DLP® Series-600 DMD Mechanical, Thermal, and Systems Mounting Concepts

Application Report

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DLP® Series-600 DMD Mechanical, Thermal, and Systems Mounting Concepts Application Report

1 Scope

This application report serves as an aid to the successful first-time utilization and implementation of the Series-600 DMD (DLP6500FYE) and addresses the following topics:

- Terminology
- Specification and design details of a Series-600 DMD
- System mounting concepts for the DMD, including key attributes and important application design considerations
- Socket for use with the Series-600 DMD

2 Terminology

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

Dark Metal — area just outside the active array but within the same plane as the active array, see Figure 5. This area is darker in color and has reduced reflectivity compared to the active array.

DMD Features— The primary features of the Series-600 DMD are described below and illustrated in Figure 1 and Figure 2

- Active array – the two-dimensional array of active DMD mirrors which reflect light
- Bond wires – the wires which electrically connect the WLP DMD Chip to the ceramic carrier
- Ceramic carrier – the structures which form the mechanical, optical, thermal, and electrical interfaces between the WLP DMD chip and the end-application optical assembly
- Corner chamfer – visual keying and orientation aid located on the ceramic carrier. Also identifies the incoming illumination corner
- DMD Chip (or just DMD) – The aggregate of the WLP chip, ceramic carrier, bond wires, encapsulation, and electrical pins
- Electrical pins – the electrical interface between the ceramic carrier and the end-application electronics
- Encapsulation – the material used to mechanically and environmentally protect the bond wires
- Symbolization pad – the area on the ceramic carrier that is used for marking the part
- Thermal interface area – the area on the ceramic carrier which allows direct contact of a heat sink or other thermal cooling device
- 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 which contains the DMD active array, window glass, and window aperture

FPCB— Flexible Printed Circuit Board

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

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

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

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

Optical Assembly— a sub-assembly of the end-application, 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 others)

Optical Illumination Overfill — the optical energy that falls outside the active area, and which does not contribute to the projected image (see Figure 5)

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

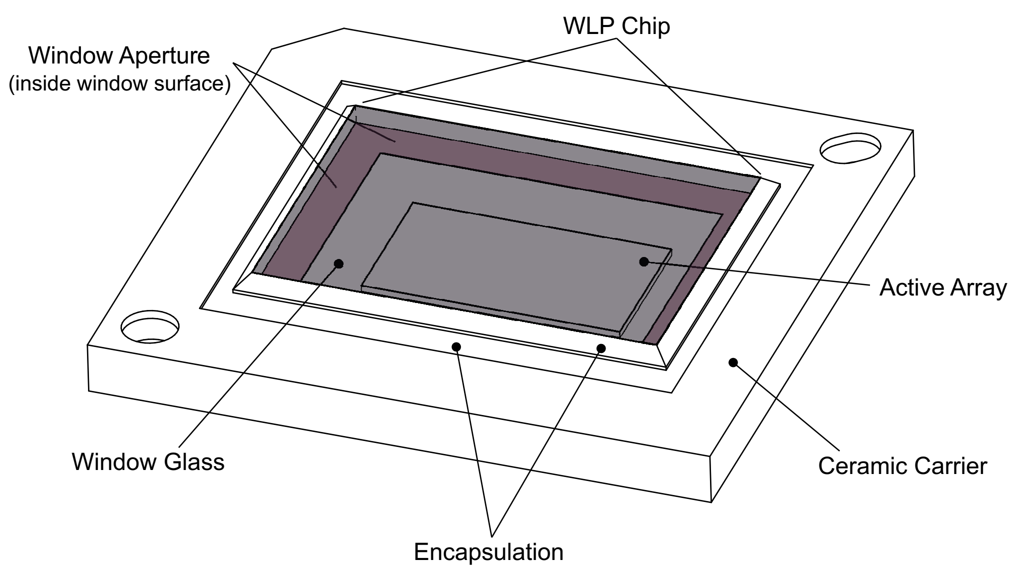

Figure 1. Series-600 DMD Features – Window Side

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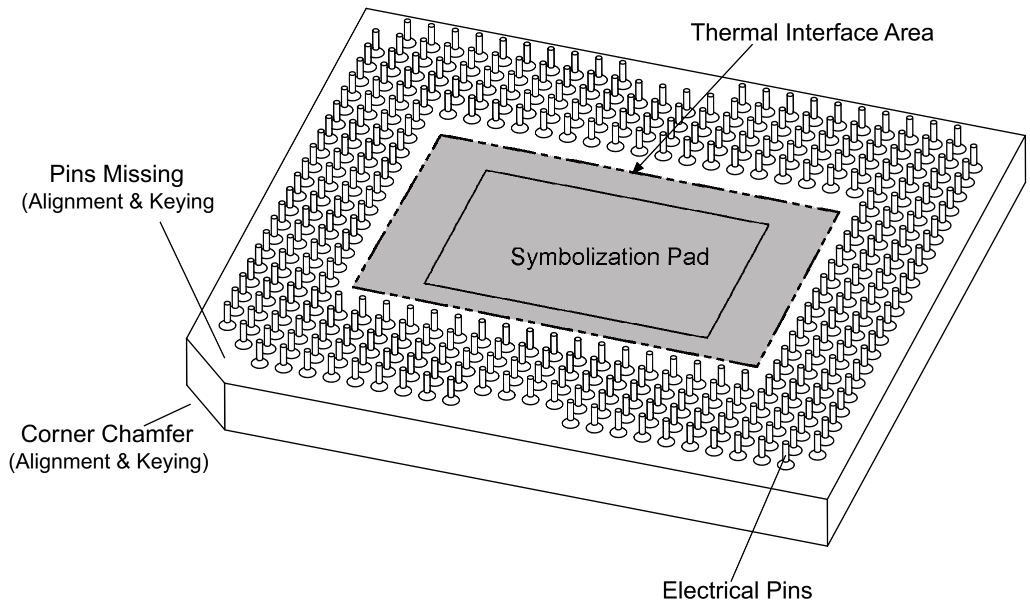

Figure 2. Series-600 DMD Features – Pin Side

3 DMD Specifications

The key mechanical and thermal specifications for the DMD are described in this application note. The actual parameter values are specified in the DMD data sheet. The package geometry characteristics are defined in the Mechanical ICD drawing part of the DMD data sheet. A 3D-CAD model of the nominal DMD geometry, in STEP format, is available for download from information listed in *Section 6* Table 4.

Information available in the DMD data sheet includes:

- Package mechanical characteristics (geometry, dimensions, mounting datum's, window thickness, window aperture size, active array size, and mores
- Thermal characteristics
- Mechanical mounting Loads
- Optical properties (window material, mirror tilt angle, mirror size, and others)
- Electrical characteristics (signal names, voltage, wave form, and others)
- Operating environment
- Storage environment
- Part identification

NOTE: In all cases of any conflict between this document and the data sheet, or the 3D-CAD model and the mechanical ICD part of the data sheet, the data sheet information should be used.

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-600 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.

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Datum ‘A’ – Primary datum

Datum ‘A’ is a plane specified by 3 areas on the surface of the ceramic carrier. 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 relative to 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. Datum ‘A’ are areas identified on the surface of the ceramic carrier, and not (identifiable) raised separate features.

Datum ‘B’ – Secondary Datum

Datum ‘B’ is a hole with a specified depth. While Datum ‘A’ provides the reference for 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 hole in the ceramic carrier but rather the top region closest to the Datum ‘A’ areas, see Figure 3.

Datum ‘C’ – Tertiary Datum

Datum ‘C’ is the center of a slot with a specified depth. Datum ‘C’ establishes the reference for rotation of the active array within the Datum ‘A’ plane and about the Datum ‘B’ X-Y reference position. Datum ‘C’ is not the entire depth of the slot in the ceramic carrier but rather the top region closest to the Datum ‘A’ areas, see Figure 3.

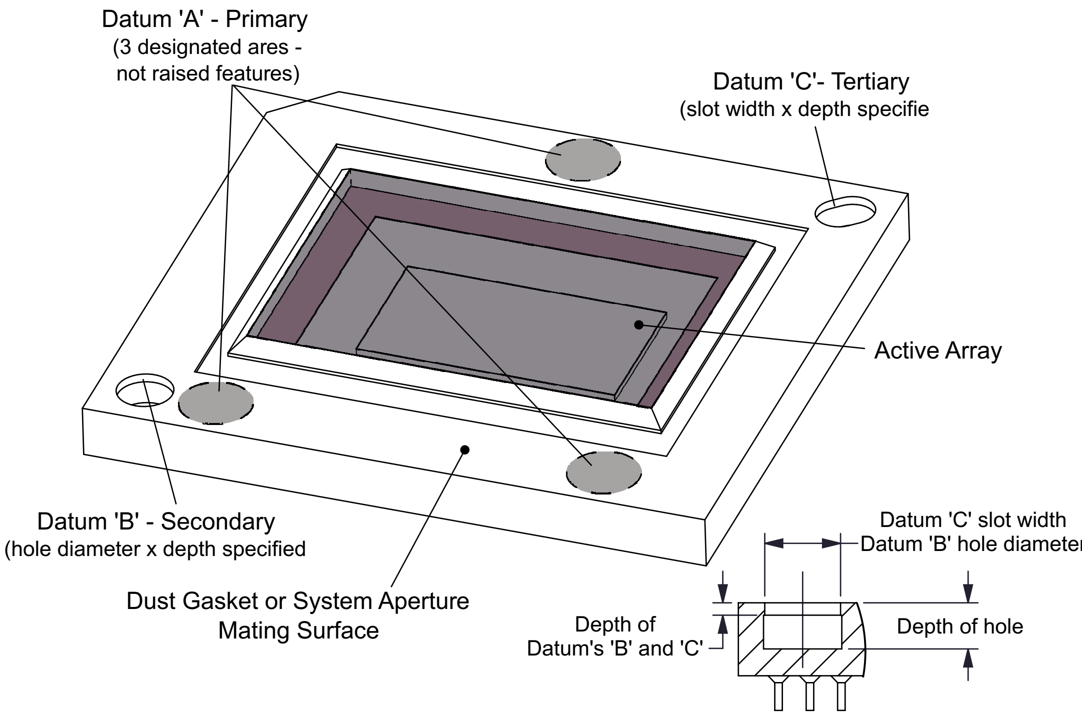

Figure 3. Series-600 DMD Datum Features

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 height), window aperture location, pin length, ceramic carrier, Datum ‘A’ plane location, active array plane, encapsulation, and socket-seating plane. The nominal distance and tolerance between these features are defined in the DMD Mechanical ICD.

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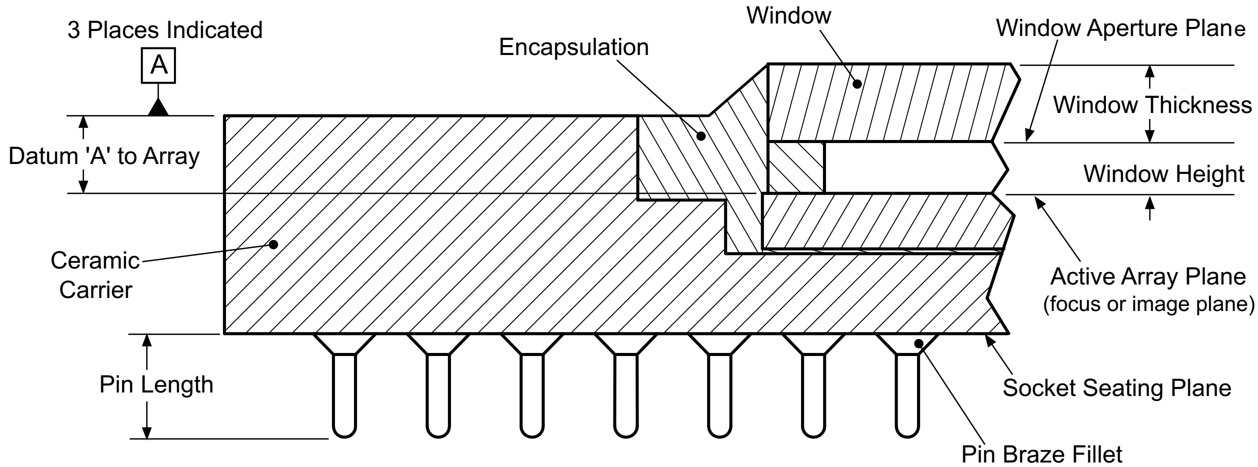

Figure 4. Series-600 DMD Cross Section View

3.3 Dust Gasket or System Aperture Mating Surface

As shown in Figure 4 the exterior surface of the DMD window is relatively close to the image plane of the DMD active array. Since the DMD active array is the optical focus plane, there is a risk for any dust particles on the outside window surface to 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 using gaskets, tape, and so forth)
- Maintain optical cleanliness of all components used in the optical assembly, including the mechanical parts
- Assemble the optical engine in a clean-room environment, including installation of the DMD
- Avoid processes that could produce loose particles that could reach the DMD window

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

Depending on the specific optical design there is the potential for low-level light that scatters off the optical chassis or optical components to enter the projection pupil and be displayed in or around the projected image. To prevent or reduce this a system aperture could be used to block this light from entering the projection pupil. The design of the system aperture is very dependent on each optical design and optical chassis.

