



**THE DATASHEET OF
DLP2010FQJ**



DLP2010 .2 WVGA DMD

1 Features

- 0.2-Inch (5.29-mm) diagonal micromirror array
 - Displays 854 × 480 pixel array, in an orthogonal layout
 - 5.4-micron micromirror pitch
 - ±17° micromirror tilt (relative to flat surface)
 - Side illumination for optimal efficiency and optical engine size
 - Polarization-independent aluminum micromirror surface
- 4-Bit SubLVDS input data bus
- Dedicated DLPC3430, DLPC3435, or DLPC3470 display and light controllers and DLPA2000 PMIC and LED driver for reliable operation

2 Applications

- Embedded Displays for Products Including:
 - Tablets, Mobile Phones
 - Artificial Intelligence (AI) Assistants, Smart Speakers
- Control Panels, Security Systems, and Thermostats
- Wearable Displays
- Integrated Display and 3D Depth Capture
- 3D Depth Capture: 3D Camera, 3D Reconstruction, AR/VR, Dental Scanner
- 3D Machine Vision: Robotics, Metrology, In-line Inspection (AOI)
- Light Exposure: 3D Printers, Laser Marking

3 Description

The **DLP2010** digital micromirror device (DMD) is a digitally controlled micro-opto-electromechanical system (MOEMS) spatial light modulator (SLM). When coupled to an appropriate optical system, this DMD is capable of displaying images, video, and patterns. The DLP2010 is part of the chipset that is composed of the DLP2010 DMD, **DLPC3430** or **DLPC3435** or **DLPC3470** controller and **DLPA2000** PMIC and LED driver. The compact physical size of this DMD can be used in portable equipment where small form factor and low power is important. The compact package compliments the small size of the LEDs for space-constrained light engines.

Visit the [getting started with TI DLP®Pico™ display technology](#) page to learn how to get started with the DLP2010.

The ecosystem includes established resources to help the user accelerate the design cycle, which include [production ready optical modules](#), [optical modules manufactures](#), and [design houses](#).

Device Information⁽¹⁾

| PART NUMBER | PACKAGE | BODY SIZE (NOM) |
|-------------|----------|------------------|
| DLP2010 | FQJ (40) | 15.9 mm × 5.3 mm |

(1) For all available packages, see the orderable addendum at the end of the data sheet.

