignment Mounting Concept

4.3.2.1 DMD Clip-Alignment Features

The location of the DMD is important for both optical (array position) and electrical (pad position) considerations. A consistent and repeatable DMD location requires the DMD be manually pushed into contact with the optical interface Datums 'B' and 'C' features, and then held in place while the mounting screws are tightened. To facilitate holding the DMD in position this mounting concept utilizes a clip. The function of the clip is to keep the DMD from shifting locations while the clamp and heat sink are secured. The DMD is to be manually pushed against Datums 'B' and 'C' (as described in Section 4.2.1) using the clip and then clip secured in place with the screw. The clip and Datum features are shown in Figure 18.

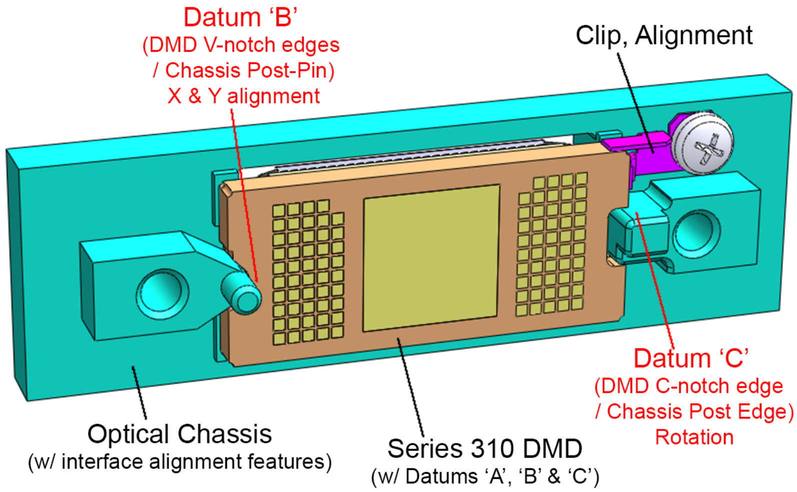

Figure 24. Alignment Clip

4.3.2.2 Thermal Mechanical Load Details

The method for mounting the heat sink shown in Figure 23 uses shoulder screws and a flat spring to control the forces applied to the DMD thermal interface area. The minimum load needed for good thermal performance and maximum load allowed on the DMD are described in Section 4.2.4. The flat spring is compressed between the heat sink and the head of the shoulder screw. The variation in the gap (identified as 'Critical Gap' in Figure 25) determines the range of loads applied to the DMD. Figure 25 illustrates a tolerance-analysis schematic used to determine the variation of the 'Critical Gap'. The tolerance schematic starts at the top of the heat sink (right-hand side of Figure 25) where the flat spring contacts and continues to the head of the shoulder screw (left-hand side) where the flat spring contacts. The size of the 'Critical Gap' varies with the part manufacturing tolerances.

