Texas Instruments

Application Report
DLPA069–March 2016

DLP® Series-244 DMD and System Mounting Concepts Mechanical and Thermal Application Report

ABSTRACT

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1 Scope

This application report serves as an aid to the successful first-time utilization and implementation of the Series-244 DMD (DLP2010 and DLP2010NIR) and addresses the following topics:

- Terminology
- Specification and Design Details of a Series-244 DMD
- System Mounting concepts for a Series-244 DMD, including key attributes and important application design considerations
- Mating connectors for use with a Series-244 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.

FPCB – Flex Printed Circuit Board

PCB – Printed Circuit Board

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

Dark Metal - The area just outside the micromirror array but within the same plane as the micromirror array, see Figure 5.

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

DMD Features - The primary features of the Series-244 DMD are described below and illustrated in Figure 1 and Figure 2.

- WLP Chip – Wafer Level Package (WLP) DMD chip which contains the DMD micromirror array, window glass, and window aperture
- 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 Chip (or just DMD) – the aggregate of the WLP Chip, ceramic substrate, bond wires, encapsulation, and electrical pads
- DMD test pads – pads on the ceramic substrate used by TI to electrically test the DMD during the manufacturing process (do not connect these pads in the system application)
- DMD micromirror array – the two-dimensional array of DMD micromirrors which reflect light
- Encapsulation – the material used to mechanically and environmentally protect the bond wires
- System interface connector – the connector that provides the electrical interface between the ceramic substrate and the end-application electronics
- 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 micromirror area (mirrors)
- Window aperture – the dark coating on the inside surface of the window glass around the perimeter of the micromirror array

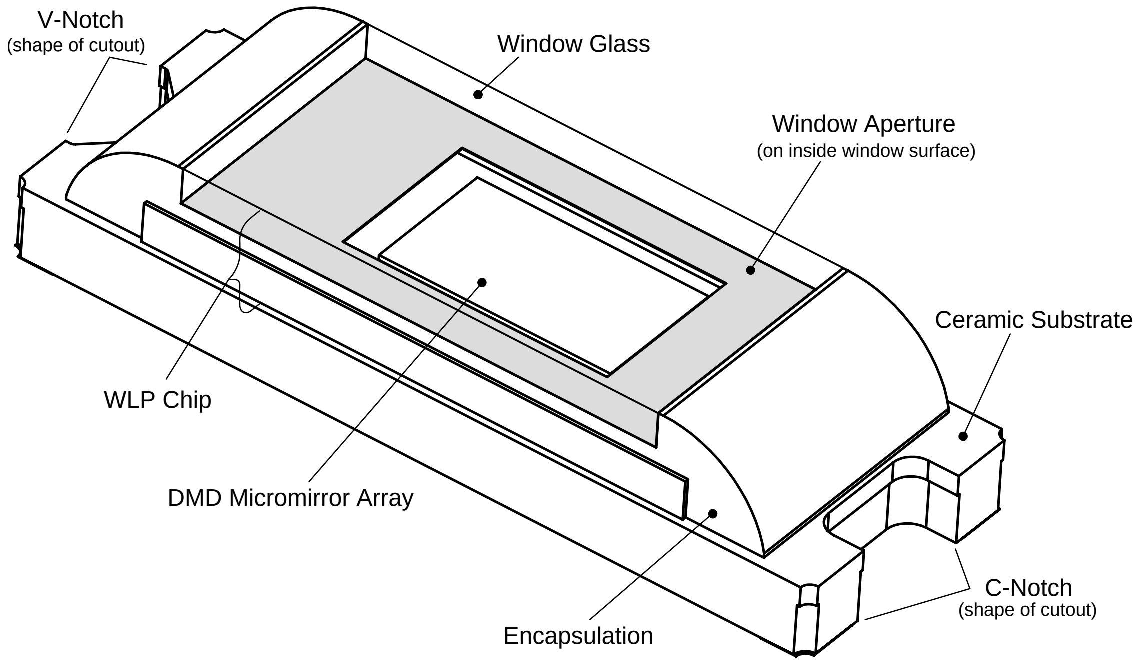

Figure 1. DMD Features, Window Side

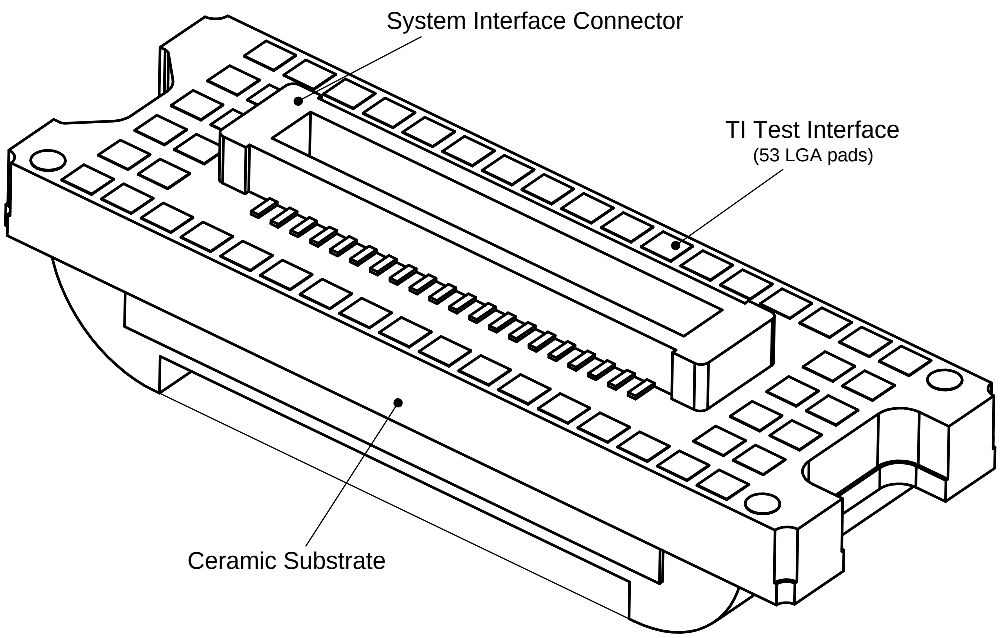

Figure 2. DMD Features, Electrical Side

Illumination light bundle – refers to the illumination cross-section area (size) at any location along the illumination light path but specifically at the DMD micromirror array and within the same plane as the micromirror 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)

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 micromirror area 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

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 report. The actual values of the parameters are specified in the DMD data sheet and mechanical ICD. The information in the mechanical ICD and data sheet should be used in case of any discrepancy with information in this document. A 3D-CAD file of the DMD nominal geometry in STEP format is available for download, see Section 6. (The mechanical ICD is also referred to as the Package Mechanical Characteristics in the DMD data sheet.)

3.1 Optical Interface Features

To facilitate the physical orientation of the DMD micromirror array relative to other optical components in the optical assembly, the Series-244 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. The three datum features are shown in Figure 3 and described below.

Datum ‘A’ – Primary datum Datum ‘A’ is a plane specified by three areas on the surface of the ceramic substrate. The plane of the DMD micromirror array is parallel to the plane formed by the three Datum ‘A’ areas. The DMD micromirror array has a controlled distance and parallelism from Datum ‘A’, as defined in the mechanical ICD. Datum ‘A’ allows the plane of the micromirror 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 2.50 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 line contact with the theoretical 2.50 mm diameter. While Datum ‘A’ defines the reference location of the micromirror array plane axially along the system optical axis, Datum ‘B’ establishes the reference for the X and Y position of the micromirror 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 2.50 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 micromirror 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.