DLP® DLP2010 (0.2 WVGA) Chipset

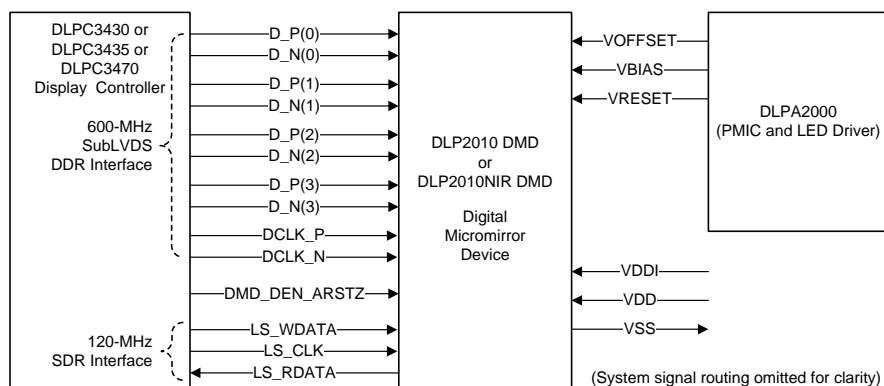


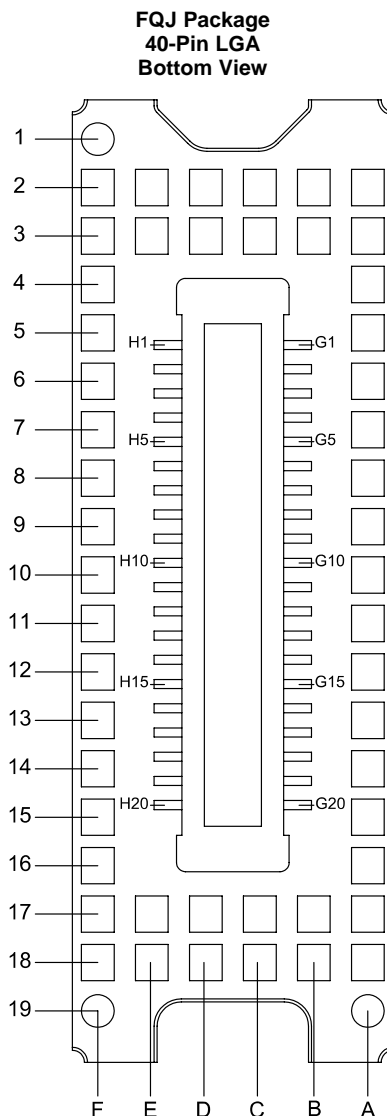
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4 Revision History

| DATE | REVISION | NOTES |
|---------------|----------|------------------|
| February 2019 | * | Initial release. |

5 Pin Configuration and Functions



Pin Functions – Connector Pins⁽¹⁾

| PIN | | TYPE | SIGNAL | DATA RATE | DESCRIPTION | PACKAGE NET LENGTH ⁽²⁾ (mm) |
|--------------------|-----|------|---------|-----------|----------------|--|
| NAME | NO. | | | | | |
| DATA INPUTS | | | | | | |
| D_N(0) | G4 | I | SubLVDS | Double | Data, Negative | 7.03 |
| D_P(0) | G3 | I | SubLVDS | Double | Data, Positive | 7.03 |
| D_N(1) | G8 | I | SubLVDS | Double | Data, Negative | 7.03 |
| D_P(1) | G7 | I | SubLVDS | Double | Data, Positive | 7.03 |
| D_N(2) | H5 | I | SubLVDS | Double | Data, Negative | 7.02 |
| D_P(2) | H6 | I | SubLVDS | Double | Data, Positive | 7.02 |

(1) Low speed interface is LPSDR and adheres to the Electrical Characteristics and AC/DC Operating Conditions table in JEDEC Standard No. 209B, *Low Power Double Data Rate (LPDDR) JESD209B*.

(2) Net trace lengths inside the package:
Relative dielectric constant for the FQJ ceramic package is 9.8.
Propagation speed = $11.8 / \sqrt{9.8} = 3.769$ inches/ns.
Propagation delay = 0.265 ns/inch = 265 ps/inch = 10.43 ps/mm.

Pin Functions – Connector Pins⁽¹⁾ (continued)