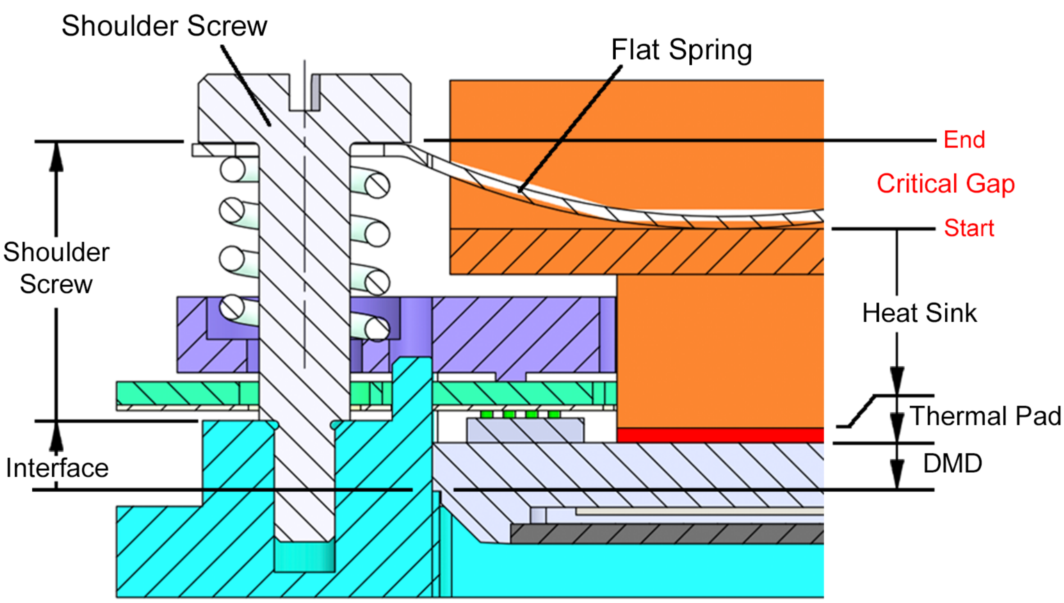

Figure 25. Flat Spring Gap Tolerance-Analysis Schematic (Clip)

Table 5 lists the nominal value and tolerance for each part feature in the tolerance-analysis schematic. The nominal values and tolerances used are those on the part drawings for the mounting concept shown in Figure 23. The parts are dimensioned in a manner to minimize variations in the 'Critical Gap'. The tolerance analysis indicates the nominal gap size is 2.846 mm. The simple (SUM) method of tolerance analysis (worst case) yields a tolerance of ±0.370 mm. This results in a (SUM) minimum gap of 2.476 mm, and a maximum gap of 3.216 mm. The RSS method of tolerance analysis yields a tolerance of ±0.173 mm. This results in a RSS minimum gap of 2.673 mm, and a maximum gap of 3.019 mm.

The design of the flat spring needs to comprehend:

- minimum and maximum gap ranges
- flat spring manufacturing tolerances
- spring constant variation of the flat spring

Table 5. Flat Spring Gap Analysis (Shim)

	Nominal (mm)	Direction Sign	Nominal (mm)	Tol (±) (mm)	Tolerance Method	Gap	
Heat Sink	6.5700	–1	–6.5700	0.100			
Thermal Pad	0.4836	–1	–0.4836	0.050			
DMD	1.6000	–1	–1.6000	0.100			
Interface	2.3300	1	2.3300	0.050			
Shoulder Screw	9.1700	1	9.1700	0.070			
						Max	**Min**
SUM			2.846	0.370	**SUM**	2.476	3.216
			(1)	0.173	**RSS**	2.673	3.019
(1) Nominal value must be positive to have a gap between heat sink and shoulder screw.							

4.3.2.3 Electrical Mechanical Load Details

When mounting the PCB a compressive load must be maintained on the spring contacts of the interposer to enable an electrical connection. The method for mounting the PCB shown in Figure 23 uses shoulder screws and coil springs to control the forces applied to the DMD electrical interface area. The minimum load needed for good electrical performance and maximum load allowed on the DMD are described in Section 4.2.4. The coil springs are compressed between the clamp and the flat spring (near head of the shoulder screw). The variation in the gap (identified as 'Critical Gap' in Figure 26) determines the range of loads applied to the DMD. Figure 26 illustrates a tolerance-analysis schematic used to determine the variation of the 'Critical Gap'. The tolerance schematic starts at the recessed area of the clamp (right-hand side) where the coil spring contacts and continues to the flat spring (near head of the shoulder screw – left-hand side) where the coil spring contacts the flat spring. The size of the 'Critical Gap' varies with the part manufacturing tolerances.