The flat area of the ceramic carrier which is generally in the same plane as Datum 'A', but not including the Datum 'A' areas, can provide a resting (or mating) surface for a system aperture and/or dust gasket. The system aperture or gasket should be kept clear of the Datum 'B', Datum 'C', and Datum 'A' areas to ensure the optical alignment of the DMD is not interfered with. The surface is depicted in Figure 3.

3.4 Optical Illumination Overfill

Optical illumination overfill is defined as the optical energy that falls outside the active area. 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. An example overfill from an 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):

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- 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)
- 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. It is especially important to avoid optical overfill energy on the window aperture. The heat absorbed by the window aperture (due to overfill incident upon the window aperture) is more difficult to remove (has a highly resistive thermal path) than heat absorbed in the dark metal area surrounding the active array.

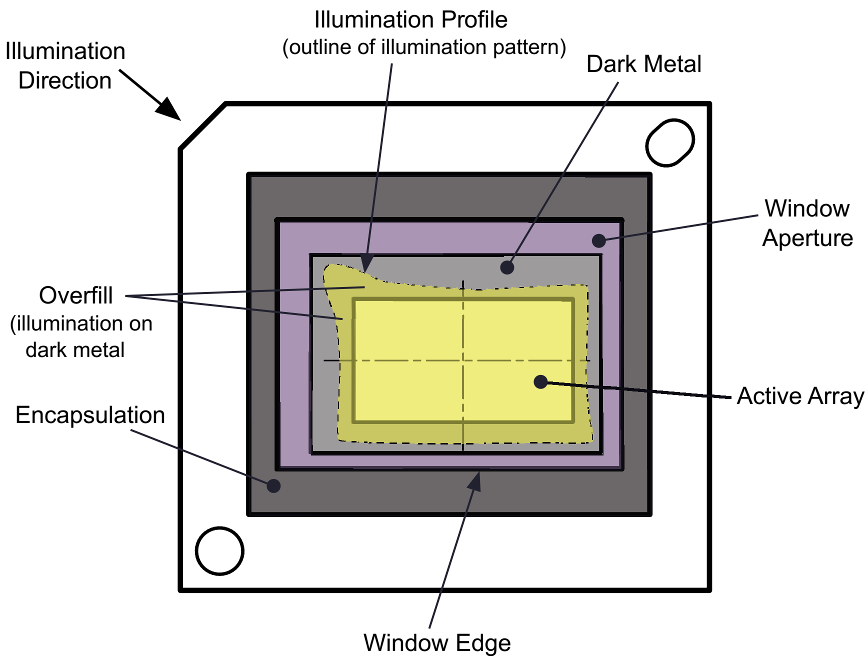

Figure 5. Optical Illumination Overfill

3.5 Active Size and Location

The size and location of the DMD Datum 'A' areas, Datum 'B' hole, and Datum 'C' slot are the same for all DMDs in the Series-600 family. While the active array size is different for each DMD resolution within the Series-600 family, the center of the active array relative to the Datum's is the same for all Series-600 DMDs.

Note the center of the active array is not at the center point between Datum's 'B' and 'C', but rather offset both top-to-bottom and left-to-right.

The active array offset and other characteristics of the active array position relative to the Datum's for the Series-600 family of DMDs are illustrated in Figure 6. See the DMD Mechanical ICD for the specific parameters of array size and distance from Datum 'B' to edge of array location.

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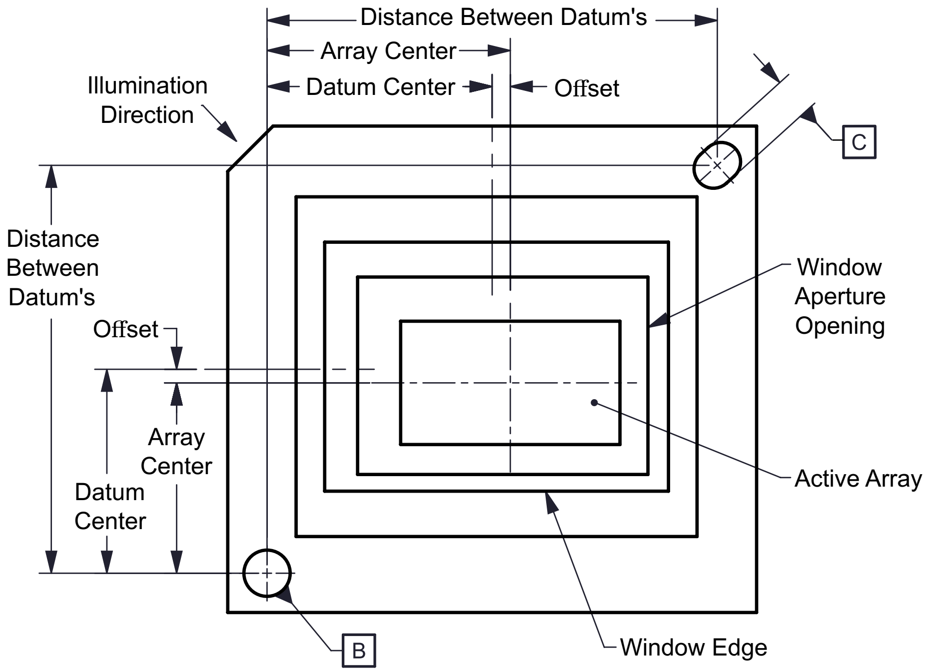

Figure 6. Active Array Location

3.6 *Electrical Interface Features*

The Series-600 DMD incorporates a 350-pin micro pin grid array (PGA) style of electrical interface. To achieve an electrical connection between the Series-600 DMD and the DMD printed circuit board (PCB) requires a micro-PGA socket to be installed on the system PCB. See *Section 5* for information on the Series-600 socket.

The pin length, pin diameter, and pin spacing used on the Series-600 DMD is similar to the micro-PGA technologies used for many microprocessors, but with a different arrangement of the pins. The pin numbering scheme used for Series-600 DMDs is illustrated in Figure 7.

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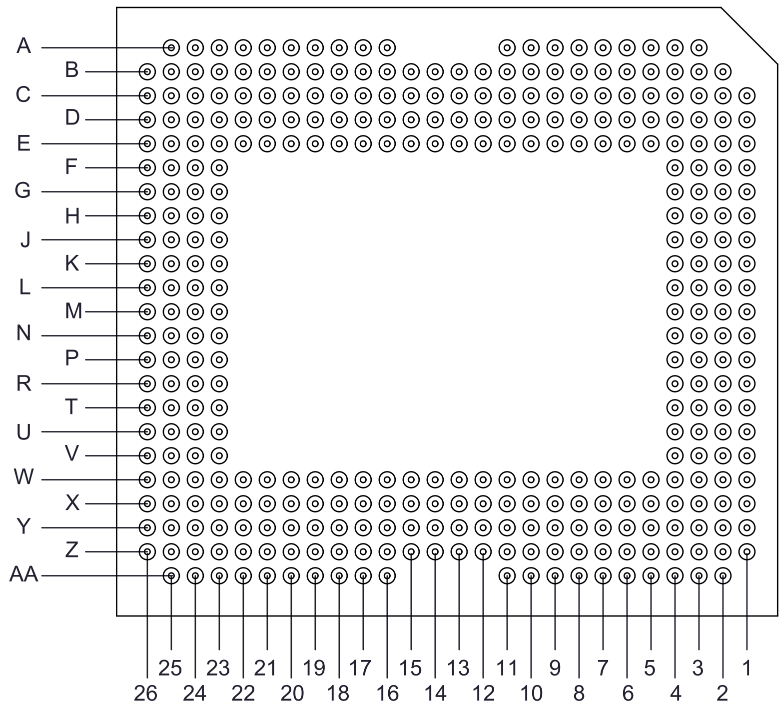

Figure 7. Pin Numbering Scheme

The key features of the Series-600 Electrical Interface are illustrated in Figure 8 and are summarized below:

- Corner chamfer – The chamfered corner of the ceramic carrier identifies the pin A1 corner as well as the intended direction of the illumination source. This provides a visual aid when installing the DMD into the socket or the DMD into the system optical interface.
- Missing Pins – Pins A1, A2, and B1 have been omitted to provide orientation when installing the DMD into a socket. The keying provided by the missing pins prevents the DMD from being installed with the incorrect orientation.
- Socket-seating Plane (also Electrical Mating Plane) – The socket-seating plane (on the DMD) is the surface that will make contact with the DMD-seating plane (on the socket). The socket-seating plane is pointed out in Figure 8, and the DMD-seating plane pointed out in the cross-section shown in Figure 4.
- Braze Fillet – The electrical pins are brazed to the ceramic and results in a fillet. The mating socket will need clearance to accommodate the size of the braze fillet without interfering with the proper seating of the DMD into the socket.
- Symbolization Pad – The symbolization pad on the pin side of the DMD ceramic carrier provides an area to mark the DMD with part number information. Note that this pad is electrically connected to signal ground.

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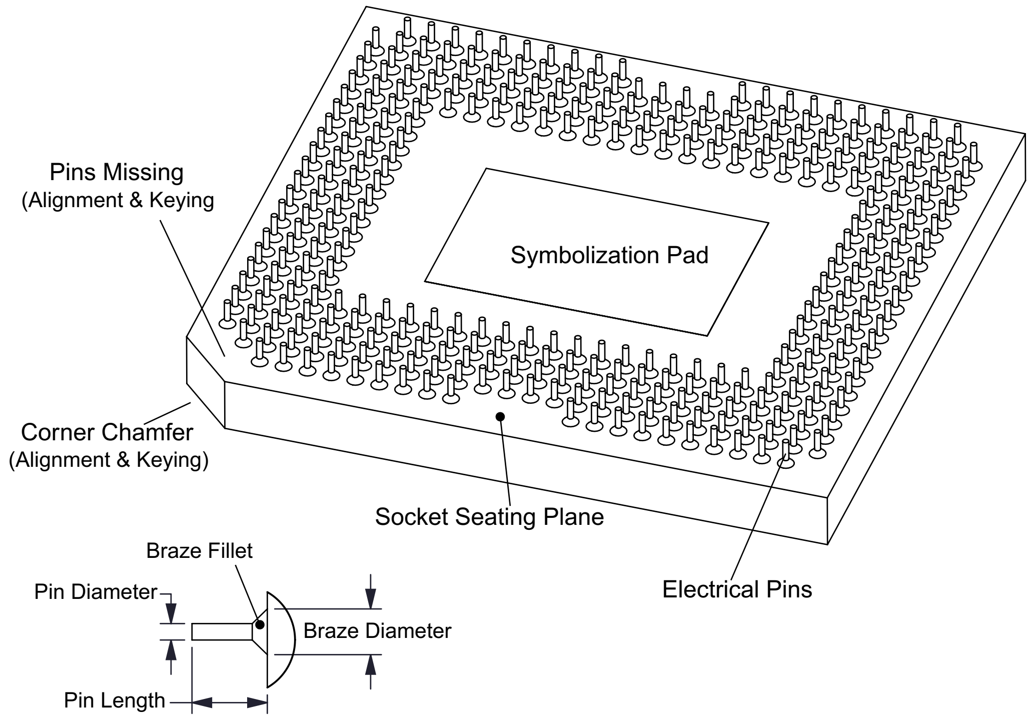

Figure 8. Electrical and Thermal Interface

3.7 Thermal Characteristics

The Series-600 DMD has a dedicated thermal interface area on the pin side of the DMD, which allows for conductive cooling of the DMD. The thermal interface includes the area of the symbolization pad and the adjacent ceramic areas, as illustrated in Figure 8.

The thermal specifications in the DMD data sheet includes both recommended operating conditions and absolute maximum ratings. The recommended (thermal) operating conditions represent the temperature limits within which the DMD will meet all operational specifications. Full-function operation of the DMD is not implied when conditions exceed those specified in the recommended operating conditions.

The absolute maximum (thermal) ratings represent the temperature limits within which no permanent (physical) damage will occur to the DMD, but exposing the DMD to temperatures beyond these conditions can cause permanent damage to the DMD, and should be avoided. The absolute maximum ratings are provided as stress limits for use in accelerated reliability stress testing.