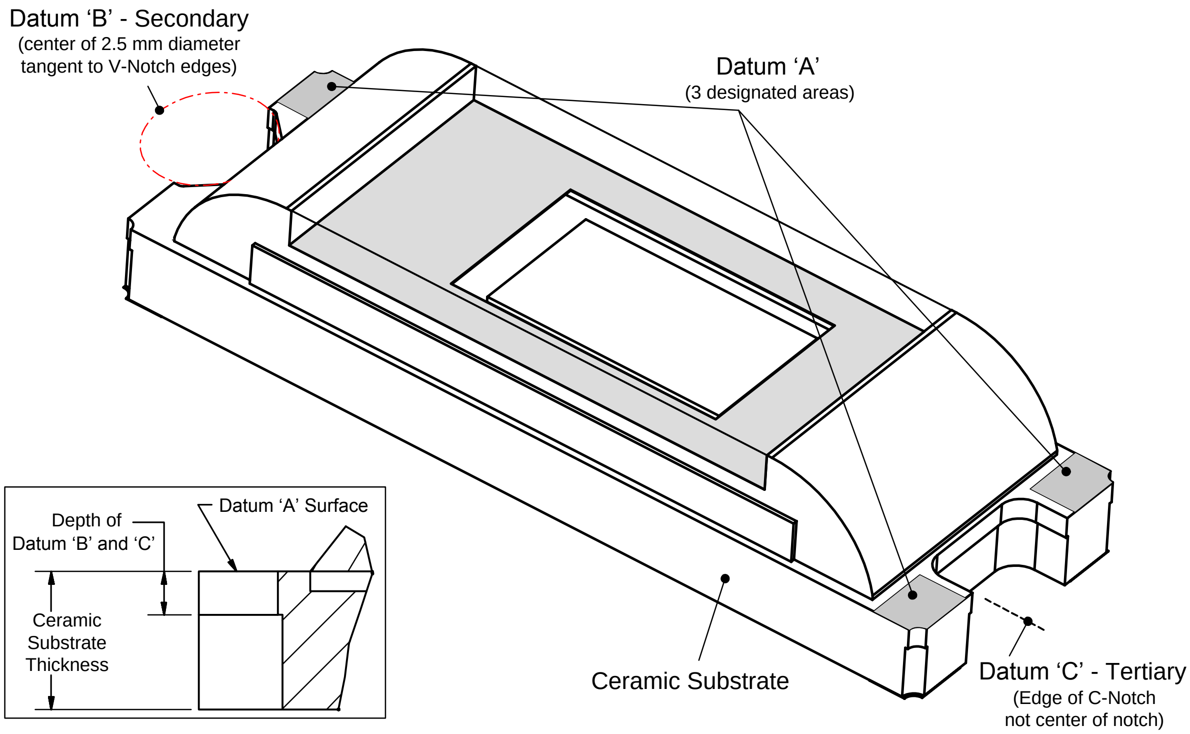

Figure 3. DMD Datum Features

3.2 DMD Cross Section Features

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

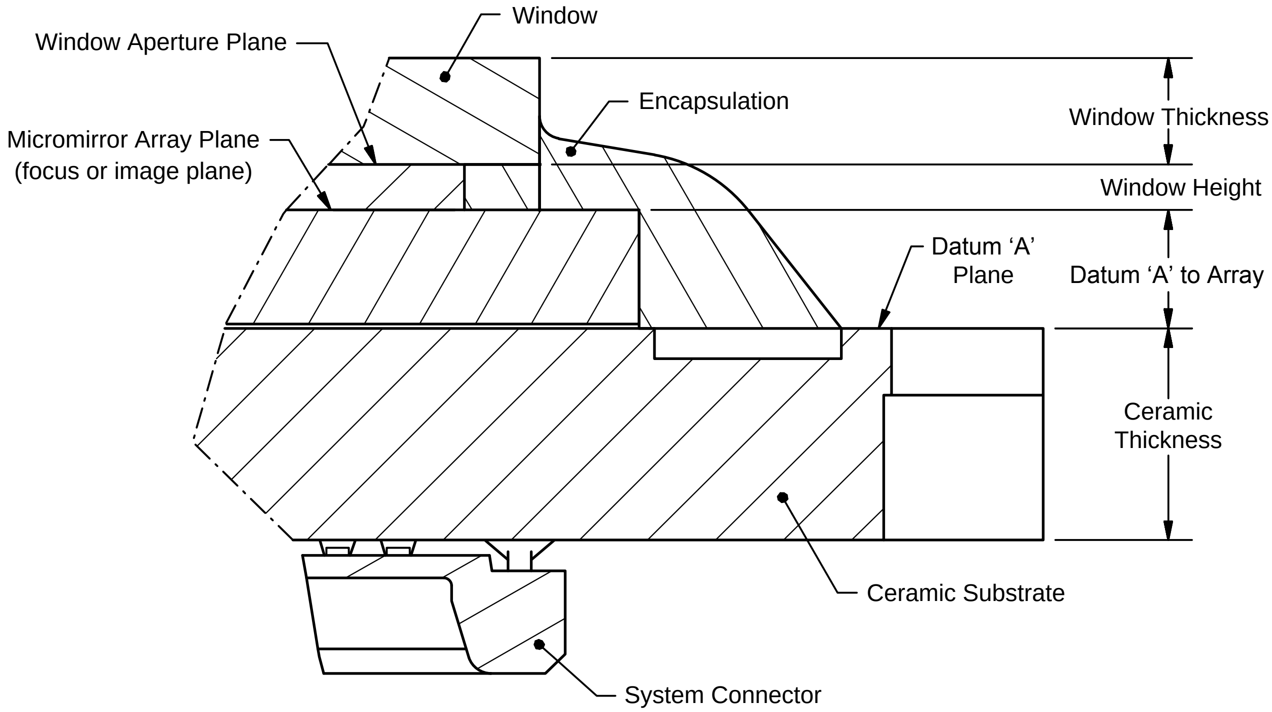

Figure 4. DMD Cross Section View Features

3.3 Optical Illumination Overfill

Optical illumination overfill is defined as the optical energy that falls outside the micromirror area. The overfill is wasted light 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, optical aberrations (such as distortion and/or color separation), and type of optical design. Telecentric optical designs will generally have less overfill and a more rectangular illumination shape.

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

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

- The total amount of energy being reflected from the DMD micromirror 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 the overfill is incident (window aperture, dark metal area around the micromirror 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, spectroscopy, and so forth)
- The specific wavelengths of light used (NIR/UV/VIS)

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

Optical overfill energy on the window aperture (if present) should especially be avoided. 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 micromirror array.

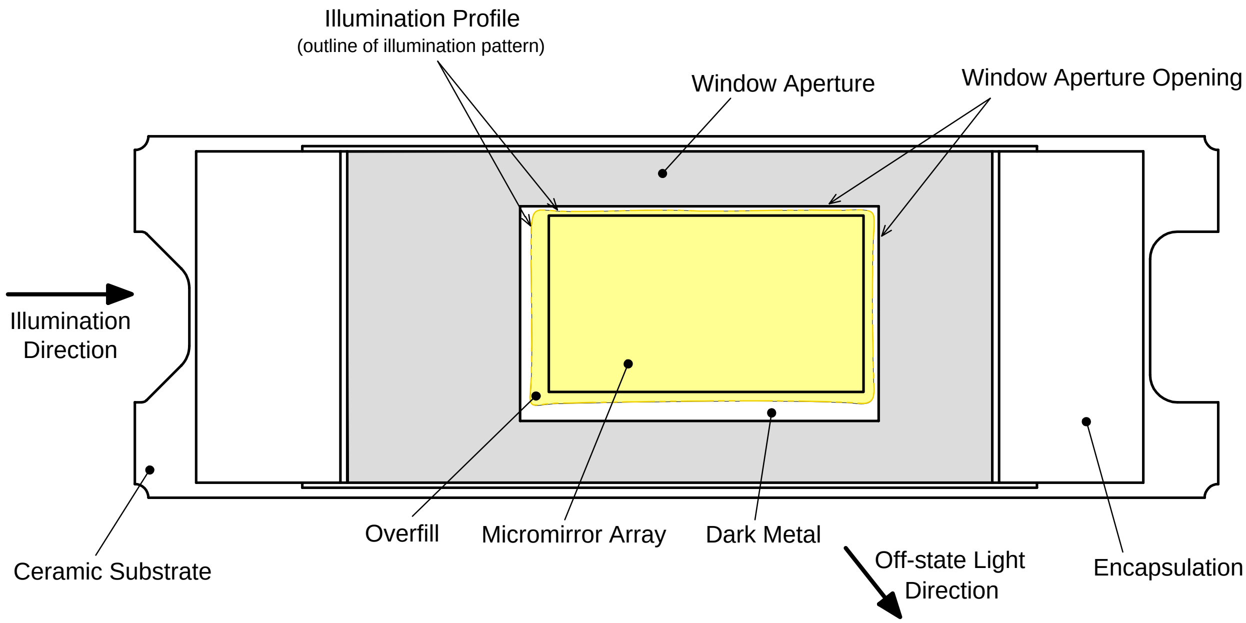

Figure 5. Optical Illumination Overfill

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 micromirror array, as shown in Figure 4. Since the DMD micromirror array is the optical focus plane, there is a risk that dust particles on the outside window surface will be re-imaged and appear 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
- Assemble in a clean room environment

It is import 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.

Be aware of the temperatures the gaskets will be exposed during operation and storage. Gasket materials and coating processes used on them that could result in out-gassing should be avoided. Out-gassing for the materials could collect on the optical elements and result in reduced optical performance.

3.5 Micromirror Array Size and Location

The micromirror array size and location is specified in the Mechanical ICD drawing. The micromirror array is located relative to the specified DMD Datum ‘A’, Datum ‘B’ (2.50 diameter), and Datum ‘C’ (edge of C-notch) features.