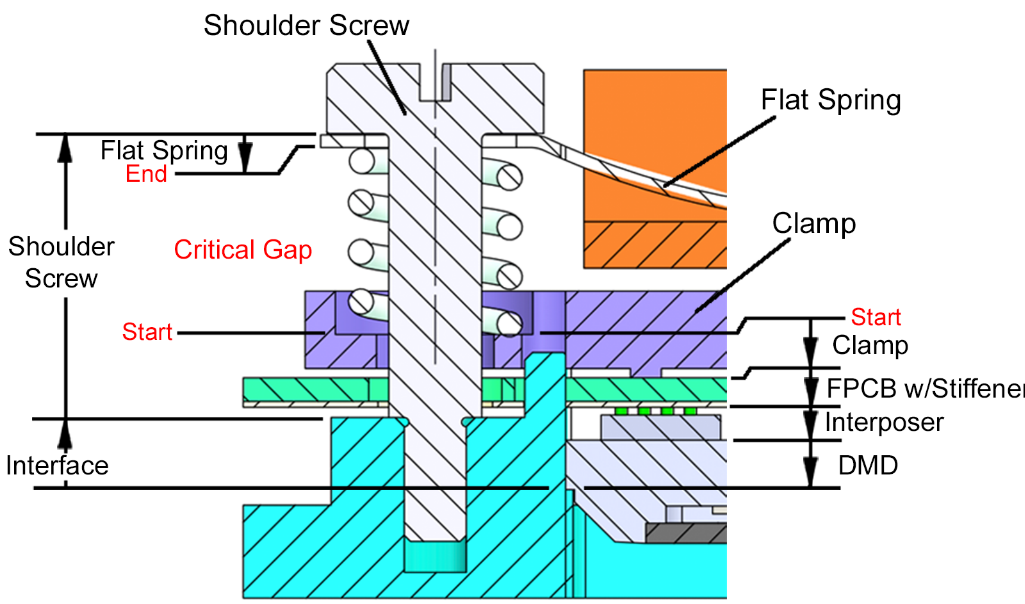

Figure 26. Coil Spring Gap Tolerance-Analysis Schematic (Clip)

Table 6 lists the nominal value and tolerance for each part feature in the tolerance-analysis schematic. The nominal values and tolerances used are those on the part drawings for the mounting concept shown in Figure 23. The parts are dimensioned in a manner to minimize variations in the 'Critical Gap'. The tolerance analysis indicates the nominal gap size is 6.084 mm. The simple (SUM) method of tolerance analysis (worst case) yields a tolerance of ±0.600 mm. This results in a minimum (SUM) gap of 5.483 mm, and a maximum gap of 6.684 mm. The RSS method of tolerance analysis yields a tolerance of ±0.252 mm. This results in a minimum RSS gap of 5.832 mm, and a maximum gap of 6.335 mm.

Table 6. Coil Spring Gap Analysis (Clip)

	Nominal (mm)	Direction Sign	Nominal (mm)	Tol (±) (mm)	Tolerance Method	Gap	
Clamp	1.400	–1	–1.400	0.100			
Insulator	0.130	–1	–0.130	0.000			
PCB	0.820	–1	–0.820	0.100			
Interposer	1.060	–1	–1.060	0.160			
DMD	1.6000	–1	–1.6000	0.100			
Interface	2.3300	1	2.3300	0.050			
Shoulder Screw	9.1700	1	9.1700	0.070			
Flat Spring (mtl thk)	0.406	–1	–0.406	0.020			
						Max	**Min**
SUM			6.084	0.600	**SUM**	5.483	6.684
			(1)	0.252	**RSS**	5.832	6.335

(1) Nominal value must be positive to have a gap between clamp and flat spring

The variation in the gap is used to design or select the coil springs used to apply the load to compress the contacts of the electrical interposer.

The design of the coil spring needs to comprehend:

- minimum and maximum gap range
- nominal free length of the coil spring
- nominal spring constant of the coil spring
- coil spring manufacturing tolerances for both free length and spring constant

The following is the basis for the coil spring analysis in Table 7:

- Coil spring rate tolerance of ±10% (see spring manufacturer for value)
- Coil spring free length of ±0.55 mm (see spring manufacturer for value)
- Nominal gap for spring of 6.084 mm (from Table 6)
- Minimum gap for SUM tolerance analysis of 5.483 mm (from Table 6)
- Maximum gap for SUM tolerance analysis of 6.684 mm (from Table 6)
- Minimum gap for RSS tolerance analysis of 5.832 mm (from Table 6)
- Maximum gap for RSS tolerance analysis of 6.335 mm (from Table 6)
- Minimum load of 15.7 N per spring (required to compress the 40 contacts in one interposer)
- Maximum load of 50 N (slightly less than maximum allowed on DMD electrical interface area)