The thermal specifications provided in the DMD data sheets are based upon illumination loads, which are evenly distributed across the active array. Applications utilizing illumination profiles that 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 of that application.

The primary thermal load on the DMD originates from the absorbed optical load and the electrical load that drives the mirrors. Secondary heating from other components near the DMD can exist, and the 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 pin side of the ceramic carrier. The primary thermal dissipation path for optical energy on the window aperture is the same thermal interface area of the pin side of the ceramic carrier. The conduction path from the window aperture to the thermal interface area is higher resistance than for the active array. Hence optical energy on the window aperture should be eliminated or reduced as much as possible.

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Note that optical energy on the window aperture creates a thermal load and must be cooled, but does not contribute to the optical efficiency of the DMD.

Additionally, the data sheet specifies the maximum UV power density that can be incident upon the active array. A UV filter may be required, depending on the spectral content of the illumination source.

3.7.1 Thermal Test Points

Standard thermal test points are identified in the DMD data sheet, and illustrated in Figure 9. The active array temperature can not be measured directly but must be computed analytically using information in the DMD data sheet, the ceramic thermal test point (TP1) temperature, measured screen lumens, and electrical DMD power dissipation. The relationship to calculate the array temperature from this information is shown in the DMD data sheet and described in *Section 3.7.2*

The test points on the window side of the DMD are to monitor the window temperature. The maximum window temperature in the DMD specification is for anywhere on the window edge, not just the standard test points identified in the data sheet. The location of the maximum temperature on the window edge will need to be determined in order to be sure it is below the maximum window temperature.

The image displayed when making temperature measurements should be the image that produces the worst-case temperatures. For display type end-applications 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 from an all black image. For display end-application where the energy on the active 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” or fine checker board image.

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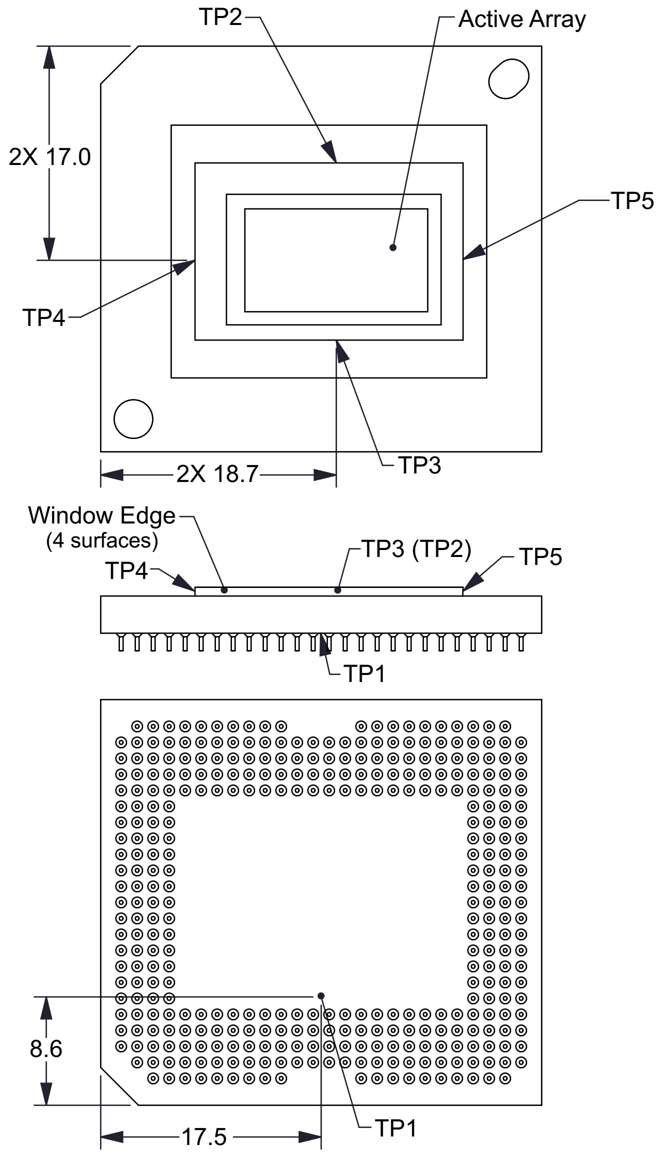

Figure 9. Thermal Test Points – Standard Locations

3.7.2 Array Temperature and its Calculation

The total thermal load on the DMD is a result of the electrical power dissipated by the DMD, plus the optical energy absorbed by the DMD. The electrical load to be used for the active array calculations should be measured when possible. If measurement is not possible a typical value (associated with a display application) is identified in the DMD data sheet. The energy absorbed from the illumination source is a variable and depends on the operating state of the mirrors, the intensity of the light source, and the 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 array temperature can be calculated using the formulas below.

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

$$Q_{ARRAY} = Q_{ELECTRICAL} + Q_{ILLUMINATION} \quad (2)$$

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

where

- T_{ARRAY} = Computed active array temperature (°C)

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- $T_{CERAMIC}$ = Temperature measured at the thermal test point (TP1 in Figure 9) on the ceramic (°C)
- $R_{ARRAY\text{-}TO\text{-}CERAMIC}$ = DMD package thermal resistance from active array to thermal test point (TP1) (°C/watt) (see DMD Data sheet)
- Q_{ARRAY} = Total power on DMD array from electrical plus absorbed optical (watts)
- $Q_{ELECTRICAL}$ = Nominal DMD electrical power dissipation (watts) (see DMD data sheet)
- $Q_{ILLUMINATION}$ = Absorbed illumination energy (watts) (application specific value)
- C_{L2W} = Conversion constant to determine absorbed optical power on the DMD from measured screen lumens (watt/lm)
- SL = Measured screen lumens (lm) (3)

The amount of energy can vary from unit-to-unit and over time with many illumination sources so when verifying the thermal design of an end-application it is important to verify the amount of illumination energy each time a temperature measurement is taken.

The DMD is characterized for an illumination load that is evenly distributed across the active array. Applications utilizing illumination sources which have high energy density (for example, highly collimated laser beams) have not been characterized and need to be investigated for the specific illumination source and application.

3.7.3 Sample Array Calculation for a Typical 1-Chip Display Application

Absorbed optical power from the illumination source is variable and depends on the operating state of the micromirrors and the intensity of the light source. Equations shown below are valid for a 1-chip display application with total projection efficiency through the projection lens from DMD to the screen of 87%.

The conversion constant (CL2W) of 0.00293 watts/lumen is based on the DMD active array characteristics and assumes:

- spectral efficiency of 300 lm/W for the projected light
- illumination distribution of 83.7% on the DMD active array, and 16.3% on the border around the DMD array, and window aperture.

Sample active array temperature calculation for 1-chip display application:

- .65 1080p Series 600 DMD

so $R_{ARRAY\text{-}TO\text{-}CERAMIC}$ = 0.6° C/watt (from DMD Data sheet) (4)

so $Q_{ELECTRICAL}$ = 2.9 watts (from DMD Data sheet for nominal electrical power dissipation for typical display application) (5)

SL = 2000 lumens (measured) (6)

$T_{CERAMIC}$ = 55 °C (measured) (7)

Q_{ARRAY} = 2.9 watts + (.00293 watts/lumen × 2000 lumens) = 8.76 watts (8)

T_{ARRAY} = 55°C + (8.76 watts × 0.6° C/watt) = 60.3 °C (9)

3.8 Mechanical Loading

Installing a DMD into an end-application environment will involve placing a mechanical load on the DMD, and more specifically, upon the ceramic carrier. The maximum mechanical load to be applied to the DMD is specified in the DMD data sheet. The areas the loads are to be distributed are shown in Figure 10. The load applied to the DMD should not exceed the specified maximum value during the installation process, or the continuous load after the DMD has been installed.

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The three areas of the DMD which accommodate a mechanical load are:

Electrical Interface Area

The Series-600 DMD is designed to accommodate mechanical loads evenly distributed across the electrical interface area shown in Figure 10. The maximum load to be applied to this area is defined in the DMD data sheet. The socket available for use with the DMD utilizes ZIF style contacts so no load is applied to this area during, or after insertion of the DMD into the socket. The micro-PGA socket designed for use with the Series-600 DMDs does not require a continuous load after the DMD is installed in the socket to maintain electrical connection. The load applied to the electrical interface area generally results from mounting the DMD-PCB. The only mechanical load required on these areas is that which is required to support the mass of the DMD, micro-PGA socket and DMD-PCB under mechanical vibration and shock conditions.

Thermal Interface Area

The Series-600 DMD is designed to accommodate a mechanical load evenly distributed across the thermal interface area shown in Figure 10. The maximum load to be applied to this area is defined in the DMD data sheet. The load on this area is to allow contact on the DMD with a heat sink (or other thermal hardware) in order to facilitate conductive cooling of the DMD. A thermal pad is typically used to facilitate the transfer of heat from the DMD to the heat sink. The minimum force (or pressure) applied to the thermal pad is that which is needed for good heat transfer, but increasing the pressure at some point does not improve the thermal performance substantially and may result in damage to the DMD (if above the maximum DMD specification value). Items to consider when determining the range of mechanical loads that could result are:

- Manufacturing tolerances of all parts associated with how the load is applied
- Assembly processes associated with how the load is applied (screw torque, and others)
- Minimum force required for good thermal (pad) performance
- Thermal pad pressure (load) versus amount of pad deflection
- Pressure (load) versus thermal impedance

Datum ‘A’ Area

The Series-600 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 on the opposite sides of the DMD. The Mechanical ICD defines the location and size of the Datum 'A' 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 service life of the DMD.

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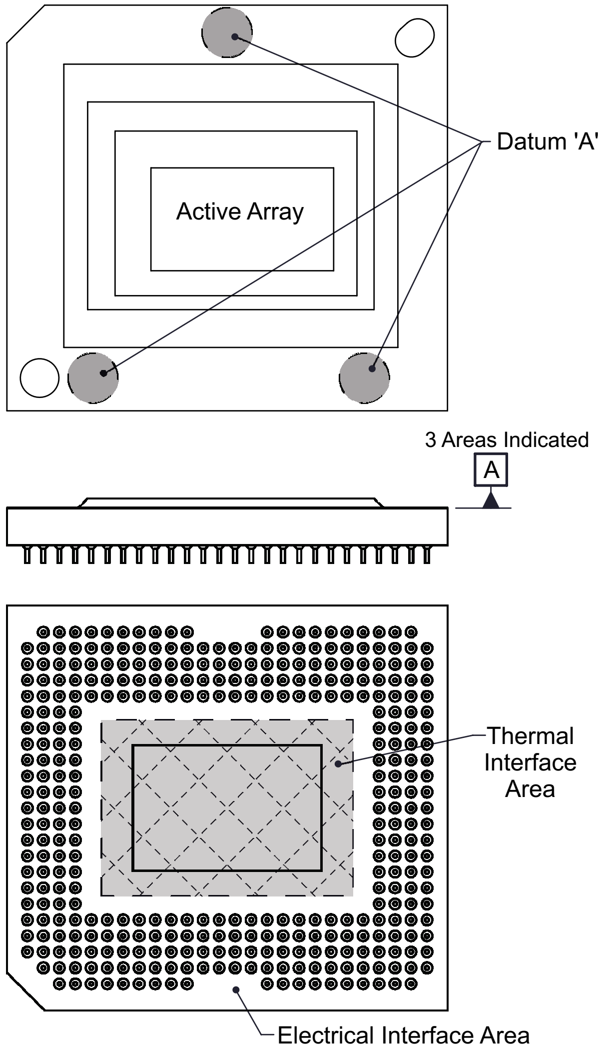

Figure 10. DMD Mechanical Loads

4 System DMD Mounting

The DMD is an opto-electrical device and has more considerations than a typical electrical component when mounting it into the end-application. The optical considerations of the DMD drive additional mechanical requirements that include alignment of the DMD with the other optical components, and additional thermal dissipation (cooling) associated with the optical energy (thermal load) on the DMD. This section of the application report discusses the critical considerations when mounting the DMD, the basics of a mounting concept, and specific details of a mounting concept. The features of the DMD that allow alignment in an end-application are described in *Section 3.1*.

4.1 Critical Considerations for Mounting and Utilizing the DMD

The method used to mount the DMD into the end-application needs to meet the functional requirements of the end-application, while ensuring that the DMD mechanical and thermal specifications are satisfied.