The micromirror array is not on the same center line of Datum ‘B’ (2.50 diameter), but rather offset to one side as shown in Figure 6. The locating dimension is from Datum ‘B’ to the edge of the micromirror array.

Also the micromirror array center is not centered between the edge of the Datum ‘B’ (V-notch) and the edge of Datum ‘C’ (C-notch edge) as illustrated in Figure 6. The locating dimension is from Datum ‘B’ to the edge of the mirror array.

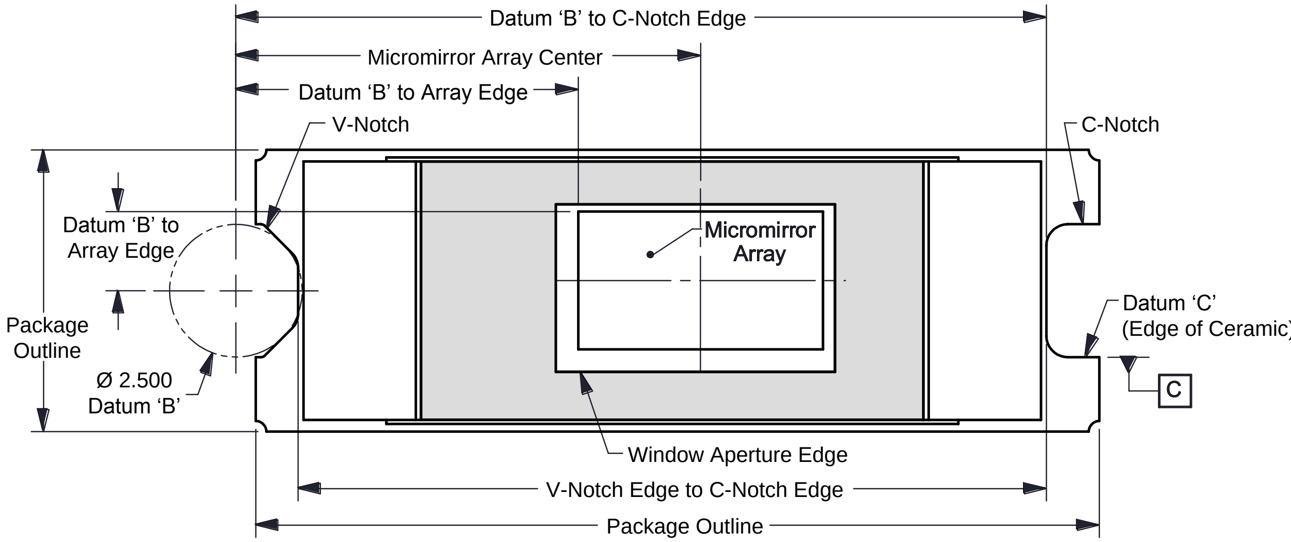

Figure 6. Micromirror Array Location

3.6 Electrical Interface Features

The electrical interface to the Series-244 DMD is a Board-to-Board (BTB) connector. The connector on the DMD is a 40 contact 0.4 mm pitch Panasonic part number AXT640124DD1. See Section 5 for the system mating connector information.

The pin numbering scheme for the BTB connector used on Series-244 DMDs is illustrated in Figure 7. The signal names for each pin G1 – G20 and H1 – H20 are identified in the DMD data sheet.

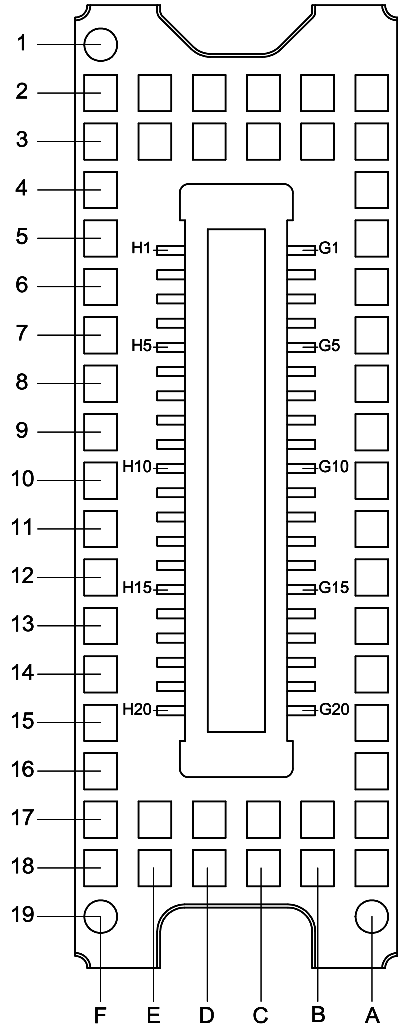

Figure 7. Pin Numbering Scheme

The LGA pads surrounding the BTB connector are reserved for 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 the LGA pads are not shorted together (electrically connected together) as this may cause damage to the DMD, or cause it to not function properly.

3.7 Thermal Considerations

The Series-244 DMD does not have a dedicated thermal interface area. This is generally not an issue as the DMD is intended for applications with low thermal loads from the illumination source.

The primary thermal load on the DMD originates from the dissipated electrical load that drives the mirrors and the absorbed optical load. The DMD data sheet provides an estimate for the electrical power of the DMD and a conversion factor for the optical power. The conversion factor for the optical power provided in the DMD data sheet is based upon assumptions of the illumination being evenly distributed across the micromirror array and having less than 16% overfill (by energy).

NOTE: 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.

Components near the DMD can cause additional heating of the DMD, but the significance depends upon the magnitude and location relative to the DMD. The secondary heating sources could be electrical components near the DMD (convective transfer of heat), or components mounted to the same optical chassis as the DMD (conductive transfer of heat). The DMD control chip or light source control chips are examples of components that may transfer heat by convection to the DMD. LED or laser light sources are examples of components that may be mounted to the optical chassis and transfer heat by conduction. The transfer of heat from secondary heating sources to the DMD should be eliminated or minimized 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. The amount of energy on the window aperture is determined by the optical illumination design. 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.

The thermal specifications in the DMD data sheet include ‘Recommended Operating Conditions’, ‘Storage Conditions’, and ‘Absolute Maximum Ratings’. The ‘Recommended Operating Conditions’ are for anytime the DMD is operating, whether in the final product or a test configuration. The ‘Storage Conditions’ are for times when the DMD is not operating. The ‘Storage Conditions’ apply before the DMD is installed in the final product, when the final product is stored in a warehouse, during shipping, and when the end user has the final product.

The ‘Absolute Maximum Ratings’ section of the data sheet provides specification values that are outside the ‘Recommended Operating Conditions’ for the device, and are intended for short-term exposure only. This value is appropriate when considering accelerated testing but is not a normal value to which the device should be exposed to and expect long service life.

The temperature specifications apply for specific test points identified in the data sheet and the micromirror array. The micromirror array temperature can not be measured directly but must be computed analytically using information in the DMD data sheet, measurement of the thermal test point, and the thermal load absorbed from the illumination energy. Calculation of the micromirror array temperature from this information is shown in the DMD data sheet and described in Section 3.7.2.

The image that is displayed when making the temperature measurements should be the image that produces the worst-case temperatures. For an end-application where the largest thermal load is the illumination on the DMD (rather than the electrical load of the DMD) the worst-case temperatures would typically result when the mirrors are in the off-state. For a display application this would be from an all black image. For an end-application where the energy on the micromirror array is low and the thermal load on the DMD is dominated by the electrical load the worst case temperatures would typically result from a “white noise” image.

3.7.1 Thermal Test Points

The Series-244 DMD has three defined thermal test points. One is on the connector side of the ceramic (TP1) and the other two are on the edge of the window (TP2, TP3). The minimum and maximum thermal requirements are summarized in the DMD data sheet for the specific test points and the array. The temperature of the reference locations (TP1, TP2, TP3) can be measured directly, but the micromirror array temperature must be computed as described in Section 3.7.2. The locations of thermal test points TP2 and TP3 in Figure 8 are intended to measure the highest window edge temperature. If a particular application causes another point on the window edge to result in a higher window temperature then this point should be used for highest window temperature, and in the computation for the delta temperature from the ceramic and window.