The nominal force occurs when:

- the gap is 'as designed' (no tolerances associated with part manufacturing applied)
- the spring rate is the nominal specified value
- the free length is the 'as designed' length (no tolerances applied)

The maximum force occurs when:

- the gap is the smallest (using either SUM or RSS tolerance analysis)
- the spring rate is on the high side of tolerance
- the free length of the spring is on the high side of tolerances

The minimum force occurs when:

- the gap is the largest (using either SUM or RSS tolerance analysis)
- the spring rate is on the low side of tolerance
- the free length of the spring is on the low side of tolerances

Table 7 summarizes the loads on a single electrical interface area of the DMD for Nominal, SUM (worst case) and RSS tolerance analysis for several candidate coil springs (identified as A-G).

Table 7. Analysis Summary for Coil Springs (Clip)

Spring	Free Length (mm)	Spring Rate (N/mm)	DMD Electrical Area Load (Force)				
			Nominal	Worst-Case (SUM) Tolerance		RSS Case Tolerance	
			(N)	Min (N)	Max (N)	Min (N)	Max (N)
A	9.499	7.19	24.56	14.60	36.18	16.86	33.42
B	9.524	8.59	29.56	17.64	43.36	20.33	40.17
C	11.125	4.05	20.42	14.15	27.62	15.42	26.07
D	11.125	4.57	23.04	15.97	31.17	17.40	29.42
E	11.125	6.26	31.56	21.87	42.70	23.84	40.30
F	11.125	7.72	38.92	26.97	52.65	29.40	49.70
G	11.125	8.15	41.09	28.48	55.59	31.03	52.46

The results of the tolerance analysis in Table 7 indicates:

- all springs (A-G) have a nominal force that is between the minimum and maximum loads desired (15.7 – 50.0 N).
- springs A and C have loads less than the minimum (15.7 N) desired for the worst-case (SUM) tolerance analysis, spring C has a load less than the minimum desired for RSS tolerance analysis while spring A has a load greater than the minimum desired for RSS tolerance analysis
- springs F and G have loads greater than the maximum (50.0 N) desired for the worst-case (SUM) tolerance analysis, spring G has a load greater than the maximum desired for RSS tolerance analysis while spring F has a load less than the maximum desired for RSS tolerance analysis
- the candidate springs that meet the minimum and maximum loads allowed for nominal and all tolerance analysis conditions (SUM and RSS) are B, D and E

A final selection between these spring candidates would be based on several factors, including but not limited to:

- what is the likelihood that the worst-case (SUM) conditions would occur?
- if the worst-case (SUM) conditions did occur what type of failure is likely to result? (Would the DMD be damaged? Would the electrical connection to the DMD be compromised?, and so forth)
- if a failure did result, could it be identified before the product was shipped to the final customer?
- if a failure did result, what would the impact on the final customer be?

4.3.2.4 PCB Mounting

Section 4.2.5 describes the importance of keeping the PCB (or FPCB) from bending to assure a good electrical connection. Bending that does occur can be minimized by reducing the distance (or gap) between the PCB and optical chassis. The variation in the gap determines the amount the PCB could bend. Figure 27 illustrates a tolerance-analysis schematic used to determine the variation of the ‘Critical Gap’. The tolerance schematic starts at the PCB and continues to the area of the optical engine where the PCB could contact and prevent any further bending.