| PIN | | TYPE | SIGNAL | DATA RATE | DESCRIPTION | PACKAGE NET LENGTH ⁽²⁾ (mm) |
|------------------------|-----|--------|----------------------|-----------|---|--|
| NAME | NO. | | | | | |
| D_N(3) | H1 | I | SubLVDS | Double | Data, Negative | 7.00 |
| D_P(3) | H2 | I | SubLVDS | Double | Data, Positive | 7.00 |
| DCLK_N | H9 | I | SubLVDS | Double | Clock, Negative | 7.03 |
| DCLK_P | H10 | I | SubLVDS | Double | Clock, Positive | 7.03 |
| CONTROL INPUTS | | | | | | |
| DMD_DEN_ARSTZ | G12 | I | LPSDR ⁽¹⁾ | | Asynchronous reset DMD signal. A low signal places the DMD in reset. A high signal releases the DMD from reset and places it in active mode. | 5.72 |
| LS_CLK | G19 | I | LPSDR | Single | Clock for low-speed interface | 3.54 |
| LS_WDATA | G18 | I | LPSDR | Single | Write data for low-speed interface | 3.54 |
| LS_RDATA | G11 | O | LPSDR | Single | Read data for low-speed interface | 8.11 |
| POWER | | | | | | |
| VBIAS ⁽³⁾ | H17 | Power | | | Supply voltage for positive bias level at micromirrors | |
| VOFFSET ⁽³⁾ | H13 | Power | | | Supply voltage for HVCMOS core logic. Includes: supply voltage for stepped high level at micromirror address electrodes and supply voltage for offset level at micromirrors | |
| VRESET ⁽³⁾ | H18 | Power | | | Supply voltage for negative reset level at micromirrors | |
| VDD ⁽³⁾ | G20 | Power | | | Supply voltage for micromirror low voltage CMOS core logic includes supply voltage for LPSDR inputs and supply voltage for normal high level at micromirror address electrodes. | |
| VDD | H14 | Power | | | | |
| VDD | H15 | Power | | | | |
| VDD | H16 | Power | | | | |
| VDD | H19 | Power | | | | |
| VDD | H20 | Power | | | | |
| VDDI ⁽³⁾ | G1 | Power | | | Supply voltage for SubLVDS receivers | |
| VDDI | G2 | Power | | | | |
| VDDI | G5 | Power | | | | |
| VDDI | G6 | Power | | | | |
| VSS ⁽³⁾ | G9 | Ground | | | Ground. Common return for all power. | |
| VSS | G10 | Ground | | | | |
| VSS | G13 | Ground | | | | |
| VSS | G14 | Ground | | | | |
| VSS | G15 | Ground | | | | |
| VSS | G16 | Ground | | | | |
| VSS | G17 | Ground | | | | |
| VSS | H3 | Ground | | | | |
| VSS | H4 | Ground | | | | |
| VSS | H7 | Ground | | | | |
| VSS | H8 | Ground | | | | |
| VSS | H11 | Ground | | | | |
| VSS | H12 | Ground | | | | |

(3) The following power supplies are all required to operate the DMD: VSS, VDD, VDDI, VOFFSET, VBIAS, VRESET.

Pin Functions – Test Pads

| NUMBER | SYSTEM BOARD | NUMBER | SYSTEM BOARD |
|--------|----------------|--------|----------------|
| A2 | Do not connect | D2 | Do not connect |
| A3 | Do not connect | D3 | Do not connect |
| A4 | Do not connect | D17 | Do not connect |
| A5 | Do not connect | D18 | Do not connect |
| A6 | Do not connect | | |
| A7 | Do not connect | E2 | Do not connect |
| A8 | Do not connect | E3 | Do not connect |
| A9 | Do not connect | E17 | Do not connect |
| A10 | Do not connect | E18 | Do not connect |
| A11 | Do not connect | | |
| A12 | Do not connect | F1 | Do not connect |
| A13 | Do not connect | F2 | Do not connect |
| A14 | Do not connect | F3 | Do not connect |
| A15 | Do not connect | F4 | Do not connect |
| A16 | Do not connect | F5 | Do not connect |
| A17 | Do not connect | F6 | Do not connect |
| A18 | Do not connect | F7 | Do not connect |
| A19 | Do not connect | F8 | Do not connect |
| | | F9 | Do not connect |
| B2 | Do not connect | F10 | Do not connect |
| B3 | Do not connect | F11 | Do not connect |
| B17 | Do not connect | F12 | Do not connect |
| B18 | Do not connect | F13 | Do not connect |
| | | F14 | Do not connect |
| C2 | Do not connect | F15 | Do not connect |
| C3 | Do not connect | F16 | Do not connect |
| C17 | Do not connect | F17 | Do not connect |
| C18 | Do not connect | F18 | Do not connect |
| | | F19 | Do not connect |