Critical design requirements when mounting a Series-600 DMD include:

- Establish (and maintain) the physical placement of the DMD's active array relative to the optical axis of the end-applications optical assembly
- Establish (and maintain) a reliable electrical connection between the DMD's electrical interface and the socket on the end-application's DMD-PCB or DMD-FPCB

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- Establish (and maintain) a proper thermal connection between the DMD's thermal interface area and the application's thermal solution
- Establish (and maintain) a dust-proof seal between the DMD and the chassis of the optical assembly

To meet these design requirements requires that some minimum mechanical load be applied to the DMD. The allowed mechanical loads on the DMD are described in *Section 3.8*. The mechanical loads in the thermal area result from securing the heat sink, and the loads in the electrical area result from securing the DMD and DMD-PCB in position. The detailed DMD mounting concept presented in this application report achieves the minimum mechanical load to meet the critical design requirements while illustrating various concepts for controlling the maximum mechanical loads applied to the DMD.

The ideal mounting design is one which:

- Does not rely upon strict assembly techniques or processes to control the loads
- Accounts for manufacturing variations (tolerances) of all the parts utilized
- Minimizes the variation in mechanical loads applied to the DMD

If not understood and minimized the mechanical load variations can easily result in lower forces than what are needed to hold the DMD in place or higher forces which could result in damage to the DMD. A wide range of mechanical loads is possible on the DMD and depends on the specific details of the DMD mounting design implemented.

Insufficient load to the thermal interface area could result in movement of the DMD position or poor thermal contact of the heat sink, while excess load could result in mechanical damage to the DMD. Movement of the DMD could result in a focus change or image shift. Poor thermal contact (between the DMD and heat sink) could result in thermal damage to the DMD.

Insufficient load to the electrical interface area could result in movement of the DMD position, while excess load could result in mechanical damage to the DMD.

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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).

A basic concept for mounting the Series-600 DMD that incorporates the drop-in-place method is illustrated in Figure 11 and described below:

- Optical chassis – The representative features associated with mounting the DMD are incorporated into the optical chassis. These features are described in more detail in *Section 4.2.1*. The part, as shown, is not intended for use as a separate standalone part, but rather as a reference for the features to be incorporated into the system optical chassis. Additional features can be included which aid the installation and mounting of the DMD or DMD-PCB.
- System aperture – located between the DMD window and system optics. The aperture is to reduce or block unintended stray and scattered light reflected off the DMD or other optical component from becoming part of the image (either in the actual picture or the area just adjacent to it).
- Dust gasket (dust seal) - provides a barrier between the optical chassis and DMD to prevent dust particles from getting onto the outer surface of the DMD window glass.
- Series-600 DMD – any of the active array resolutions in the Series-600 family of DMDs.
- S600 socket – provides electrical connection between the pins on the DMD and the end-applications

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DMD-PCB assembly. Section 5 contains information about socket designs.

- DMD-PCB – the electrical board the s600 socket and DMD mount. This could be a small board with the s600 socket and minimum components, or the full system electronics assembly with all the end-application features.
- Thermal pad – thermally conductive pad that facilitates conductive heat transfer from the DMD thermal contact area to the system heat sink. The pad could be electrically conductive or non-conductive depending on the system requirements. Note when selecting the electrically conductivity of the thermal pad material that the marking pad on the back of the DMD is electrically connected to signal ground.
- Heat sink – conducts the heat from the DMD thermal interface area to a larger surface area where the heat can be transferred to the air and then out of the end-application.
- Compression springs - compliant elements that absorb the variation of part manufacturing tolerances used to mount the DMD heat sink to the optical chassis. The selection (or design) of the springs are critical for control of the mechanical loads on the DMD. See Section 4.2.2 for more details about mounting the heat sink.
- Shoulder screws – are used to mount the heat sink to the optical chassis. The design of these is critical for controlling mechanical loads applied to the DMD thermal area. See Section 4.2.2 for more details about mounting the heat sink.
- Push nut – retaining hardware that captivates the compression spring and shoulder screw onto the heat sink. Thus enabling the heat sink assembly.
- Heat sink sub-assembly – is comprised of the heat sink, thermal pad, shoulder screws, compression springs, and push nuts. Allows for simpler installation of the DMD by providing for a single assembly (that contains multiple parts) to be handled during DMD installation rather then multiple individual parts.

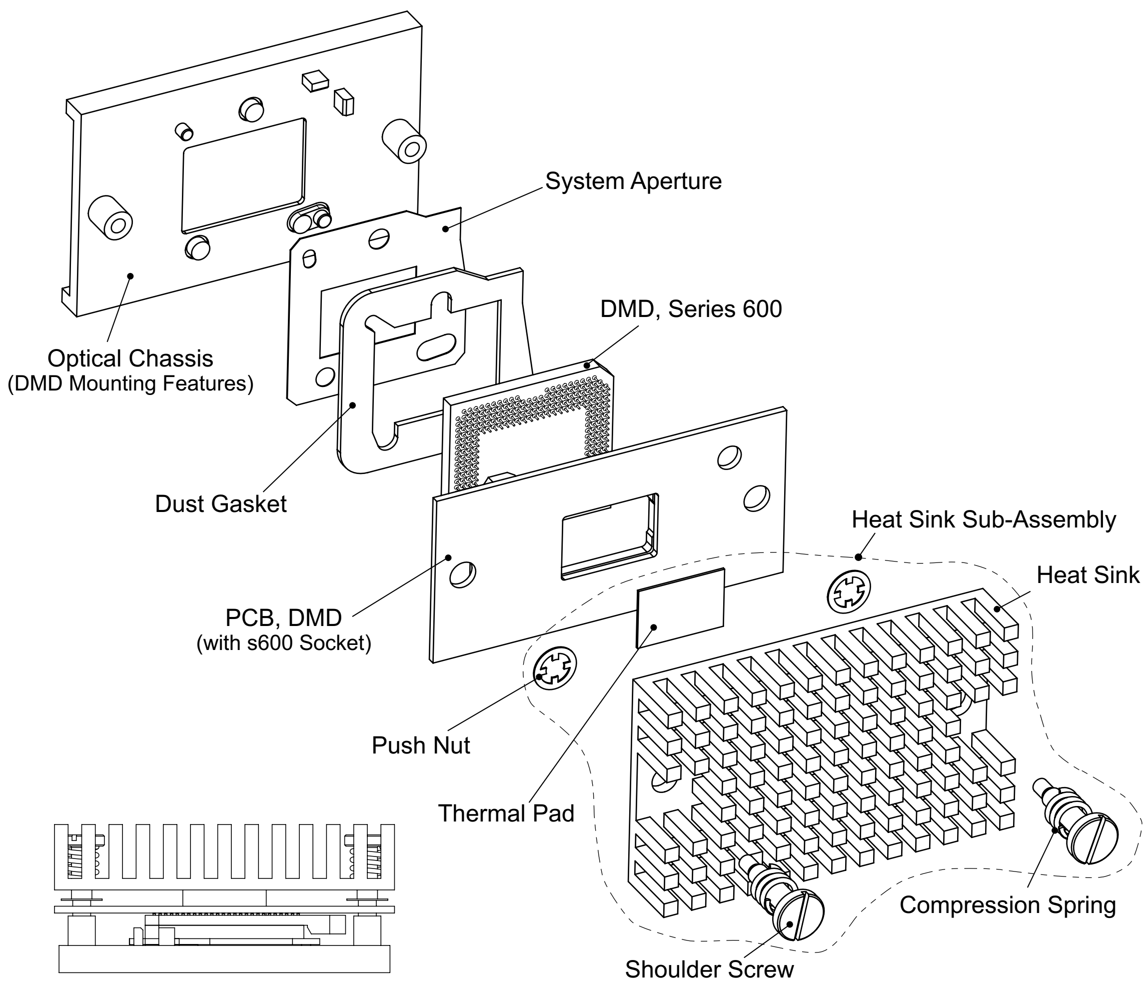

Figure 11. Basic DMD Mechanical Mounting Concept

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Not shown in Figure 11 but equally important is the method used to secure the DMD-PCB assembly. The method used to secure the DMD-PCB in the system can result in a wide range of loads applied to the DMD electrical interface area. The DMD electrical interface mechanical load is discussed in *Section 3.8* and mounting concepts discussed in *Section 4.2.3*.

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 12 are summarized as follows:

- Datum ‘A’ Areas - three coplanar areas that contact the DMD Datum ‘A’ area. These establish the relationship for the position of the active array along the axis of the projection lens and other optical components.
- Datum ‘B’ Ø 2.99 mm round pin – mates with the DMD Datum ‘B’ hole. This establishes the X and Y-axis location for the active array relative to the axis of the projection lens and other optical components.
- Datum ‘C’ Ø 2.09 mm round pin – mates with the DMD Datum ‘C’ slot. This establishes the rotation location for the active array relative to Datum ‘B’.
- Boss, threaded (2) - secure the DMD against the Datum ’A’ features of the system optical chassis and mount the heat sink.

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

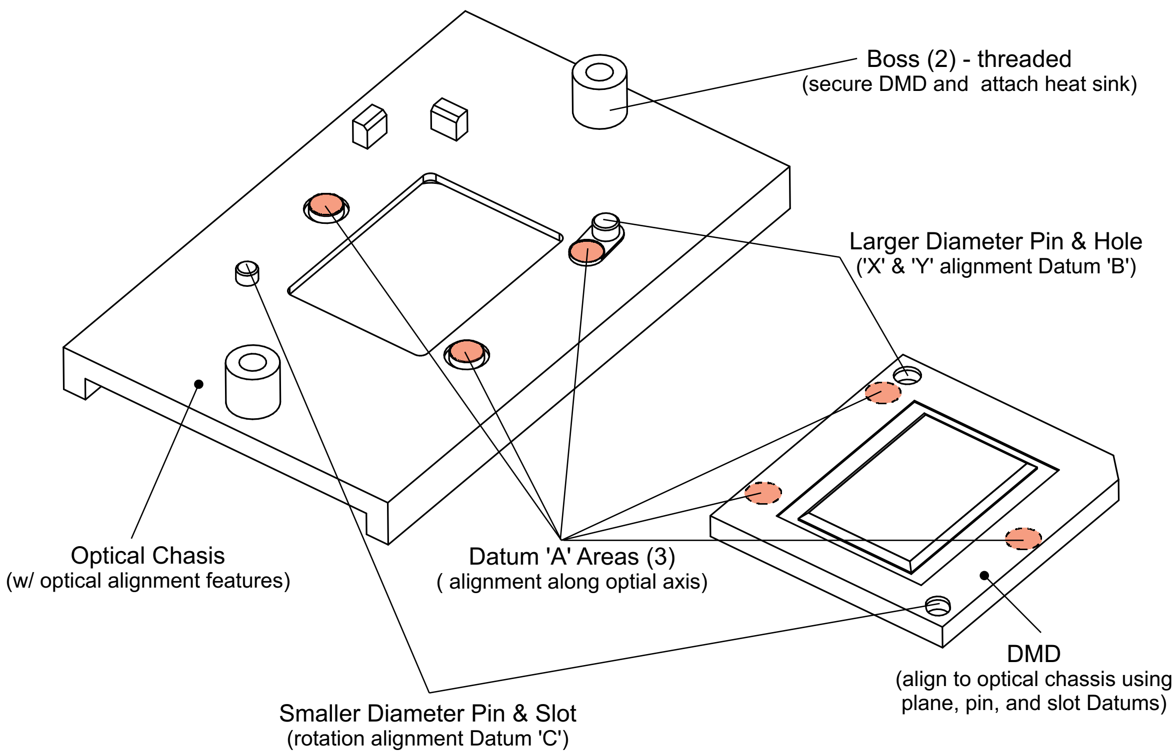

Figure 12. Optical Interface (Alignment) Features

The following characteristics of the Series-600 Optical-Mechanical alignment features should be noted:

- Physical keying when installing the DMD into the system optics is provided by different size of Datum ‘B’, and Datum ‘C’ features (hole and slot).
- The three Datum ‘A’ tabs on the optical chassis must be coplanar to ensure uniform focus of the active array, and focus repeatability between systems. The co-planarity of these features, the DMD parallelism, optical design depth of focus, and position sensitivity of optical components combine to

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determine the uniform focus of all four corners of the image.

- The outline 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.
- The Datum ‘B’ and ‘C’ features on the DMD (hole and slot) are not the full depth of the ceramic, see Figure 3. For this reason the maximum length of the mating features (pins) on the optical chassis must be controlled to keep the top of the optical chassis pin from contacting the bottom of the DMD hole before the Datum ‘A’ surfaces of the DMD and optical chassis have properly contacted.
- The system gasket or aperture (if used) should be designed to not interfere with the proper mating of the DMD Datum’s and corresponding Datum features on the optical chassis. Any gasket or aperture material that overlaps the DMD Datum ‘A’ features could cause focus problems and overlapping material in the Datum ‘B’ and ‘C’ areas could cause active array position issues. Another issue that could result in focus problems is if the gasket material is not compliant enough to allow sufficient compression so the Datum ‘A’ features can fully contact.
- The base of the protruding features (where connected to the optics chassis) can be used to align the system aperture or dust gasket. See *Section 4.2.6*
- Avoid sharp edges on the Datum ‘A’ tab features in order to prevent damage to the DMD ceramic carrier. A sharp contact point could result in a highly concentrated load (in a very small area), and potentially lead to damaging (cracking) the DMD’s ceramic carrier.