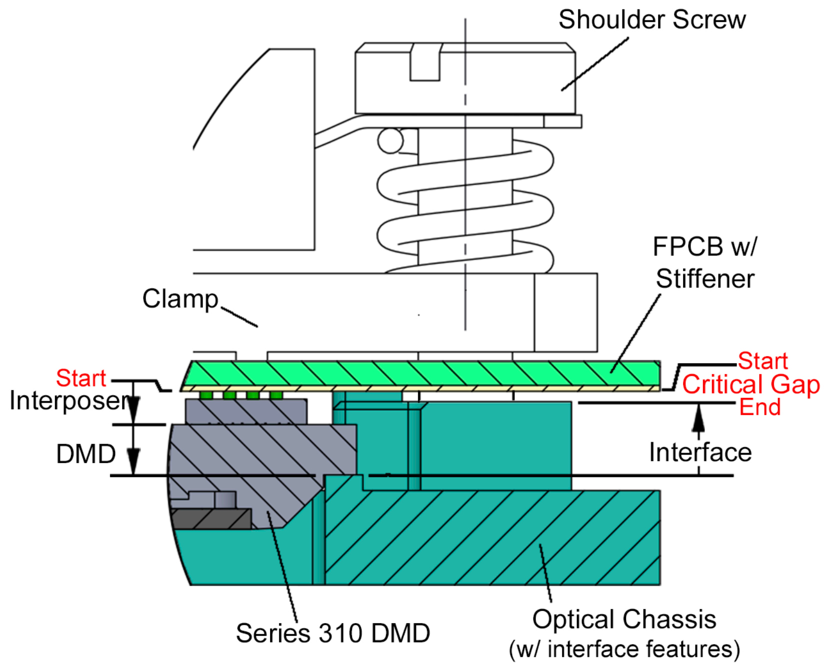

Figure 27. PCB Gap Tolerance-Analysis Schematic (Clip)

Table 8 lists the nominal value and tolerance for each part feature in the tolerance-analysis schematic. The nominal values and tolerances used are those on the part drawings for the mounting concept shown in Figure 23. The parts are dimensioned in a manner to minimize variations in the ‘Critical Gap’. The tolerance analysis indicates the nominal gap size is 0.33 mm. The simple (SUM) method of tolerance analysis (worst case) yields a tolerance of ±0.310 mm. This results in a (SUM) minimum gap of 0.020 mm, and a maximum gap of 0.640 mm. The RSS method of tolerance analysis yields a tolerance of ±0.195 mm. This results in a RSS minimum gap of 0.135 mm, and a maximum gap of 0.525 mm.

Table 8. PCB Gap Analysis (Clip)

	Nominal (mm)	Direction Sign	Nominal (mm)	Tol (±) (mm)	Tolerance Method	Gap(2)	
Interposer	1.060	–1.060	–1	–1.060	0.160		
DMD	1.6000	–1	–1.6000	0.100			
Interface	2.3300	1	2.3300	0.050			
						Max	**Min**
SUM			–0.330	0.310	**SUM**	0.020	0.640
			(1)	0.195	**RSS**	0.135	0.525

(1) Nominal value must be negative to have a gap between interface and PCB

(2) The gap is the potential amount the PCB could bend if the clamp is not stiff enough for the selected coil spring, or PCB stop not used.

5 System Electrical Interposer (connector or socket)

The electrical interface to the DMD consists of 80 LGA pads. The 80 LGA pads are divided into two groups of 40 pads, where each group is a 4x10 array of pads. An interposer is available with a 4x10 array of contacts that will provide electrical connection between the DMD and the system PCB or FPCB. Each DMD will require two of these interposers. This interposer is intended to be soldered to the PCB and has spring contacts to contact the DMD LGA pads. The interposer developed is shown in Figure 28.

The TI drawing number for the interposer concept is 2510978. A 3D-CAD file of the nominal geometry (in STEP format) and drawing (in pdf format) are available for download, see Section 6. See the interposer supplier for a detailed drawing of the part.

The Series-310 DMD and electrical interposer do not have features for direct alignment between them. To achieve electrical alignment between the DMD and the PCB, the DMD mounting concepts described herein utilize a combination of features on the DMD, optical engine, and PCB. See Section 4.2.2 for description.