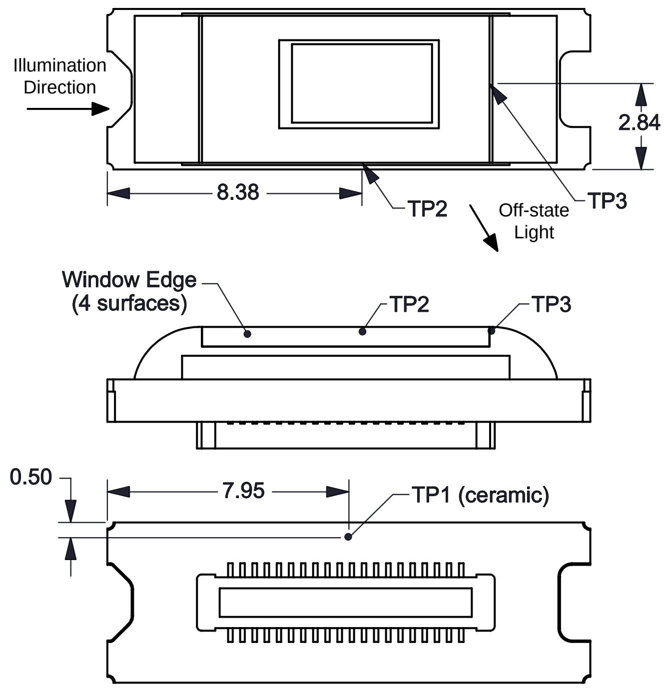

Figure 8. Thermal Test Points

3.7.2 Array Temperature and its Calculation

The total thermal load on the DMD is a result from the electrical power dissipated by the DMD, plus the optical energy absorbed by the DMD. The electrical load to be used for the DMD micromirror array calculations should be measured when possible. If measurement is not possible a typical value is identified in the DMD data sheet. The energy absorbed from the illumination source is variable and depends on the operating state of the mirrors, the intensity of the light source, and the spatial distribution of overfill illumination. The energy absorbed from the optical load must be determined for each specific end-application and each specific illumination design. The basic formula for determining the array temperature is provided by the following equations:

$$T_{ARRAY} = T_{CERAMIC} + (Q_{ARRAY} \times R_{ARRAY\text{-}TO\text{-}CERAMIC}) \quad (1)$$

$$Q_{ARRAY} = Q_{ELECTRICAL} + Q_{ILLUMINATION}$$

where

- T_{ARRAY} = Computed DMD micromirror array temperature (°C)
- $T_{CERAMIC}$ = Measured ceramic temperature (°C), test point (TP1) location in Figure 8
- Q_{ARRAY} = Total DMD thermal load (electrical power plus absorbed optical) (watts)
- $R_{ARRAY\text{-}TO\text{-}CERAMIC}$ = thermal resistance between the thermal test point (TP1) and the DMD micromirror array (°C/watt), value specified in the DMD data sheet
- $Q_{ELECTRICAL}$ = Nominal electrical power dissipation (watts) (measured if possible, otherwise refer to the DMD data sheet for a typical value)
- $Q_{ILLUMINATION}$ = Absorbed optical energy (watts) (end-application specific) (2)

When verifying the thermal design of a specific end-application, measurements of the amount of illumination energy should be done each time a series of temperature measurements are made. This is important to accurately determine the array temperature, and understand if the system being tested is representative of a typical or worse case system. The temperatures can vary from such items as the variation in illumination power and adjustment of the illumination onto the DMD micromirror array. The adjustment of the illumination has the greatest impact to the amount of energy on the window aperture and resulting window temperatures.

3.7.2.1 Sample Micromirror Array Calculation for a 1-Chip Display Application

For a typical 1-chip display application the thermal load on the DMD from the illumination has been characterized to a factor based on average measured screen intensity. The formula for the optical thermal load on the DMD is:

$Q_{ILLUMINATION} = (C_{L2W} \times SL)$

where

- $Q_{ILLUMINATION}$ = Absorbed optical energy (watts) (end-application specific)
- C_{L2W} = Conversion constant for screen lumens to absorbed optical power on DMD (watts/lm)
- SL = Measured ANSI screen intensity (lm) (3)

The conversion factor (C_{L2W}) for energy on the DMD based on measured screen intensity (lumens) is 0.00266. This is based on the following:

- efficiency from DMD to the screen of 87%
- spectral efficiency of 300 lumens/watt for projected light
- illumination distribution on the DMD of
  - 83.7% on the micromirror array
  - 16.3% on the dark metal border around the micromirror array and window aperture

Sample display calculation for .2 WVGA Series-244 DMD:

SL = 150 lumens (measured) (4)

$T_{CERAMIC}$ = 55 °C (measured) (5)

$Q_{ELECTRICAL}$ = 0.0908 watts (from DMD data sheet) (6)

$R_{ARRAY\text{-}TO\text{-}CERAMIC}$ = 7.9°C/watt (from DMD data sheet) (7)

C_{L2W} = 0.00266 watts/lumen (8)

$Q_{ARRAY} = 0.0908 + (0.00266 \times 150) = 0.489$ watts (9)

T_{ARRAY} = 55°C + (0.489 watts x 7.9°C/watt) = 58.9°C (10)

3.7.2.2 Sample Micromirror Array Calculation for a 1-Chip NIR Application

For a typical 1-chip NIR application the thermal load on the DMD from the illumination has been characterized to a DMD absorption factor based on area illuminated and power density on that area. The formula for the optical thermal load on the DMD is:

$Q_{ILLUMINATION} = (A_{ILLUMINATION} \times P_{NIR} \times \text{DMD absorption factor})$

where

- $Q_{ILLUMINATION}$ = Absorbed optical energy (watts) (end-application specific)
- $A_{ILLUMINATION}$ = Illumination area (assumes 83.7% on the active array and 16.3% overfill)
- P_{NIR} = Illumination power density (W/cm^2) (11)

The absorbed power from the illumination source is variable and depends on the operating state of the mirrors and the intensity of the light source. The DMD absorption constant of 0.42 assumes nominal operation with an illumination distribution of 83.7% on the DMD active array, and 16.3% on the DMD array border and window aperture.

Sample NIR calculation for DLP2010NIR (.2 WVGA) DMD:

$T_{CERAMIC}$ = 35°C (measured) (12)

$Q_{ELECTRICAL}$ = 0.0908 watts (from DMD data sheet) (13)

$R_{ARRAY\text{-}TO\text{-}CERAMIC}$ = 7.9°C/watt (from DMD data sheet) (14)

P_{NIR} = 2 watts/cm^2 (15)

$A_{ILLUMINATION}$ = 0.143 cm^2 (16)

$Q_{ARRAY} = 0.0908 + (2 \text{ watts/cm}^2 \times 0.143 \text{ cm}^2 \times 0.42) = 0.211$ watts (17)

T_{ARRAY} = 35°C + (0.211 watts x 7.9°C/watt) = 36.67°C (18)

3.7.3 Temperature and UV

In addition to specifying the Absolute Maximum and Recommended Operating temperature ranges, the DMD data sheet specifies the maximum UV power density that can be incident upon the micromirror array and/or overfill areas. To ensure the highest possible reliability the DMD should not be exposed to the maximum operating temperature and maximum UV levels at the same time.

3.8 Mechanical Loading Considerations

Installing a DMD into an end-application 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. The areas the loads are to be distributed are shown in Figure 9. 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:

Connector area - The Series-244 DMD is designed to accommodate mechanical loads evenly distributed across the connector area. Load on this area is associated with the insertion of the connectors to make electrical connection, and that which is continuously applied to ensure proper electrical connection is maintained.

DMD mounting area - The Series-244 DMD is designed to accommodate a mechanical load evenly distributed across the areas shown in Figure 9. These areas are on the opposite side of the ceramic and directly opposite the Datum ‘A’ and Datum ‘E’ areas. Load on this area is associated with mounting and securing the DMD into the optical engine.

Datum ‘A’ and ‘E’ areas - The micromirror array plane is referenced to the three Datum ‘A’ areas shown in Figure 9. The Datum ‘E’ is nominally in the same plane as Datum ‘A’ but is not used for reference of the micromirror array plane. The Series-244 DMD is designed to accommodate a mechanical load evenly distributed across the three Datum ‘A’ areas, however Datum ‘E’ can and should be used so the mechanical load is more evenly distributed on the package when mounting the DMD. The load on the Datum ‘A’ and Datum ‘E’ functions to counteract the combined loads from the connector and mounting areas. The Mechanical ICD defines the location and size of the Datum ‘A’ and Datum ‘E’ areas.

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.

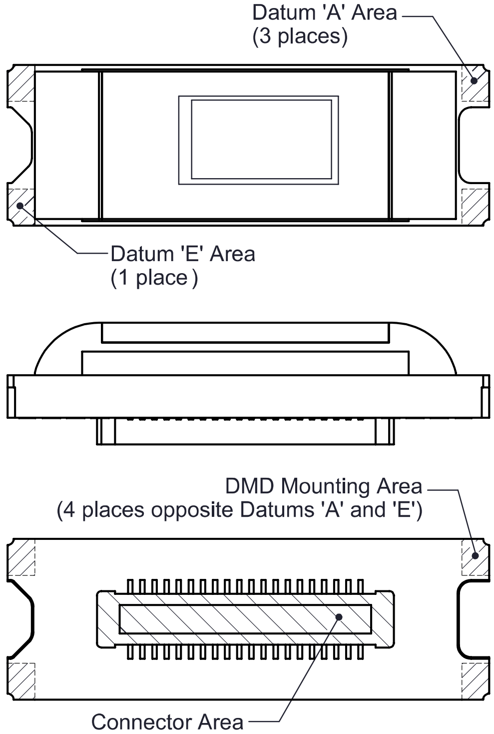

Figure 9. DMD Mechanical Loads

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 satisfied.