4.2.2 Heat Sink Mounting

The end-application’s thermal solution (heat sink) is intended to contact the DMD thermal interface area. The method used to mount the heat sink to the optical chassis will determine the mechanical load being applied to the DMD thermal interface area. The minimum mechanical load is that which is required to provide good thermal performance for conduction of heat from the DMD to the heat sink. The maximum mechanical load applied should not exceed the maximum load for the DMD described in *Section 3.8*.

A key consideration of any mounting concept is how the minimum and maximum mechanical loads on the DMD will be controlled. Controlling the mechanical loads by design rather than relying on assembly processes (techniques) is more consistent and less likely to get out of control during production.

4.2.2.1 Direct Control of Heat Sink Mounting Loads

To control the mechanical loads by design typically requires the use of a compressive component (like a coil spring or flat spring), and an understanding of the variation in the gap that the compressive component fits in. A design concept that controls loads by design is illustrated in Figure 13 where the loads are controlled by the use of compression springs in conjunction with shoulder screws. The springs are selected (or designed) such that the forces applied to the DMD thermal area are sufficient to ensure good thermal conductivity of the thermal pad, but not exceed the maximum load of the DMD.

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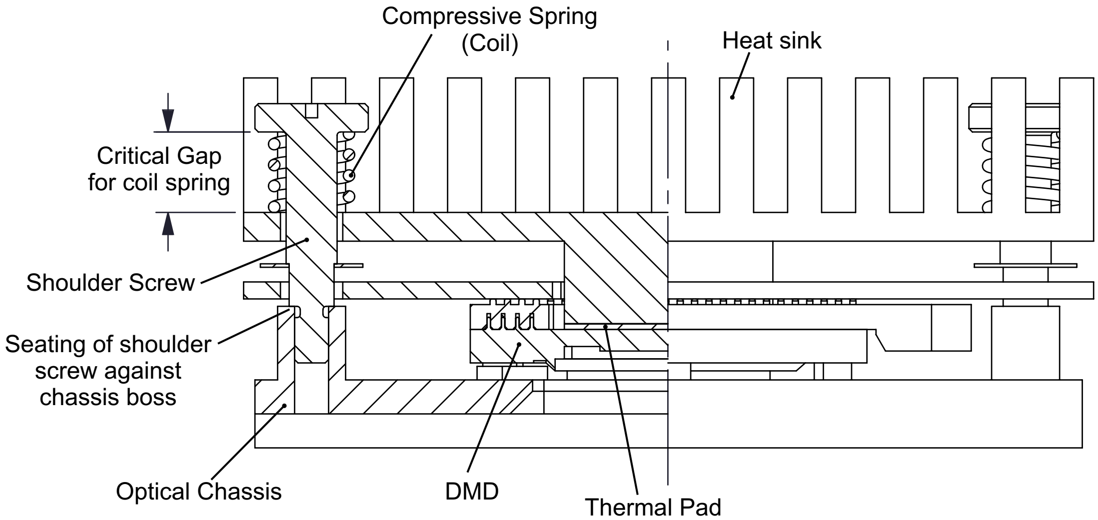

Figure 13. Heat Sink Mounting – Load Control by Design

The first step in this type of design is to understand the size and variation of the gap into which the spring will fit. This is identified as the ‘critical gap’ in Figure 13. The minimum force occurs when the gap is the largest (least compression of spring), and the maximum force when the gap is the smallest (most compression of spring). For the design concept illustrated in Figure 13 the parts that contribute to the variation in the gap size include the shoulder screw, optical chassis, DMD, thermal pad and heat sink. The shoulder screw is tightened until the shoulder of the screw seats (contacts) the optical chassis. This eliminates any variation in the ‘critical gap’ associated with the amount of screw torque applied.

The variations of the ‘critical gap’, along with those of the spring size, and spring-rate determine the variation of the force applied to the DMD Thermal Interface area. Refer to *Section 4.3.1.1* for a detailed example of a ‘critical gap’ size analysis and the associated range of forces applied to the DMD by various coil springs.

4.2.2.2 Indirect Control of Heat Sink Mounting Loads

Replacing the shoulder screws and coil springs in Figure 13 with traditional screws would represent a mounting concept that does not control the force applied to the DMD by design, but rather attempts to control it by the assembly process and associated torque of the screws. The clamping force from tightening the screws would determine the force applied to the DMD.

The clamping force would vary widely from such things as:

- Heat sink stiffness
- Diameter of the screws
- Pitch of the screws
- Type of screw – machine, thread forming, thread cutting, etc.
- Friction factors between the screws and optical chassis threads
- Amount of torque applied to the screws
- Method of tightening the screws - order, partial tightening all screws before final tightening of any screw, etc.
- Distance from mounting screws to the DMD

To understand the variation in the clamping force requires a characterization study and tests of the many contributors to the variation in forces.

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4.2.3 DMD-PCB Mounting

The DMD is primarily held in place (on the optical chassis) by the heat sink and does not require any additional securing. However the DMD-PCB must be mounted in a manner which prevents it from moving during mechanical shock, mechanical vibration, or inadvertent movement during a subsequent assembly operation (like attaching another electronics assembly). The DMD-PCB typically requires only a minimum amount of securing to prevent disengagement of the DMD from the socket (although, this does depend on the size of the DMD-PCB, because the larger the DMD-PCB the larger the mass and moment arm).

The method used to mount the DMD-PCB is critical for controlling the load applied to the DMD’s electrical interface area. The maximum allowable load for the DMD’s electrical area is specified in the DMD Data Sheet and described in *Section 3.8*.

Considerations for mounting the DMD-PCB include:

- Prevention of any movement which may result in separation of the DMD Datum ‘A’ features and the corresponding features on the optical chassis
- Prevention of any tilting of the DMD about the optical chassis Datum ‘A’ surface
- Prevention of any flexing or bending of the DMD-PCB which could result in damage to the solder joints of the socket or other components on the PCB or excess mechanical loads on the DMD
- Prevention of any movement of the DMD caused during the assembly of other electronic assemblies
- Minimizing the size and weight of the DMD-PCB (if important to the end-application)
- Simplification of assembly processes and preferred assembly methods

The DMD-PCB can be mounted in many ways. The optimum mounting method in a specific end-application will be dependent upon the geometry and design objectives of the end-application. There are many mounting methods, which can be categorized as either "direct control of loads" or "indirect control of loads", according to how the resulting mechanical forces on the DMD are controlled.

The ‘direct control of loads’ methods are ones that enable the minimum and maximum mechanical load on the DMD electrical interface area to be determined by design using simple direct calculations, like the compression range of a spring. Methods that require no load on the PCB also fall in this classification.

The ‘indirect control of loads’ methods are those that rely on screw torques or that have components that bend. The variation in clamping forces associated with screw torques and properties of components that bend (DMD-PCB, stiffener plate, etc.) make it much more difficult to predict the minimum and maximum mechanical loads. These methods typically require careful assembly processes to prevent damage to the DMD.

4.2.3.1 Direct Control of PCB Mounting Loads

A variety of ‘direct load control’ techniques for mounting the DMD-PCB are illustrated in Figure 14. These techniques provide a direct means of determining and controlling the forces applied to the DMD. Additionally, the forces applied to the DMD by some of these techniques are often negligible.

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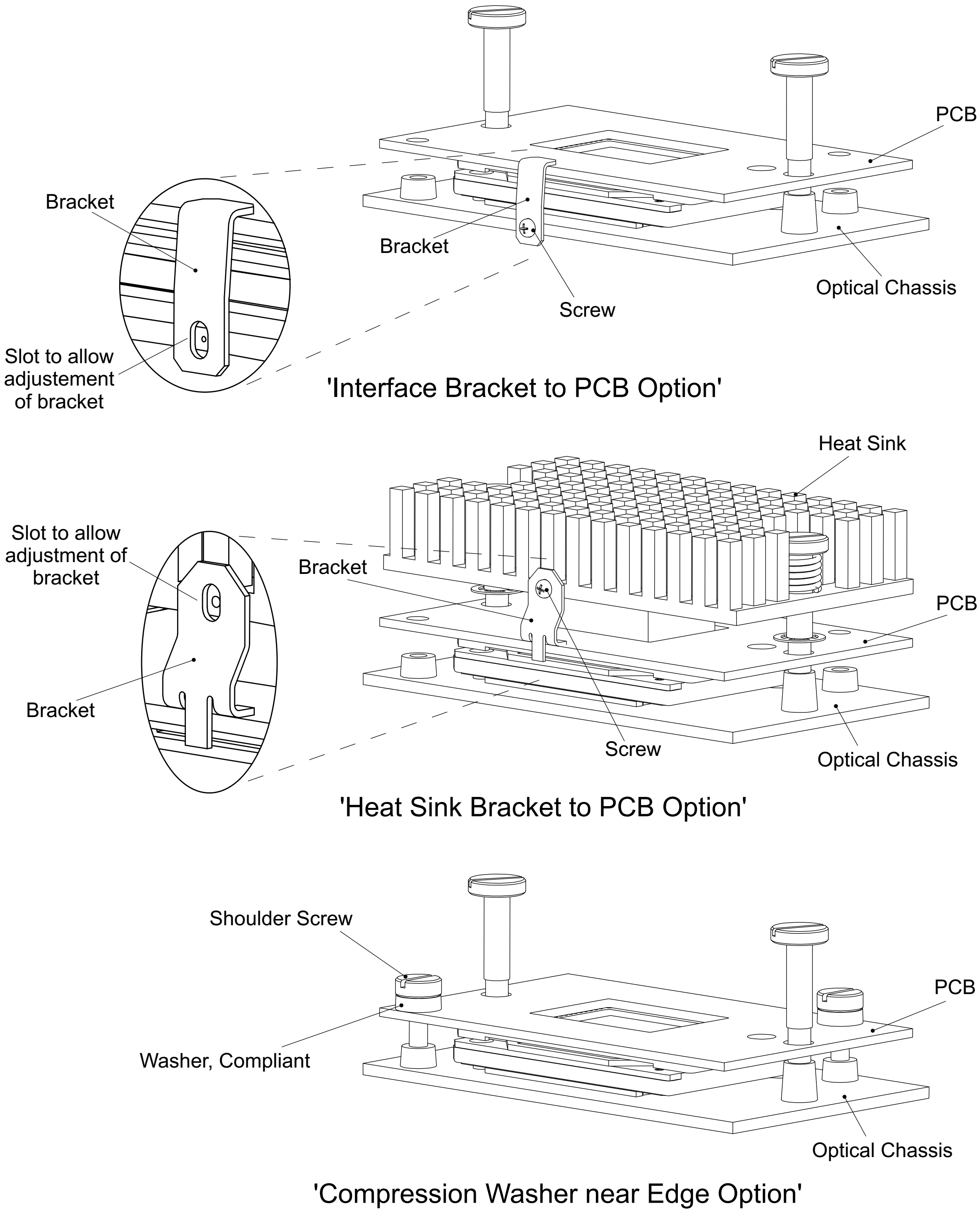

Figure 14. Direct Control of DMD-PCB Mounting Options

A direct control method is thought to have fewer variations in production and result in fewer issues and damaged DMDs. The three options included in this application note are concepts to stimulate ideas for implementing a direct control mounting method. The specific details can vary widely. Some of the key points for these options include:

- “Interface Bracket to PCB” mounting option
  - Simplest and most direct method to design and implement
  - Results in no forces added to the heat sink springs

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  - Results in no movement of PCB
  - Cannot be assembled top down (when installing screws)
  - Slot allows adjustment of bracket (to accommodate part tolerances)
- “Heat Sink Bracket to PCB” mounting option
  - Simple and direct method to design and implement
  - Preventing PCB movement requires forces be applied to the heat sink springs which reduces force applied to the heat sink area
  - Small amounts of movement may be possible in high shock environments
  - Cannot be assembled top down (when installing screws)
  - Slot allows adjustment of bracket (to accommodate part tolerances)
- “Compression Washer Near Edge” mounting option
  - Top down assembly method possible (when installing screws)
  - Shoulder screws and washer compliance are key to controlling forces on DMD
  - Variation in washer material compression will cause variation in forces
  - Difficult to get or develop force vs. deflection data for the washer material; making it difficult to calculate the force characteristics
  - Part tolerances (shoulder screw, washer, interface boss for screw) are more critical than for a simple bracket

The ‘interface bracket to DMD-PCB’ and ‘heat sink bracket to DMD-PCB’ options shown in Figure 14 apply no forces to the DMD. The ‘interface bracket to DMD-PCB’ option is the simplest of these to design and implement, and the ‘compression washer near edge’ the most challenging.