The alignment needed for the electrical connection is achieved by careful control of manufacturing tolerances for each of the features on the optical engine and PCB described in Section 4.2.2, proper use of the DMD Datums, and an assembly procedure which ensures uniform clamping of interposers.

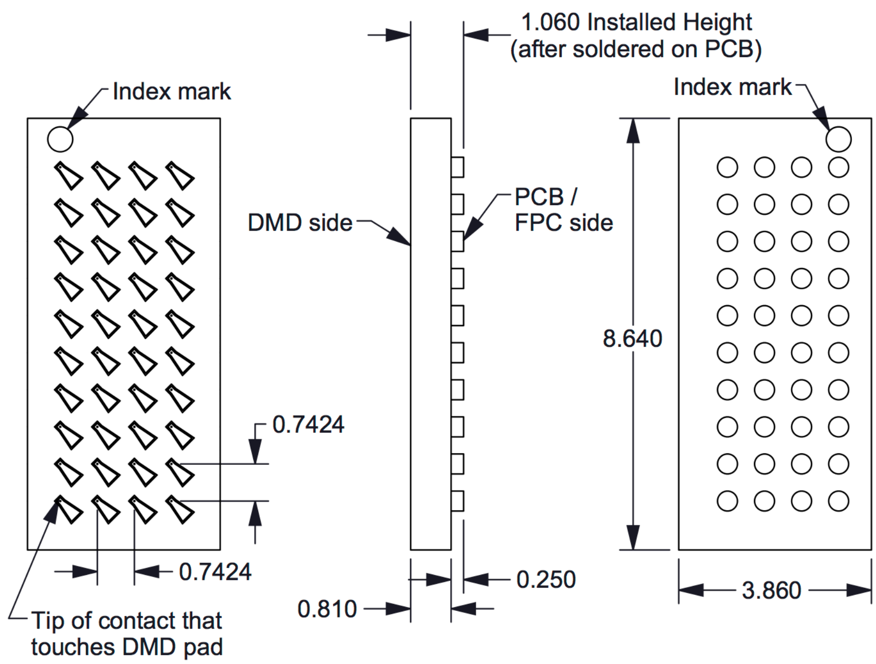

Figure 28. System Interposer

The installed height of the interposer shown in Figure 29 is important for controlling the magnitude and uniformity of the mechanical clamping loads applied to the DMD.

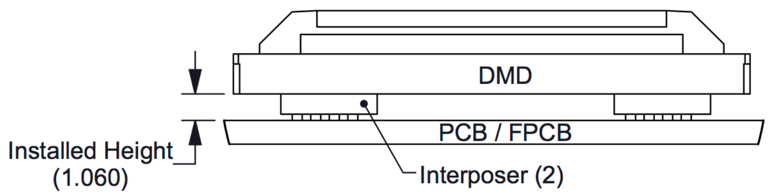

Figure 29. Interposer Installed Height

6 Drawing and 3D-CAD File References

Drawings (in pdf format) and 3D-CAD models (in STEP format) for many of the parts discussed in this application report are available to facilitate study, when designing an end-application. Two 3D-CAD files are available for the DMD. The first represents the nominal geometry of all the features and the second represents nominal geometry for all the features except the encapsulation, which is modeled at the maximum encapsulation size. Table 9 summarizes the literature numbers for the drawings and 3D-CAD models that are available for download.

Table 9. Reference Drawings and 3D-CAD Models

FILE NAME	DESCRIPTION
DLPS028	DLP4500FQD DMD (Series 310) Data Sheet
DLPC076	DLP4500FQD DMD (Series 310) 3D-CAD model file with nominal geometry
DLPC077	DLP4500FQD DMD (Series 310) 3D-CAD model file with maximum encapsulation geometry
DLPC078	Assembly and Part drawing of Shim Alignment Mounting Concept (2513122) – also includes 3D-CAD model file
DLPC079	Assembly and Part drawing of Clamp Alignment Mounting Concept (2511348) – also includes 3D-CAD model file
DLPC080	Part Drawing of Series 310 interposer (2510978) – also includes 3D-CAD model file

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