The functional design objectives of the mounting system include:

- Establish (and maintain) the physical placement of the DMD's micromirror 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 mating system 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 connection

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 report achieve the minimum mechanical load to meet the functional objectives, and also describe how to control the maximum mechanical loads applied to the DMD.

The ideal design is one which:

- Does not rely upon strict adherence to assembly techniques or processes
- Is tolerant to 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 are needed to hold the DMD in place, or higher forces than necessary that could result in damage to the DMD.

4.2 Basic System DMD Mounting Concept

The DMD mounting concepts described in this application report 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. 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 each of the individual DMD's to each other in order to form a single combined image.

Most times when using a “drop-in-place” mounting concept the illumination light bundle still needs to be aligned to the DMD micromirror array. Generally the illumination light bundle is adjusted to align it to the DMD after the DMD is installed into the system. A convenient way to perform this adjustment is by adjusting an integrating element (light tunnel) or fold mirror.

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). The specific tolerance requirements vary for each system design. Key areas for consideration include:

- Alignment of the illumination light bundle to the DMD micromirror array (X-axis, Y-axis, and rotation)
- Size and location of the illumination overfill
- Uniform focus across the entire micromirror array
- Variation in the location (and rotation) of the micromirror array relative to the illumination light bundle due to size and location tolerances of the DMD mounting features (optical interface) on the optical chassis (this is less critical if DMD replacement without readjusting the illumination is not important)
- Variation in the location (and rotation) of the micromirror array within the DMD package due to size and location tolerances of the DMD datum features, and the placement of the micromirror array relative to the datum features (this is less critical if DMD replacement without readjusting the illumination is not important)

Alignment of the illumination light bundle to the micromirror array, the overfill size, and the overfill shape are all interrelated and determine the amount of adjustment needed to ensure the micromirror array is fully illuminated. The illumination alignment (or adjustment) range needs to comprehend the size and shape of the overfill caused by the dimensional tolerances of the piece parts (for example integrator size, integrator position, Datum features on the DMD, Datum features on the optical chassis, etc…). Adjustment of the illumination is nearly always required to avoid an excessive amount of overfill. Note that excessive overfill increases the amount of DMD cooling required and reduces both the optical and electrical-power efficiency of the system. For these considerations it is nearly always best to minimize the amount of overfill (size) and design the system with alignment of the illumination to the micromirror array. The details of the alignment process should be considered when doing the alignment design.

A key characteristic of the "drop-in-place" mounting concept is that the planarity of the DMD (micromirror array perpendicular to the projection lens axis) does not need to be adjusted in order to achieve acceptable focus across the entire micromirror array. The depth-of-focus of the optical design is critical to achieving acceptable focus. Key considerations when determining the depth-of-focus requirements for the optical design include:

- The angular relationship between the DMD Datum 'A' mounting areas, the corresponding Datum 'A' areas on the optical chassis, and the features used to mount the projection lens (optical axis) to the optical chassis. Typically this translates to a parallelism or perpendicularity between the indicated surfaces depending on the specific optical design.
- Parallelism of the DMD micromirror array to the three Datum 'A' areas on the DMD ceramic. The DMD mechanical ICD has the linear distance and the parallelism tolerances.

4.2.1 Optical-Mechanical Alignment Features

The DMD optical-mechanical alignment features (datum) are used to establish and maintain the physical placement of the DMD's micromirror 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 alignment features shown in Figure 10 are summarized below:

- Defined Datum 'A' and 'E' areas - four coplanar areas that contact the DMD Datum 'A' areas and Datum 'E' area. These establish the relationship for the position of the micromirror array relative to the projection lens axis and other optical components.
- Datum 'B' Post-Pin (Ø2.50 mm) – contacts with the DMD Datum 'B' (V-notch edge feature) providing two line contact areas on the edge of the ceramic.
- Datum 'C' Post – mates with the DMD Datum 'C' (C-notch edge feature). Datum 'C' is the edge of the post, not the center of post.
- Threaded holes to secure a bracket (or clamp) which clamps the DMD against the Datum 'A' and 'E' features of the system optical chassis.

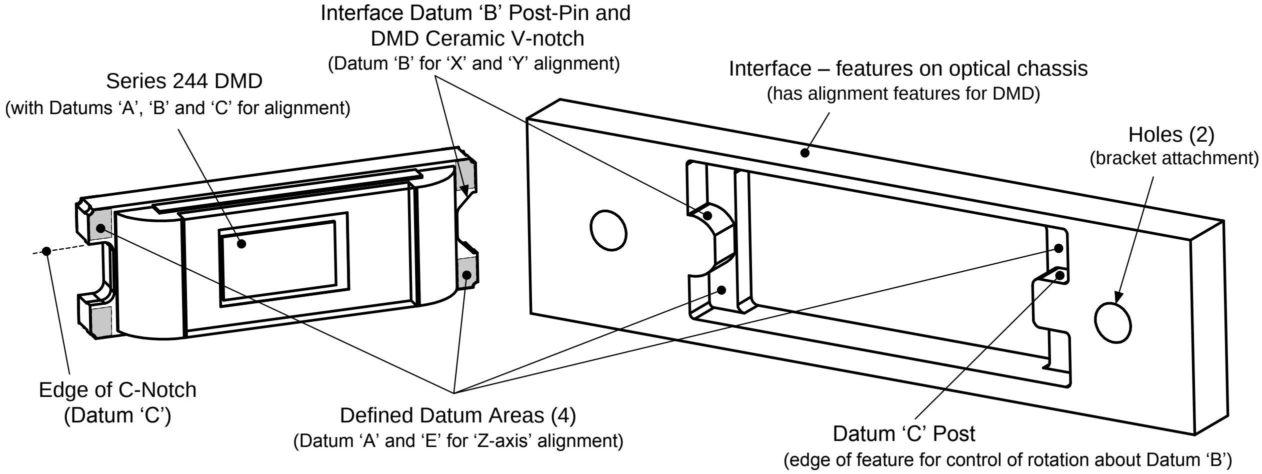

Figure 10. Optical Interface (Alignment) Features

The following characteristics of the Series-244 Optical-Mechanical alignment features should be noted:

- The simplest form for the Datum ‘B’ interface feature is a precision 2.50 mm diameter pin with a flat side. The flat side is to accommodate the shape of the V-notch on the edge of the DMD ceramic. 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 10.
- The three Datum ‘A’ areas and one Datum ‘E’ area on the optical chassis must be coplanar to ensure uniform focus of the micromirror array, and focus repeatability between systems. The coplanarity of these features and the DMD parallelism combine to determine the requirements for the depth of focus for the optical system.
- 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.
- A system gasket (if used) should be designed to not interfere with the contact between the DMD datum and corresponding Datum ‘A’ features on the optical chassis. Any gasket 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’ 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 in the optical chassis for the DMD should accommodate the maximum encapsulation size defined in the DMD mechanical ICD drawing. A 3D-CAD model of the DMD is available which 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 the DMD by use of preset torque on screws (to control the clamping force on DMD). To help in controlling loads on the DMD it is beneficial to minimize the clearance gap between the optical chassis and bracket (or clamp). Reducing the gap helps to prevent bending of the bracket and subsequent variation of clamping force. The critical clearance gaps are identified in Figure 11 and will be described in more detail in the next section.