4.2.3.2 Indirect Control of PCB Mounting Loads

Using screws to clamp the PCB against bosses on the optical chassis (as shown in Figure 15 can easily result in large mechanical forces being applied to the DMD. In this situation there are multiple items that indirectly apply force to the DMD. Therefore, controlling the force on the DMD requires close attention to the force contributed by each item. This is a difficult analysis to do because the assembly process is typically a significant factor. To do this type of analysis requires finite element modeling and making multiple assumptions.

The items when using this mounting method that influence the forces on the DMD (and thus contribute to the variation and unpredictability of the forces) include:

- Size of the gap between optical chassis boss and the PCB – amount PCB could bend
- PCB stiffness - affected by layer count, material properties, thickness, direction of routing of traces in the PCB, solid conductor planes in the PCB, etc.
- Diameter of the screws
- Pitch of the screws
- Type of screw – machine, thread forming, thread cutting, etc.
- Friction factors between the screws and optical chassis threads
- Amount of torque applied to the screws
- Method of tightening the screws - order, partial tightening all screws before final tightening of any screw, etc.
- Distance from the mounting screws to the DMD

Understanding the minimum and maximum size of the 'critical gap' between the boss and DMD-PCB enables a better understanding of the variation of the forces applied to the DMD, and also indicates if the DMD-PCB could contact the optical chassis boss before the Datum ‘A’ features (on DMD and optical chassis) have properly contacted (resulting in focus issues). There must always be a gap (between the DMD-PCB and optical chassis boss) to assure the Datum ‘A’ features contact. The size of the ‘critical gap’ can be determined by a tolerance analysis of the part features that contribute to the gap. A detailed example of such an analysis is discussed in *Section 4.3.1.2*.

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In general a larger ‘critical gap’ between the DMD-PCB and the optical chassis boss will allow for greater bending of the PCB and larger resultant forces on the DMD. Minimizing the ‘critical gap’ minimizes DMD-PCB bending and helps to reduce variations in the forces on the DMD.

It is very difficult to keep the DMD-PCB from bending by use of torque on the mounting screws, and still have the screws sufficiently tight to prevent the screws from becoming loose during vibration conditions. In this type of situation, thread-locking materials may be required to prevent the screws from loosening.

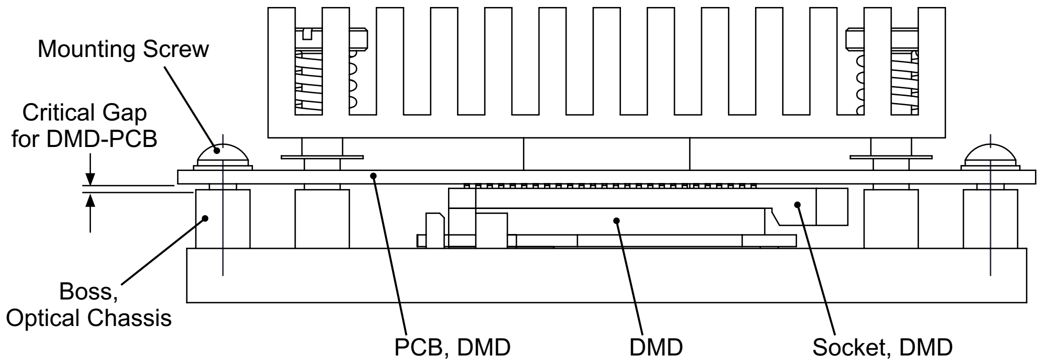

Figure 15. DMD-PCB Mounting Gap - Indirect Control of Load on DMD

4.2.4 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 and considerations for the gasket include:

- Comprised of a material which does not allow dust particles to pass through it’s volume
- Comprised of a material which does not create particles
- Creates a sufficient seal against the surfaces it contacts to prevent dust particles from reaching the DMD window glass
- Creates no interfere 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 and interfering with contact of the DMD Datum ‘A’ areas
- Gasket should not interfere with the assembly of the DMD into the optical sub-assembly

4.2.5 System Aperture

The system aperture functions to absorb or reflect stray light (either reflected or scattered) from entering the projection lens pupil and thus becoming part of the projected image. The source of the stray light could be from the surface of an optical component near the DMD (typically projection lens elements or prism), mechanical mounting parts for the optical components, or areas of the DMD outside the active array.

Characteristics and considerations for the aperture include:

- Surface finish - one which will minimize light scattering
- Surface color - generally an absorptive flat black produces the best results
- Edge of aperture opening which minimizes light scattering - sharp rather than rounded, smooth free of nicks and irregularities, etc.
- Shape and dimensions to complement the overall optical design - illumination f-number; characteristics of optical elements near the active array like shape, curvature, distance, location, etc.

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- Surface angle orientation (tilting) relative to the active array plane

It is expected that the size and shape of the opening in any TI reference aperture design would require modification to account for the specific details of an end-application’s optical design.

The usual method to determine the final aperture design (opening size, shape, and tilt relative to the active array) is to iterate the aperture design features when viewing the projected image. This method allows for iterations to be performed until any objectionable scattered light have been eliminated or reduced to a satisfactory level.

4.2.6 System Aperture and Dust Gasket Mounting

The system aperture and dust gasket can be installed as separate parts or attached together before installation. The concept illustrated in Figure 11 has separate parts that are compressed between the DMD and the optical chassis to hold them in place.

The system aperture needs to be located relative to the illumination bundle. The Datum ‘B’ and ‘C’ features on the DMD are relatively small in diameter with limited depth. This can make the corresponding features on the optical chassis difficult to use for alignment (X and Y-axis) of an aperture (or gasket).

The Datum features ‘A’, ‘B’, and ‘C’ on the optical chassis can be raised above a flat surface as shown in Figure 16 to allow for features at the base of the Datum features to be used for alignment of an aperture (or gasket). For accurate and repeatable placement of an aperture (or gasket) the location and tolerance of these features need to be controlled relative to the features that align to the DMD Datum ‘B’ and ‘C’.

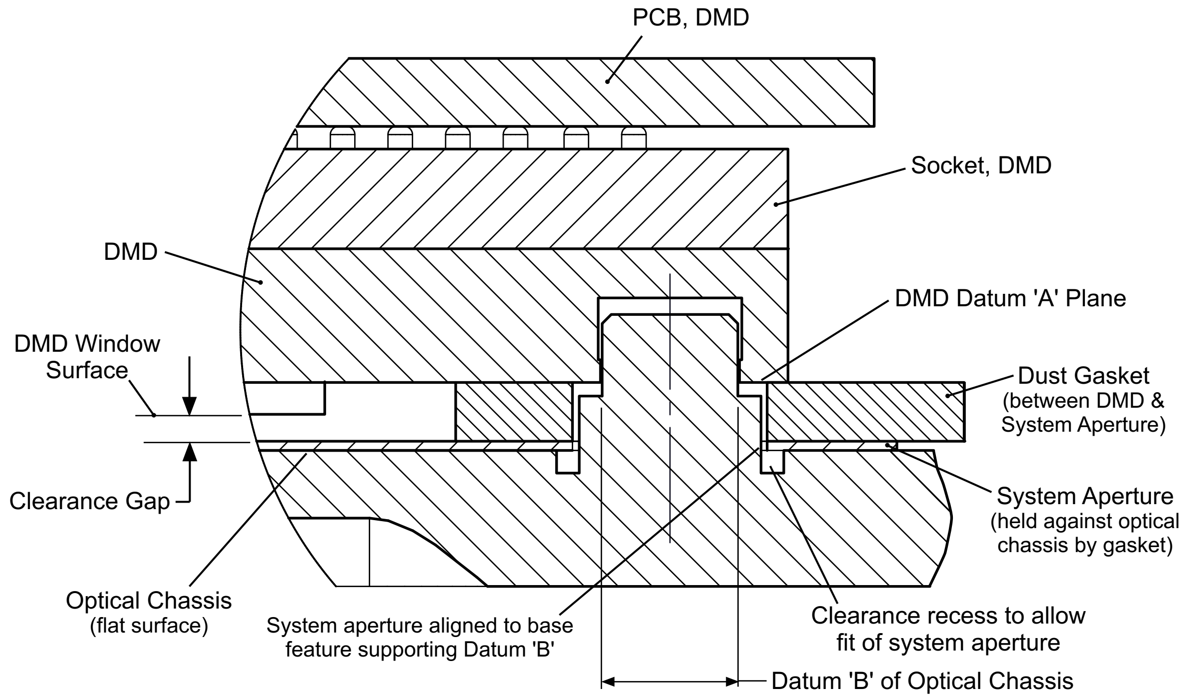

Figure 16. System Aperture and Dust Gasket

Note that using the base of the features for system aperture alignment may require a recess (around the bottom of the feature) to allow for the aperture to fit flush against the optical chassis surface and not interfere with mounting the DMD. A clearance recess around the base of an alignment feature is illustrated in Figure 16.

The system aperture functions best if it is located near the outside surface of the DMD window glass as shown in Figure 16. The desired size of the opening in system aperture may require the aperture to extend over the edge of the DMD window. To enable this there would need to be a gap between the DMD window and system aperture. Allowing for such a gap at the beginning of the design will enable more flexibility when the opening is finalized. Generally the system aperture design is not finalized until after the first engineering model and optical evaluation.

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The system aperture in Figure 16 is held in place by compression of the dust gasket between the DMD and the aperture. When this is done it is important to be sure the force required to compress the dust gasket is small enough so as to not prevent the Datum ‘A’ features of the DMD and optical chassis from contacting.

An alternative dust gasket would be one that is designed to fit around the entire DMD and then be compressed between the DMD-PCB and the optical chassis.

4.3 Detailed DMD Mounting Concepts

Detailed concepts for mounting the DMD are described in this section. It is expected that the parts and features represented in the TI concept designs will be adapted or modified to accommodate a specific end-application, part design requirements, part manufacture requirements, and other specific customer needs.

The surface area of the heat sink in the concept design is not intended to be representative of the surface area needed for adequate cooling of the DMD. The heat sink illustrates the features necessary for mounting the DMD and heat sink. The actual heat sink design (surface area, material) will need to account for the amount of cooling air available, ambient air temperature, thermal load on the DMD, and other characteristics of a particular system thermal design.

4.3.1 Edge Guide Mounting Concept

The main characteristics of this mounting concept are discussed in *Section 4.2*. Additional information and specific part details are discussed in this section. The design concept for mounting the Series-600 DMD shown in Figure 17 incorporates specific features on the optical chassis intended to aid in the alignment of the DMD during the installation of the DMD. The DMD Datum’s (‘A’, ‘B’, and ‘C’) along with their corresponding features on the optical chassis can be used as the sole alignment features when installing the DMD, but these features are small, close to the window, and not easily seen during installation of DMD. The edge alignment features on the optical chassis are intended to simply the assembly process and reduce the chance of damaging the DMD window due to inadvertent contact between the DMD window and the alignment pins on the optical chassis (Datum’s ‘B’ and ‘C’). The edge alignment features (shown in Figure 17) are larger and provide rough alignment to the edge of the DMD ceramic carrier before the small datum pin features are near the window. The Datum ‘A’, ‘B’, and ‘C’ features (described in earlier sections) are intended to provide the final alignment.