6 Specifications

6.1 Absolute Maximum Ratings⁽¹⁾

| | | | MIN | MAX | UBIT |
|-----------------|--|--|---|------------|------|
| Supply voltage | VDD | for LVCMOS core logic ⁽²⁾ Supply voltage for LPSDR low speed interface | -0.5 | 2.3 | V |
| | VDDI | for SubLVDS receivers ⁽²⁾ | -0.5 | 2.3 | |
| | VOFFSET | for HVCMOS and micromirror electrode ⁽²⁾⁽³⁾ | -0.5 | 10.6 | |
| | VBIAS | for micromirror electrode ⁽²⁾ | -0.5 | 19 | |
| | VRESET | for micromirror electrode ⁽²⁾ | -15 | 0.5 | |
| | VDDI-VDD | delta (absolute value) ⁽⁴⁾ | | 0.3 | |
| | VBIAS-VOFFSET | delta (absolute value) ⁽⁵⁾ | | 11 | |
| | VBIAS-VRESET | delta (absolute value) ⁽⁶⁾ | | 34 | |
| Input voltage | for other inputs LPSDR ⁽²⁾ | | -0.5 | VDD + 0.5 | V |
| | for other inputs SubLVDS ⁽²⁾⁽⁷⁾ | | -0.5 | VDDI + 0.5 | |
| Input pins | VID | SubLVDS input differential voltage (absolute value) ⁽⁷⁾ | | 810 | mV |
| | IID | SubLVDS input differential current | | 8.1 | mA |
| Clock frequency | f_{clock} | Clock frequency for low speed interface LS_CLK | | 130 | MHz |
| | f_{clock} | Clock frequency for high speed interface DCLK | | 620 | |
| Environmental | T _{ARRAY} and T _{WINDOW} | | Temperature – operational ⁽⁸⁾ | | °C |
| | | | Temperature – non-operational ⁽⁸⁾ | | |
| | T _{DP} | | Dew Point Temperature - operating and non-operating (non-condensing) | | |
| | T _{DELTA} | | Absolute Temperature delta between any point on the window edge and the ceramic test point TP1 ⁽⁹⁾ | | |

- Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, and functional operation of the device is not implied at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure above or below the *Recommended Operating Conditions* for extended periods may affect device reliability.
- All voltage values are with respect to the ground terminals (VSS). The following power supplies are all required to operate the DMD: VSS, VDD, VDDI, VOFFSET, VBIAS, and VRESET.
- VOFFSET supply transients must fall within specified voltages.
- Exceeding the recommended allowable absolute voltage difference between VDDI and VDD may result in excessive current draw.
- Exceeding the recommended allowable absolute voltage difference between VBIAS and VOFFSET may result in excessive current draw.
- Exceeding the recommended allowable absolute voltage difference between VBIAS and VRESET may result in excessive current draw.
- This maximum input voltage rating applies when each input of a differential pair is at the same voltage potential. Sub-LVDS differential inputs must not exceed the specified limit or damage may result to the internal termination resistors.
- The highest temperature of the active array (as calculated by the *Micromirror Array Temperature Calculation*), or of any point along the Window Edge as defined in *Figure 18*. The locations of thermal test points TP2 and TP3 in *Figure 18* are intended to measure the highest window edge temperature. If a particular application causes another point on the window edge to be at a higher temperature, that point should be used.
- Temperature delta is the highest difference between the ceramic test point 1 (TP1) and anywhere on the window edge as shown in *Figure 18*. The window test points TP2 and TP3 shown in *Figure 18* are intended to result in the worst case delta. If a particular application causes another point on the window edge to result in a larger delta temperature, that point should be used.

6.2 Storage Conditions

applicable for the DMD as a component or non-operational in a system

| | | | MIN | MAX | UNIT |
|---------------------|---|--|-----|-----|--------|
| T _{DMD} | DMD storage temperature | | -40 | 85 | °C |
| T _{DP-AVG} | Average dew point temperature, (non-condensing) ⁽¹⁾ | | | 24 | °C |
| T _{DP-ELR} | Elevated dew point temperature range, (non-condensing) ⁽²⁾ | | 28 | 36 | °C |
| CT _{ELR} | Cumulative time in elevated dew point temperature range | | | 6 | Months |

- The average over time (including storage and operating) that the device is not in the elevated dew point temperature range.
- Exposure to dew point temperatures in the elevated range during storage and operation should be limited to less than a total cumulative time of CT_{ELR}.