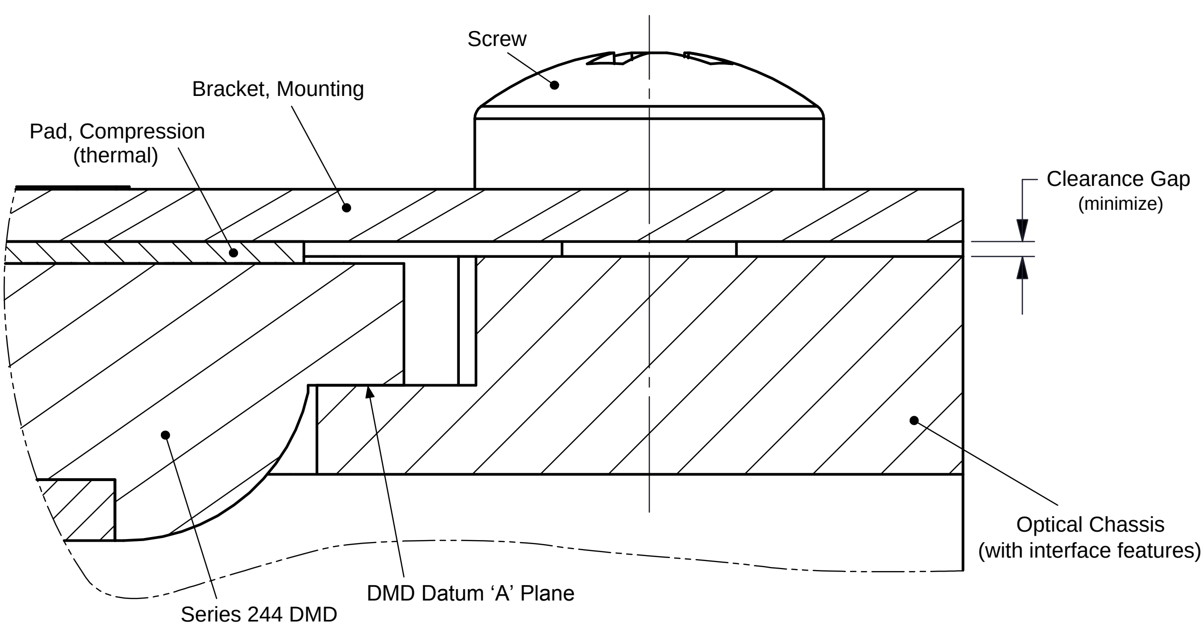

Figure 11. Mounting Clearance Gap

- 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 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 12 and clamped in place at this location.

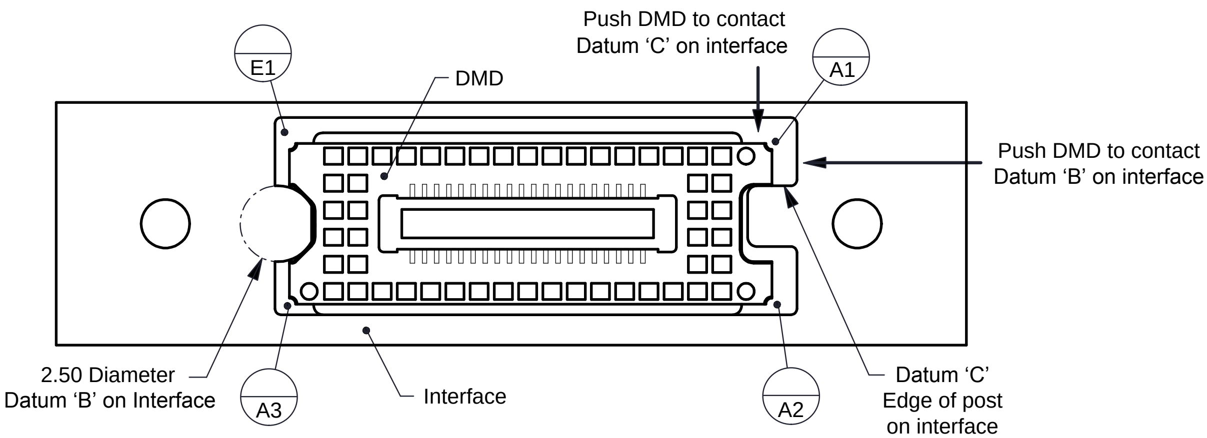

Figure 12. Mounting Datum 'B' Contact

- 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 12.
- Utilizing the DMD Datum ‘B’ and ‘C’ as described above and illustrated in Figure 12 when mounting the DMD will reduce X-Y movement and rotation variation of the DMD. This reduces the need for large amounts of illumination overfill.

4.2.2 Heat Sink

The Series-244 DMD does not have a dedicated thermal interface area to aid in thermal cooling. If a heat sink is needed to ensure the DMD thermal requirements are met, the heat sink could be incorporated into the clamp or bracket used to mount the DMD.

The areas adjacent to the system interface connector could be contacted and used to help with cooling the DMD. If this is done the material contacting the electrical pads in this area must be an electrical insulator to keep from shorting the signals together.

4.2.3 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 (micromirror 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. The sharpness of the particle edges is determined by the optical design and type of particle.

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 it's volume
- Gasket should not interfere with assembly of the DMD into the optical assembly
- Gasket or coatings on gasket should not out-gas when exposed to expected operating and storage temperatures

4.3 Detailed DMD Mounting Concept

A detailed concept for mounting the DMD that will meet the needs stated earlier is described in this section. The mounting concept illustrated utilizes shims to facilitate alignment of the DMD into the optical interface.

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

4.3.1 Shim Alignment Mounting Concept

The design concept for mounting the Series-244 DMD shown in Figure 13 is a drop-in-place concept which incorporates specific features in the interface and the use of shims to aid DMD alignment during the DMD installation process. Section 4.3.1.1 describes the details of the shim and interface features. The function of the bracket is to hold the DMD in place and in so doing applies mechanical loads to the DMD. Section 4.3.1.2 describes the control of the mechanical loads applied to the DMD.

The drawing number for the “Shim Alignment Mounting Concept” shown in Figure 13 is 2512917. Drawings (in pdf format) and 3D-CAD models (in STEP format) of each part shown are available for download, see Section 6.

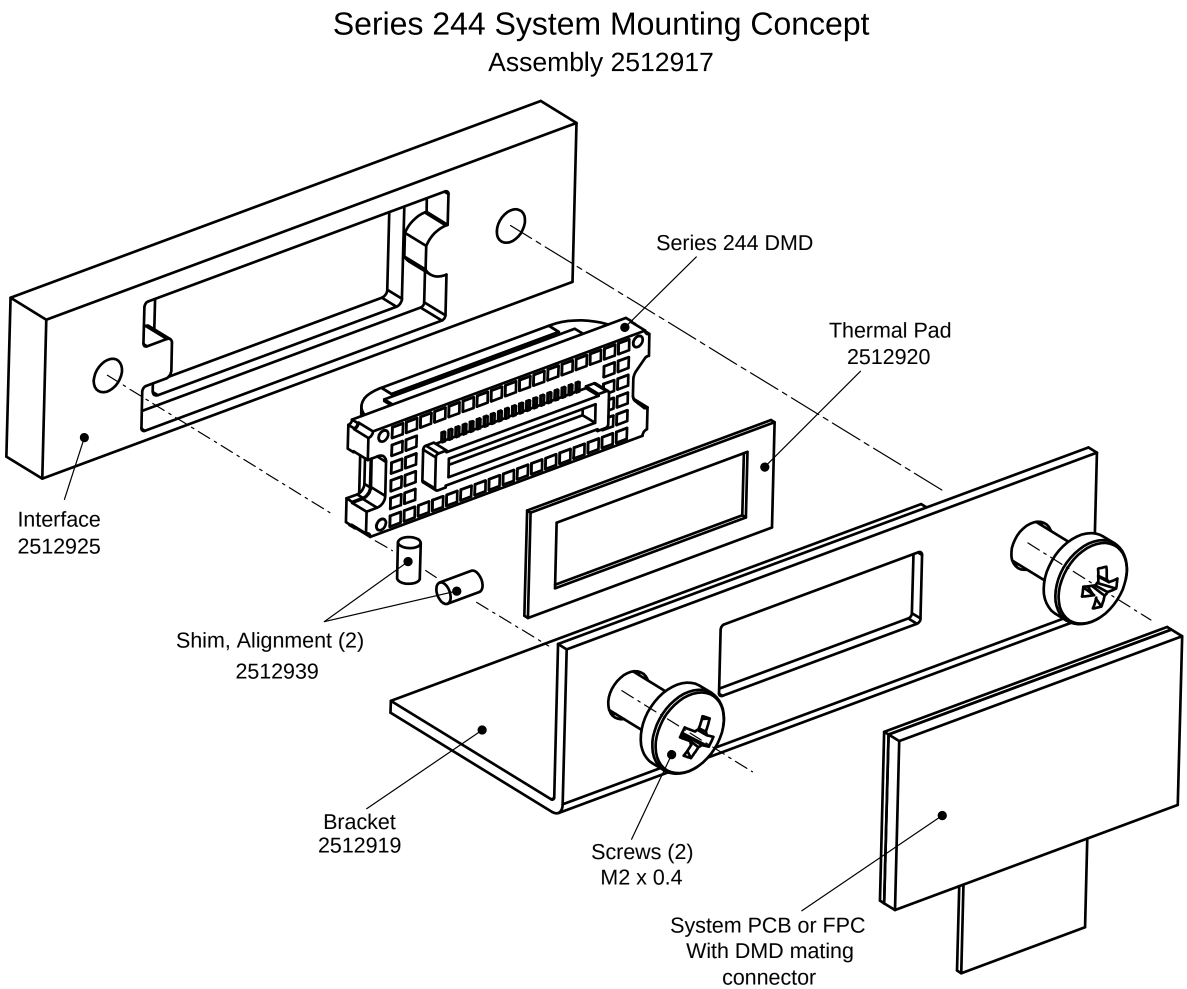

Figure 13. Shim Alignment System Mounting Concept

4.3.1.1 Shim Alignment Features

Consistent and repeatable location of the micromirror array 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. After the bracket is secured the shims are not needed. The shims are a compressible material that is wedged between the optical interface and the DMD. The shims and Datum features are shown in Figure 14.