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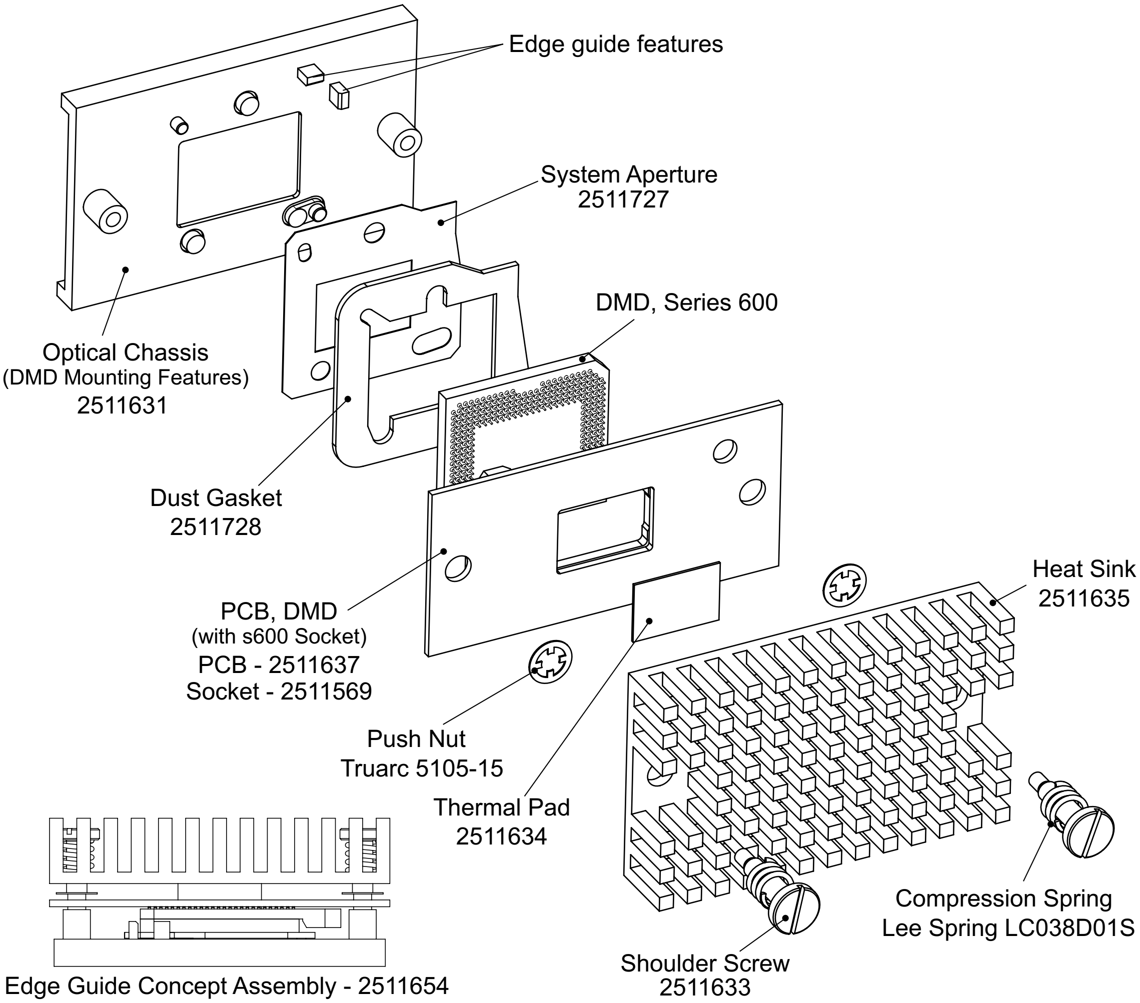

Figure 17. DMD Mounting Concept – Edge Guide

The detailed analysis of the critical gaps associated with mounting the heat sink are discussed in *Section 4.3.1.1*. The detail of securing the PCB to the optical chassis is discussed in *Section 4.3.1.2*.

The drawing number for the "Edge Guide" mounting concept assembly shown in Figure 17 is 2511654. The 3D-CAD models (in STEP format) and drawings (in pdf format) for each of the parts shown in Figure 17 are available for download. See *Section 6* for details.

4.3.1.1 Heat Sink Mounting

The method of mounting the heat sink is critical to control the mechanical loads applied to the DMD thermal interface area. See *Section 3.8* for more information on DMD thermal area mechanical loads, and *Section 4.2.2* for general heat sink mounting. The mounting concept shown in Figure 17 uses shoulder screws and compression springs to control the forces on the DMD thermal Interface area. The compression springs are compressed between the head of the shoulder screw and the heat sink. The variation in this gap (shown as 'critical gap' in Figure 18) is the result of the part manufacturing tolerances. Figure 18 illustrates the key part features and a schematic diagram of the tolerances that contribute to variation in the ‘critical gap’. The tolerance schematic starts at the head of the shoulder screw (on the left-hand side of the figure), and continues around to the surface of the heat sink that contacts the spring (on the right-hand side of the figure). The nominal value of the identified 'critical gap' is the difference between the “start” and “end” locations and the size tolerances of each part contributes to the variation of the ‘critical gap’.

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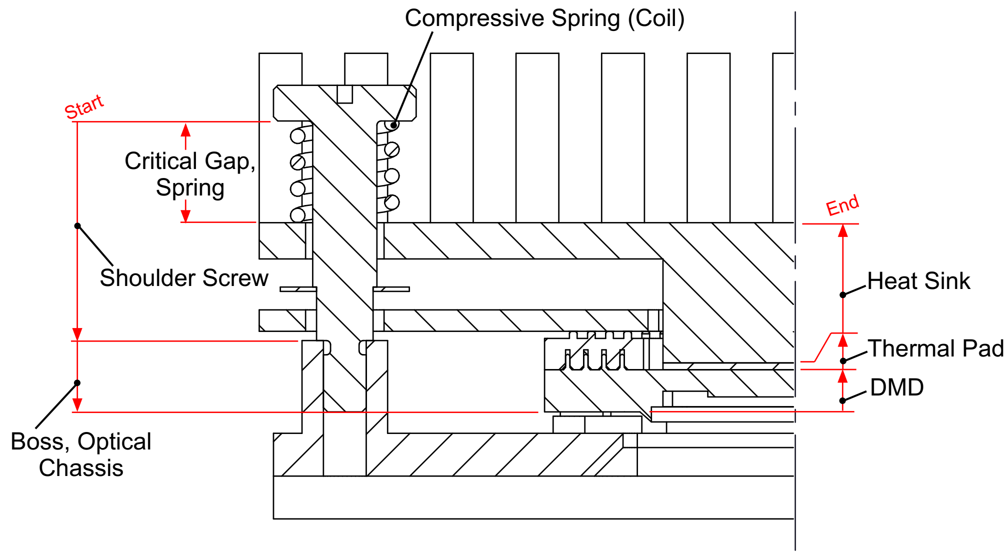

Figure 18. Heat Sink Mounting Tolerance Analysis Schematic Diagram

The nominal value and tolerance for each of the key part features shown in Figure 18 that contribute to the gap are included in the analysis shown in Table 1. The nominal and tolerance values are found on the individual part drawings for the mounting concept shown in Figure 17. See *Section 6* for drawing information. The parts are dimensioned in a manor to minimize variations in the gap.

The tolerance analysis indicates a nominal gap size of 7.1294 mm. The simple sum (SUM) method of part tolerance analysis (worst-case) is ±0.6200 mm, which results in a minimum gap of 6.509 mm, and a maximum of 7.749 mm. The root sum square (RSS) method of part tolerance analysis is ±0.3127 mm, which result in a minimum gap of 6.817 mm and a maximum of 7.442 mm.

Table 1. Gap for Compression Spring

	Nominal (mm)	Dir Sign	Nominal (mm)	Tol (+/-) (mm)	Tol Method	Min Gap	Max Gap
Shoulder Screw	15.3900	-1	–15.3900	0.0800			
Optical Chassis (Datum 'A' to Should Screw Boss)	5.0000	-1	–5.0000	0.1200			
DMD	2.9500	1	2.9500	0.2400			
Thermal Pad (compressed height)	0.4826	1	0.4826	0.0500			
Heat SInk	9.8280	1	9.8280	0.1300			
		Sum	–7.1294 (1)	0.6200 0.3127	**Sum RSS**	6.509 6.817	7.749 7.442
(1) Negative indicates a gap for spring							

The resultant force on the DMD thermal interface area depends upon:

- Minimum and maximum critical gap size for the compression spring (from above analysis)
- Nominal free length of the spring
- Tolerance of the spring free length
- Nominal spring rate
- Tolerance of the spring rate

For the concept design illustrated in Figure 17 the minimum force required for thermal performance of the thermal pad is determined as follows:

- Area of the heat sink stud and thermal pad is 12.7 × 18.4 = 234 mm^2
- To achieve a thermal pad resistance of 0.54°C/Watt will require a pressure of 171 KPa on the thermal

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area (pressure from thermal pad data sheet)

- To achieve a pressure of 171 KPa on the 234 mm^2 thermal area would require a total load of 40 Newton be applied to the DMD Thermal Interface area
- Since two compression springs are used the minimum needed per spring is 20 Newton

For a maximum load of 111 Newton applied to the DMD Thermal area the load per spring would be 55.5 Newton. Thus, the compression spring to be selected (or designed) for this application should produce a minimum of 20 Newton and a maximum of 55.5 Newton. For the springs reviewed in this force range the typical spring free length tolerance was ±0.56 mm, and a spring rate tolerance was ±10% of the nominal spring rate.

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 associated with part manufacturing applied)

The maximum force occurs when:

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

The minimum force occurs when:

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

Table 2 summarizes the SUM (worst-case) and RSS tolerance analysis results for several candidate springs.

Table 2. Analysis Summary for DMD Thermal Area Mechanical Load

Spring	Outside Dia (mm)	Wire Dia (mm)	Solid Length (mm)	Rod Dia (mm)	Free Length (mm)	Spring Rate (N/mm)	DMD Thermal Area Load (force)				
							Nominal	Worst Case Tolerances		RSS Case Tolerances	
							(N)	Min (N)	Max (N)	Min (N)	Max (N)
A	7.619	0.965	5.105	5.460	11.125	7.72	30.85	19.57	43.94	21.71	41.33
B	7.619	1.016	5.537	5.359	11.125	9.91	39.60	25.12	56.41	27.86	53.06
C	8.991	1.092	5.054	6.578	10.998	9.87	38.18	23.89	54.80	26.62	51.46
D	9.143	1.066	5.105	6.781	11.125	8.15	32.56	20.66	46.39	22.92	43.63

The results of the tolerance analysis indicates:

- All springs (A, B, C, D) have a nominal force that is between the minimum and maximum loads required (20.0 - 55.5 N).
- Spring (A) has a worst-case (SUM) load for minimum tolerances (19.57 N) just under the 20.0 N minimum, but the RSS load (21.71 N) is greater than the minimum needed.
- Spring (B) has a worst-case (SUM) load for the maximum tolerances (56.41 N) over the 55.5 N maximum, but the RSS load (53.06 N) is less than the maximum requirement
- Spring (C) has loads that are between the minimum and maximum loads required although the worst-case (SUM) load (54.80 N) is just below the maximum requirement
- Spring (D) has loads that are between the minimum and maximum loads required although the worst-case (SUM) load (20.66 N) is just above the minimum required

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?

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- If the worst-case (SUM) conditions did occur what type of failure is likely to result? (Would the DMD be damaged, the electrical connection to the DMD be compromised or general damage?)
- If a failure did result, could it be identified before the end-application was shipped to the final customer?
- If a failure did result, what would the impact on the final customer be?

4.3.1.2 PCB Mounting

It is recommended that the PCB be mounted using some type of a "direct control" method, like those described in *Section 4.3.1.1*. A method based on the ‘Interface Bracket to PCB’ is the simplest. The details of the bracket designs are very specific to the geometry of the end-application and will not be covered in detail.

Analysis of the 'critical gap' between the PCB and the boss on the optical interface shown in Figure 19 is not needed when a direct control mounting method is used, but such an analysis may help to understand the potential for PCB bending when making a decision on which mounting method to use.

One of the key items to implement the "indirect control" method (if chosen) is to minimize bending of the DMD-PCB. Minimizing the 'critical gap' (shown in Figure 19) between the DMD-PCB and the corresponding boss on the optical chassis will reduce the potential for bending.

This is achieved by minimizing the gap between the DMD-PCB and the corresponding boss on the optical chassis (optical interface). The parts in Figure 17 that contribute to the variation in the ‘critical gap’ are shown in Figure 19 along with a tolerance schematic diagram. The tolerance schematic diagram starts at the top of the mounting screw boss on the optical chassis (in the top left-hand corner of the figure) and continues around to the face of the PCB closest to the optical chassis (in the top right-hand corner of the figure). In the ideal situation the PCB would be infinitely rigid and would not bend due to the force applied by the screw, but this is not the case. The PCB is likely to bend and the largest ‘critical gap’ size determines the maximum amount of bending that can occur.