6.3 ESD Ratings

| | | VALUE | UNIT |
|-------------|-------------------------|---|------------|
| $V_{(ESD)}$ | Electrostatic discharge | Human body model (HBM), per ANSI/ESDA/JEDEC JS-001 ⁽¹⁾ | ±2000 V |

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

6.4 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)⁽¹⁾⁽²⁾⁽³⁾

| | | MIN | NOM | MAX | UNIT |
|---|---|-------|-----|-------|------|
| SUPPLY VOLTAGE RANGE⁽⁴⁾ | | | | | |
| VDD | Supply voltage for LVCMOS core logic Supply voltage for LPSDR low-speed interface | 1.65 | 1.8 | 1.95 | V |
| VDDI | Supply voltage for SubLVDS receivers | 1.65 | 1.8 | 1.95 | V |
| VOFFSET | Supply voltage for HVCMOS and micromirror electrode ⁽⁵⁾ | 9.5 | 10 | 10.5 | V |
| VBIAS | Supply voltage for mirror electrode | 17.5 | 18 | 18.5 | V |
| VRESET | Supply voltage for micromirror electrode | −14.5 | −14 | −13.5 | V |
| VDDI−VDD | Supply voltage delta (absolute value) ⁽⁶⁾ | | | 0.3 | V |
| VBIAS−VOFFSET | Supply voltage delta (absolute value) ⁽⁷⁾ | | | 10.5 | V |
| VBIAS−VRESET | Supply voltage delta (absolute value) ⁽⁸⁾ | | | 33 | V |
| CLOCK FREQUENCY | | | | | |
| f_{clock} | Clock frequency for low speed interface LS_CLK ⁽⁹⁾ | 108 | | 120 | MHz |
| f_{clock} | Clock frequency for high speed interface DCLK ⁽¹⁰⁾ | 300 | | 600 | MHz |
| | Duty cycle distortion DCLK | 44% | | 56% | |
| SUBLVDS INTERFACE⁽¹⁰⁾ | | | | | |
| V _{ID} | SubLVDS input differential voltage (absolute value) Figure 8 , Figure 9 | 150 | 250 | 350 | mV |
| V _{CM} | Common mode voltage Figure 8 , Figure 9 | 700 | 900 | 1100 | mV |
| V _{SUBLVDS} | SubLVDS voltage Figure 8 , Figure 9 | 575 | | 1225 | mV |
| Z _{LINE} | Line differential impedance (PWB/trace) | 90 | 100 | 110 | Ω |
| Z _{IN} | Internal differential termination resistance Figure 10 | 80 | 100 | 120 | Ω |
| | 100-Ω differential PCB trace | 6.35 | | 152.4 | mm |

- (1) [Recommended Operating Conditions](#) are applicable after the DMD is installed in the final product.
- (2) The functional performance of the device specified in this datasheet is achieved when operating the device within the limits defined by the [Recommended Operating Conditions](#). No level of performance is implied when operating the device above or below the [Recommended Operating Conditions](#) limits.
- (3) The following power supplies are all required to operate the DMD: VSS, VDD, VDDI, VOFFSET, VBIAS, and VRESET.
- (4) All voltage values are with respect to the ground pins (VSS).
- (5) VOFFSET supply transients must fall within specified maximum voltages.
- (6) To prevent excess current, the supply voltage delta |VDDI − VDD| must be less than specified limit.
- (7) To prevent excess current, the supply voltage delta |VBIAS − VOFFSET| must be less than specified limit.
- (8) To prevent excess current, the supply voltage delta |VBIAS − VRESET| must be less than specified limit.
- (9) LS_CLK must run as specified to ensure internal DMD timing for reset waveform commands.
- (10) Refer to the SubLVDS timing requirements in [Timing Requirements](#).