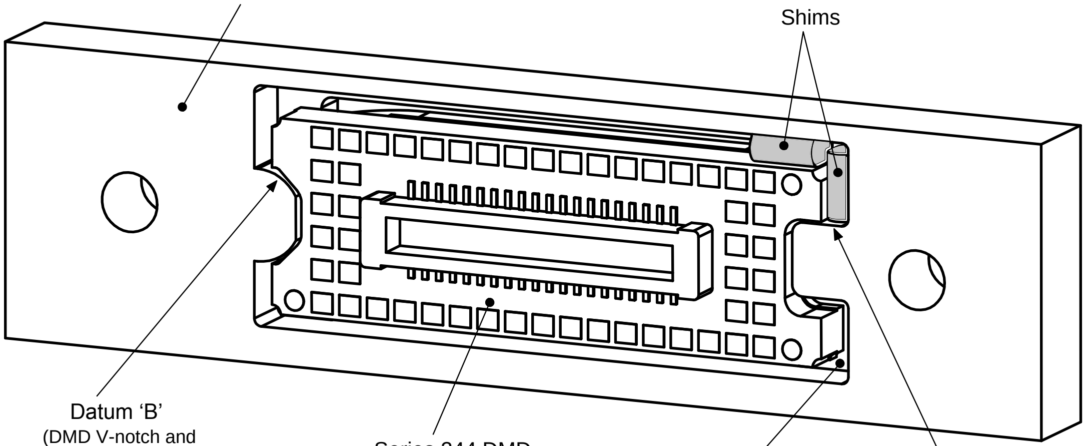

Figure 14. Alignment Shims

The gap between the optical interface and DMD varies with the interface and DMD size (manufacturing tolerances). The gaps and shim locations are shown in Figure 15. 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 in the gap the round shape of the shim increases size (height) in one direction, as illustrated in Figure 15. The shim material and gap size should be determined so the amount of increase does not interfere with the bracket or DMD installation.

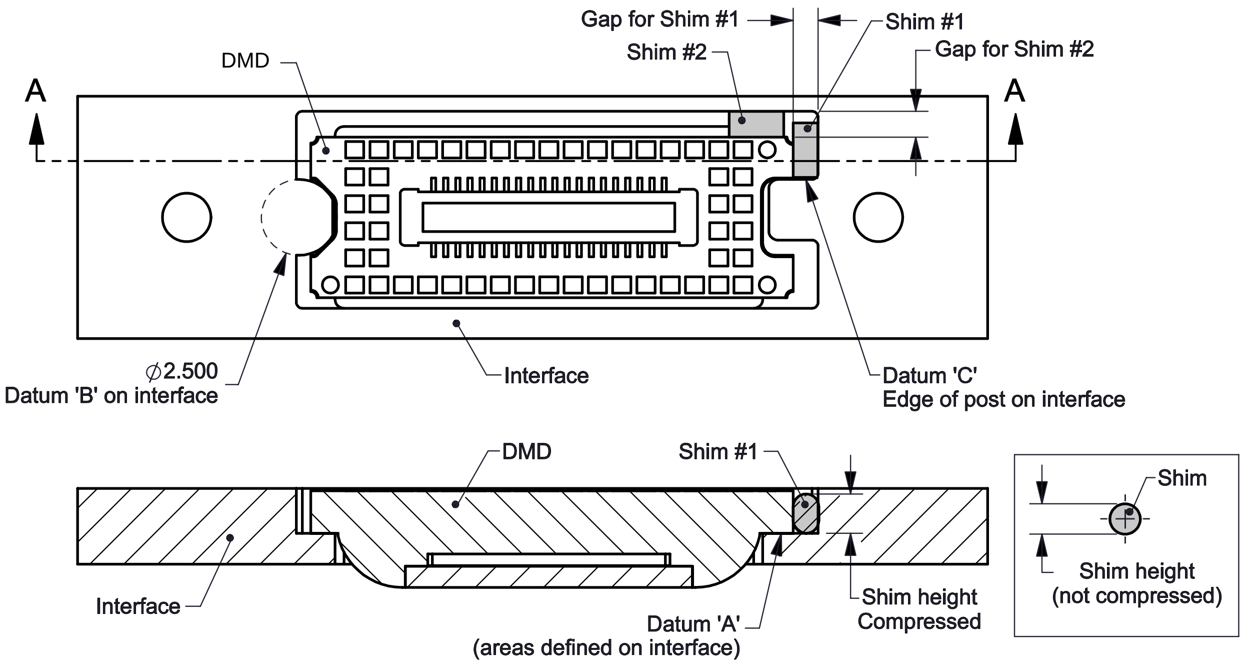

Figure 15. Gaps and Shim Shape

4.3.1.2 Mechanical Load Control

This mounting concept design is simple and has a limited number of parts. This concept includes a flexible or compliant part (compression pad) that absorbs the part manufacturing variations or part tolerances. When installing the DMD into the optical chassis ensure the mechanical loads applied to the DMD do not exceed the DMD specification. The compression pad characteristics, screw torque, and assembly procedure combine to determine the loads applied to the DMD. A summary of considerations to avoid excessive mechanical loads on the DMD include:

- Compression pad force versus deflection characteristics
- Tolerances of the critical dimension on the optical interface to minimize the gap between the interface and the bracket. This clearance gap is illustrated in Figure 16.
- Controlling the torque on the screws
- Partial tighten both screws prior to final tightening
- Use alternating order when tightening the screws for both partial and final torque

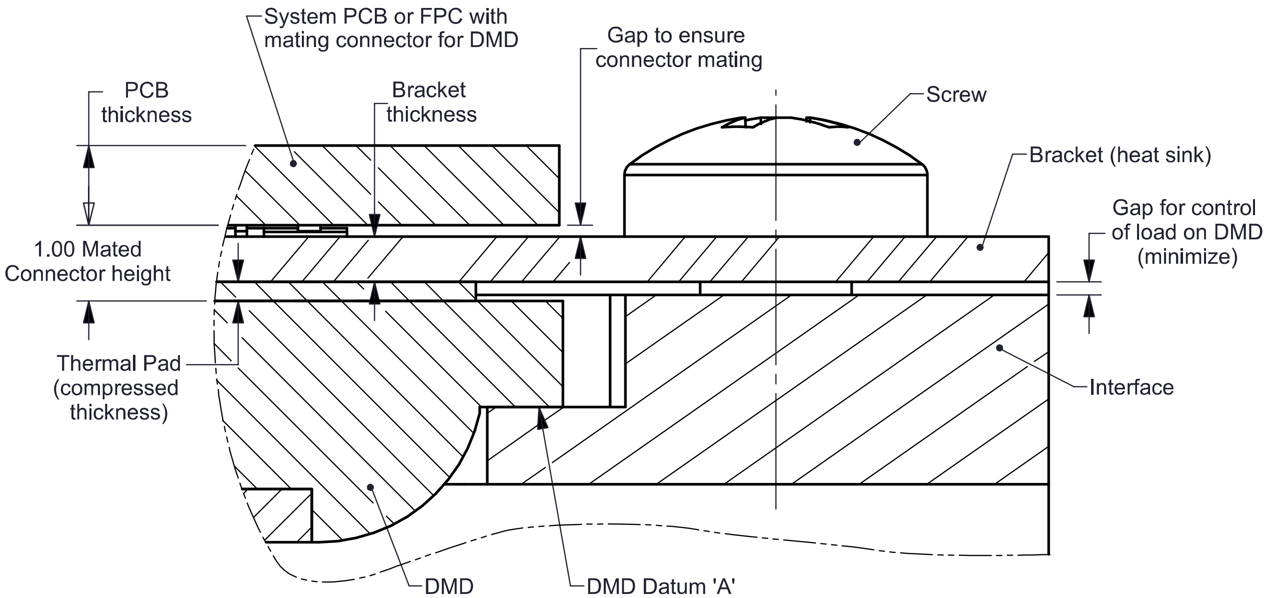

Figure 16. Critical Gap for Control of Load

The use of torque on the screws to control the forces applied to the DMD is highly dependent on the interface material, screw material, type of screw (thread forming or machine), and friction factor between the of screw threads and optical interface. Generally the force on the DMD will vary widely because of these items. The bracket will usually bow until the bracket contacts the interface. Minimizing the clearance gap between the bracket and interface helps to reduce the chances of applying excess forces to the DMD but does not guarantee it. The clearance gap is shown in Figure 16.