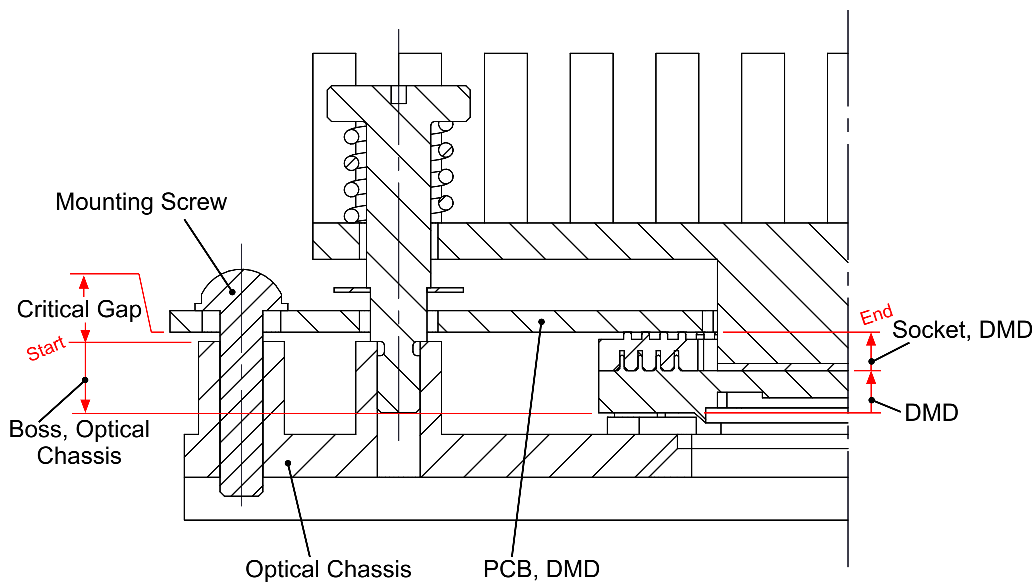

Figure 19. DMD-PCB Gap Analysis Schematic Diagram

Table 3 lists the nominal value and tolerance for each feature that contributes to the size of the 'critical gap'. The nominal values and tolerances used are those on the part drawings for the "Edge Guide" mounting concept shown in Figure 17. The parts are dimensioned in a manor to minimize variations in the “critical gap”. The tolerance analysis indicates the nominal gap size is 0.6500 mm. The simple sum (SUM) method of tolerance analysis (worst-case) yields a tolerance of ±0.5600 mm, which results in a minimum gap of 0.090 mm, and a maximum gap of 1.210 mm. The root sum square (RSS) method of tolerance analysis yields a tolerance of ±0.3347 mm, which results in a minimum gap of 0.315 mm and a maximum gap of 0.985 mm.

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Table 3. Gap between Interface Boss and DMD-PCB

	Nominal (mm)	Dir Sign	Nominal (mm)	Tol (+/-) (mm)	Tol Method	Min Gap	Max Gap
Optical Chassis (Datum 'A' to PCB Boss	5.0000	-1	–5.0000	0.1200			
DMD	2.9500	1	2.9500	0.2400			
Socket, DMD	2.7000	1	2.7000	0.2000			
		Sum	0.6500 (1)	0.5600 0.3347	**Sum** **RSS**	0.090 0.315	1.210 0.985
(1) Positive indicates a gap between interface boss and PCBoard							

The height of the boss on the optical chassis was designed to result in a minimum gap of nearly zero for the worst-case tolerances. A minimum gap greater than zero is needed to ensure the DMD Datum ‘A’ and its corresponding feature on the optical chassis are in contact. If the PCB contacts the boss (on the optical chassis) before the Datum ‘A’ features then focus and focus uniformity could be impacted.

5 System Sockets

The Micro-PGA pins on the Series-600 DMD have the same diameter, length, and spacing as many microprocessor chips. This enables the socket contacts developed for the microprocessor chip sockets to be used for the DMD sockets. The physical arrangement of the contacts on the DMD is different than those for any microprocessor; therefore the holder (or housing) that holds (and retains) the contacts is unique to the DMD sockets. But the contact design and process for manufacturing the sockets are often the same.

Low insertion force (LIF) and zero insertion force (ZIF) style of contacts are typically available that will mate with the pins on the DMD. The insertion force on the DMD is thought to be too large for using a LIF style contact because of the large number of pins on the Series-600 DMD (350 pins).

Mechanical outline control envelope specifications are available for a zero insertion force (ZIF) style socket. The outline specifications define the features, which are necessary for the socket to mechanically interface with a Series-600 DMD. Contact design details are unique and proprietary to each socket manufacture, and are therefore omitted from the outline specification. Multiple contact designs from different manufactures will work with the pins on the DMD. Consult the individual socket manufacture for information related to specific socket performance characteristics.

The purpose of the outline envelope specification is to provide a standard set of criteria for development of sockets by different manufacturers. This enables sockets from different manufacturers to be interchangeable without the need to make any changes to the DMD-PCB, or the mechanical parts used to mount the DMD.

Drawings and 3D-CAD models of the outline envelop specifications are available to DLP® customers and have also been provided to socket manufactures. The 3D-CAD models (in STEP format) and drawings (in pdf format) of the ZIF style sockets are available for download, see *Section 6*.

TI has worked with a socket supplier to develop a ZIF style socket. Other sockets supplier are capable to make a socket as well. TI does not perform socket certification or qualification, nor does TI require socket suppliers to conduct any specific suite of tests during development of the sockets. TI encourages socket suppliers to conduct the existing industry standard tests for these type of sockets (as an indication of the reliability of the socket). The final selection of the socket and supplier is the choice of each DLP Customer. It is the responsibility of each customer to verify that a given socket meets the functional and quality requirements for their end-application.

5.1 Socket Design and Selection Considerations

When designing or selecting a socket to be used with the Series-600 DMD the following factors should be considered:

- Style of Socket – both zero insertion force and low insertion force style contacts have been successfully demonstrated with DMDs. Each style has its own characteristics to be considered. Generally the LIF style have a smaller foot print on the DMD-PCB and the ZIF are easier to assemble.

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- Installed Height - the ‘Installed Height’ shown in Figure 20 represents the distance from the top surface of the DMD-PCB to the “DMD-seating plane" on the socket. The "DMD-seating plane" (shown in Figure 20) is the surface of the socket that will make contact with the DMD. Figure 4 illustrates the "socket-seating plane" on the DMD. The socket installed height is one of the key factors when determining the amount the DMD-PCB could bend if mounted by clamping against bosses on the optical chassis (see the "indirect control" method described in *Section 4.2.3.2* and *Section 4.3.1.2*)

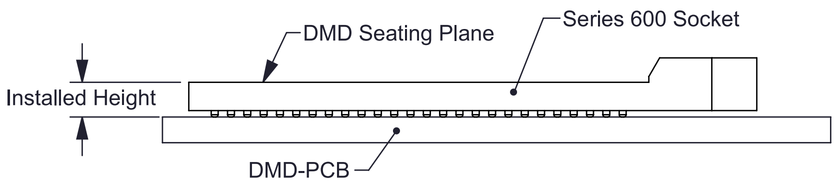

Figure 20. Socket Installed Height

- Overall X-Y Dimensions – The overall socket dimensions influence the foot print size needed on the PCB and ultimately the amount of space required for mounting the DMD. ZIF style sockets typically have larger X-Y dimensions than a LIF style socket. Consequently the DMD mounting hardware must be located further from the DMD than with LIF style sockets.
- Electrical Contact Resistance - The electrical contact resistance between the DMD pin and the socket contact should be minimal. A contact resistance of 30 milliohms is a good reasonable objective and should easily be achieved with contact designs available from socket suppliers.
- Contact Insertion Force – the contact insertion force is the force that must be applied to each socket contact by the DMD pin in order to fully seat the pin into a contact (for example, for the DMD-seating plane to make complete contact with the socket-seating plane). The contact insertion force multiplied by the total number of pins is the resultant forces that must be applied to the DMD in order to fully seat the DMD. The higher the contact insertion force, the more likely that the socket or DMD could become damaged during assembly. As the name implies the ZIF style sockets do not require any insertion force. The total force required to insert the DMD into the socket should not exceed the DMD mechanical loads described in *Section 3.8*.
- Contact extraction force – the contact extraction force is the force required to overcome the retention forces of the contacts during removal of the DMD from the socket. A socket with a high extraction force is susceptible to damage of the contact solder joint (on the PCB pad), the socket contacts, DMD pins, or DMD ceramic carrier if the DMD is not uniformly removed from the socket (all pins removed at the same time). ZIF style sockets have no extraction force.
- When using a non-ZIF style socket (LIF), it is recommended that an extraction tool or aid be designed and used to ease removal of the DMD and reduce the possibility of damage to the socket or DMD. Typically an extraction tool will make contact-with and press against the PCB. Areas on the PCB should be defined and identified as "allowable contact areas". These areas should be kept free of both components and surface traces in order to prevent damage from the extraction tool.
- Coefficient of thermal expansion (CTE) – typically the socket and PCB will be made of distinctly different materials and thus different CTE values. DMD sockets are larger than typical components soldered to a PCB. Because of the physical size and materials used, a “significant” CTE mismatch is possible between the socket and the PCB, which can result in solder joint failures during periods of high temperature cycling. What is considered a “significant” CTE mismatch will depend upon the temperature extremes over which the end-application will operate, but more importantly the solder profile used to attach the socket to the PCB. Strict adherence to the solder profiles recommended by the socket suppliers is recommended. Not using the recommended solder profile can result in higher than expected contact insertion and extraction forces.
- Pick and place features - features that facilitate vacuum pickup, and placement of the socket onto the PCB prior to solder. Some socket suppliers supply a molded cap which is clipped over the contact housing while other suppliers place a piece of kapton (polyimide) tape over the contacts and center opening.

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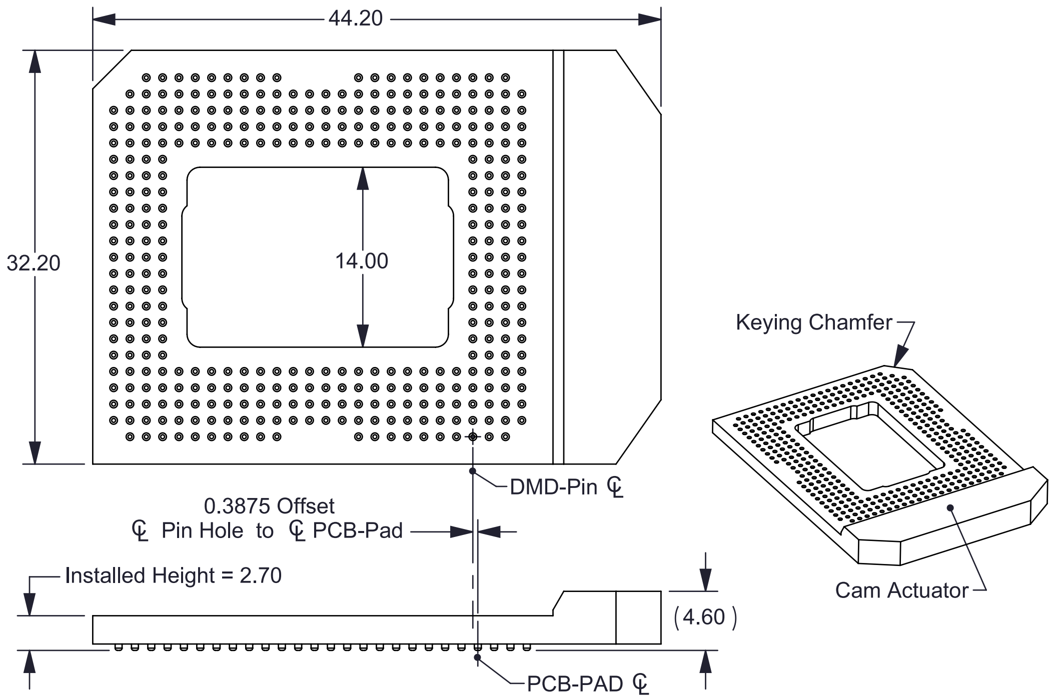
5.2 Series-600 Socket

A zero insertion force (ZIF) style socket has been developed and is available for use with the Series-600 DMDs. The socket is commonly referred to as the Series-600 socket and has 350 contacts.

The key characteristics and considerations of the socket are illustrated in Figure 21 and include:

- Overall dimensions
- Opening to accommodate a heat sink stud used to cool the DMD
- Installed height of 2.700 mm; Important for some methods of mounting the DMD-PCB for control of loads applied to the DMD electrical interface area
- Offset between DMD pin and PCB pad of 0.3875 mm
- No force applied to the DMD when inserting or removing the DMD from the socket
- Tools to aid insertion or extraction of the DMD from the socket are not likely needed

The TI drawing number for the ZIF style socket design is 2511569. A 3D-CAD file of the socket nominal geometry (in STEP format) and drawing (in pdf format) are available for download, see *Section 6*.



Note: DMD-Pin is not concentric with PCB-Pad

Figure 21. Zero Insertion Force Style Series-600 Socket

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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. Table 4 summarizes the literature numbers for the drawings and 3D-CAD models that are available for download from the links in the table.

Table 4. Reference Drawings and 3D-CAD Models

LITERATURE NUMBER	DESCRIPTION
DLPS053	DLP6500FYE DMD (.65 1080 Series-600) Data Sheet
DLPR006	DLP6500FYE DMD (.65 1080 Series-600) 3D-CAD model file with nominal geometry
DLPC091	Assembly and part drawings of Edge Guide Mounting Concept (2511654) – also includes 3D-CAD model files
DLPC092	Series-600 ZIF style socket (2511569) part drawing - also includes 3D-CAD model files

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