An analysis of the gap between the bracket and the interface will identify the potential amount the bracket could bend. Figure 17 illustrates the key part features and a schematic of the tolerances. The tolerance schematic starts at the bracket, continues to the pad, the DMD, and concludes at the interface (on the right-hand side of the figure).

The nominal, minimum and maximum gap size for this design are shown in Figure 18 for both a SUM and RSS tolerance analysis method. The nominal gap (no tolerance variation) is 0.170 mm. The gap could be as small as 0.005 or as large as 0.335 mm for the SUM analysis method (worst case). The gap range is 0.059 mm to 0.281 mm for RSS analysis method. The actual gap size will depend on the compression pads force versus deflection characteristics.

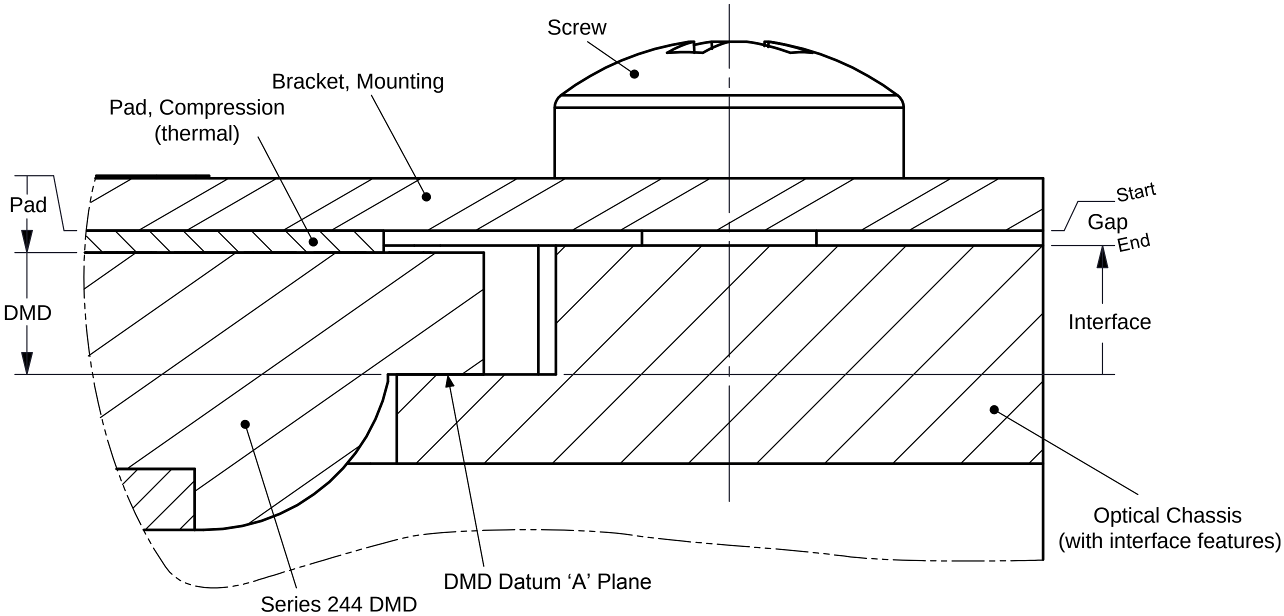

Figure 17. Gap Tolerance Analysis Schematic

	Nominal (mm)	Direction Sign	Nominal (mm)	Tol (+/-) (mm)	Tolerance Method	Gap - see Note (2) Min	Max
Pad	0.250	-1	-0.250	0.025			
DMD	1.400	-1	-1.400	0.100			
Interface	1.480	1	1.480	0.040			
	Sum		-0.170	0.165	**SUM**	-0.005	-0.335
			Note (1)	0.111	**RSS**	-0.059	-0.281

Note (1) Nominal value must be Negative for there to be a gap between interface and bracket

Note (2) The gap is the potential amount the bracket would bend (from tightening the screws) before the bracket contacts the interface. The amount the bracket bends depends on the clamping force of the screws and the force deflection characteristics of the compression pad.

Figure 18. Gap Analysis

This concept is an example of mounting the DMD. Specific requirements like size or other geometry configuration associated with a specific implementation may require alternate designs for a final product. Space available and the control of the loads on the DMD should be critical considerations.

4.3.1.3 Mating PCB or FPCB

This concept requires the PCB or FPCB that connects the DMD to fit between the bracket mounting screws. The mated connector height for the connector pair is 1.0 mm. If the PCB or FPCB over hangs the mounting screws adjustments will need to be made to accommodate the overhang.

Ensure the bracket thickness, compressed height of the compression pad, and bending of the bracket do not interfere with the proper engagement of the DMD and system connectors. The 1.0 mm mated height between the DMD and PCB (or FPCB) is shown in Figure 16.

4.3.1.4 Thermal Consideration

For applications that have higher illumination energy the dissipation of the absorbed energy from the DMD becomes more important. The DMD does not have a dedicated area to aid in cooling the DMD but does have small areas on each side of the system interface connector that can be contacted to help remove the absorbed energy.

The main purpose of the mounting bracket is to hold the DMD in position. The bracket for this option incorporates an area that supports cooling of the DMD. This is shown in Figure 19. The size and shape are flexible to accommodate the surface area needed for the amount of available air flow and the other parts near the DMD.

Consideration for the bracket include:

- Thermal conductivity of material
- Stiffness of the material to reduce bending and interfering with the connector mating
- Features to increase stiffness can be included in the bracket design
- Maximum material thickness that will not interfere with connector mating

For maximum heat transfer to the bracket from the DMD the compression pad should be made of a thermally conductive material. The compression pad material must not be made of electrically conductive material to avoid shorting the test pad signals together. See file reference DLPR017 in Section 6 for sample material on thermal pad drawing.

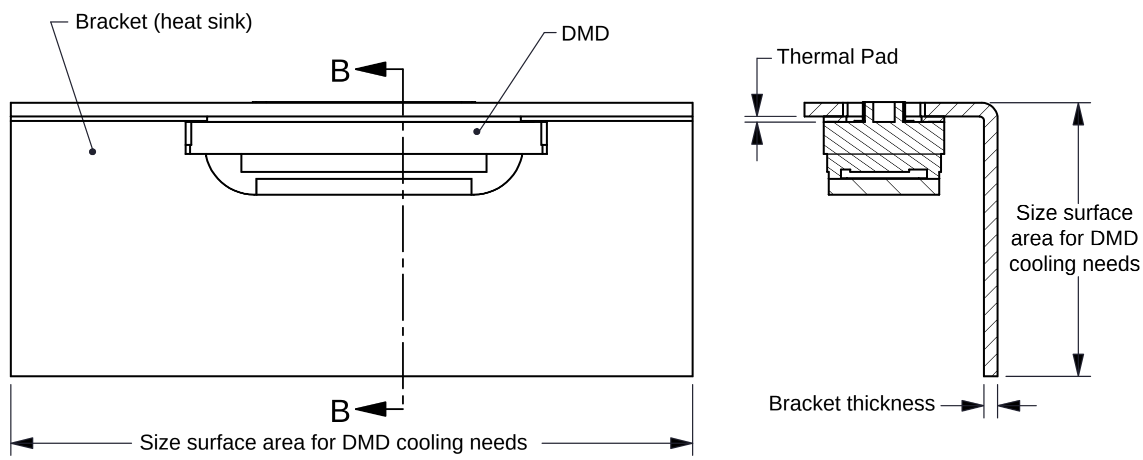

Figure 19. Mounting Bracket Thermal Considerations

5 System Connector

The connector on the DMD is a 40 contact 0.4 mm pitch made by Panasonic. The matting connector is either a Panasonic AXT540124DD1 or AXT540124. These are equivalent connectors in all aspects. The mated height for the pair of connectors (distance between DMD and PCB) is 1.0 mm. Information about the mating connector is available on the Panasonic web site by searching on the part number AXT540124. The AXT540124 part number may be available at some distributors. Searching on the part number AXT540124DD1 is not likely to yield any results, nor is it expected to be available from local distributors.

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 1 summarizes the literature numbers for the drawings and 3D-CAD models that are available for download.

Table 1. Reference Drawings and 3D-CAD Models

File Name	Description
DLPS046	DLP2010 DMD (Series 244) data sheet
DLPS059	DLP2010NIR DMD data sheet
DLPA069	DLP® Series-244 DMD and System Mounting Concepts Mechanical and Thermal Application Report
DLPR015	DLP2010 DMD (Series 244) 3D-CAD model file with nominal geometry
DLPR016	DLP2010 DMD (Series 244) 3D-CAD model file with maximum encapsulation geometry
DLPR017	Assembly and Part drawing of Shim Alignment Mounting Concept (2512917) – also includes 3D-CAD model files

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