Recommended Operating Conditions (continued)

over operating free-air temperature range (unless otherwise noted)⁽¹⁾⁽²⁾⁽³⁾

| | | MIN | NOM | MAX | UNIT |
|----------------------|---|-------------------|-----|--------------------------|--------------------|
| ENVIRONMENTAL | | | | | |
| T _{ARRAY} | Array Temperature – long-term operational ⁽¹¹⁾⁽¹²⁾⁽¹³⁾⁽¹⁴⁾ | 0 | | 40 to 70 ⁽¹³⁾ | °C |
| | Array Temperature - short-term operational, 25 hr max ⁽¹²⁾⁽¹⁵⁾ | -20 | | -10 | |
| | Array Temperature - short-term operational, 500 hr max ⁽¹²⁾⁽¹⁵⁾ | -10 | | 0 | |
| | Array Temperature – short-term operational, 500 hr max ⁽¹²⁾⁽¹⁵⁾ | 70 | | 75 | |
| T _{DELTA} | Absolute Temperature difference between any point on the window edge and the ceramic test point TP1 ⁽¹⁶⁾ | | | 30 | °C |
| T _{WINDOW} | Window temperature – operational ⁽¹¹⁾⁽¹⁷⁾ | | | 90 | °C |
| T _{DP-AVG} | Average dew point temperature (non-condensing) ⁽¹⁸⁾ | | | 24 | °C |
| T _{DP-ELR} | Elevated dew point temperature range (non-condensing) ⁽¹⁹⁾ | 28 | | 36 | °C |
| CT _{ELR} | Cumulative time in elevated dew point temperature range | | | 6 | Months |
| ILL _{UV} | Illumination wavelengths < 420 nm ⁽¹¹⁾ | | | 0.68 | mW/cm ² |
| ILL _{VIS} | Illumination wavelengths between 420 nm and 700 nm | Thermally limited | | | |
| ILL _{IR} | Illumination wavelengths > 700 nm | | | 10 | mW/cm ² |
| ILL _θ | Illumination marginal ray angle ⁽²⁰⁾ | | | 55 | deg |

- (11) Simultaneous exposure of the DMD to the maximum *Recommended Operating Conditions* for temperature and UV illumination will reduce device lifetime.
- (12) The array temperature cannot be measured directly and must be computed analytically from the temperature measured at test point 1 (TP1) shown in [Figure 18](#) and the Package Thermal Resistance using *Micromirror Array Temperature Calculation*.
- (13) Per [Figure 1](#), the maximum operational array temperature should be derated based on the micromirror landed duty cycle that the DMD experiences in the end application. Refer to *Micromirror Landed-On/Landed-Off Duty Cycle* for a definition of micromirror landed duty cycle.
- (14) Long-term is defined as the usable life of the device
- (15) Short-term is the total cumulative time over the useful life of the device.
- (16) Temperature delta is the highest difference between the ceramic test point 1 (TP1) and anywhere on the window edge shown in [Figure 18](#). The window test points TP2 and TP3 shown in [Figure 18](#) are intended to result in the worst case delta temperature. If a particular application causes another point on the window edge to result in a larger delta temperature, that point should be used.
- (17) Window temperature is the highest temperature on the window edge shown in [Figure 18](#). The locations of thermal test points TP2 and TP3 in [Figure 18](#) are intended to measure the highest window edge temperature. If a particular application causes another point on the window edge to result in a larger delta temperature, that point should be used.
- (18) The average over time (including storage and operating) that the device is not in the elevated dew point temperature range.
- (19) Exposure to dew point temperatures in the elevated range during storage and operation should be limited to less than a total cumulative time of CT_{ELR}.
- (20) The maximum marginal ray angle of the incoming illumination light at any point in the micromirror array, including Pond of Micromirrors (POM), should not exceed 55 degrees from the normal to the device array plane. The device window aperture has not necessarily been designed to allow incoming light at higher maximum angles to pass to the micromirrors, and the device performance has not been tested nor qualified at angles exceeding this. Illumination light exceeding this angle outside the micromirror array (including POM) will contribute to thermal limitations described in this document, and may negatively affect lifetime.

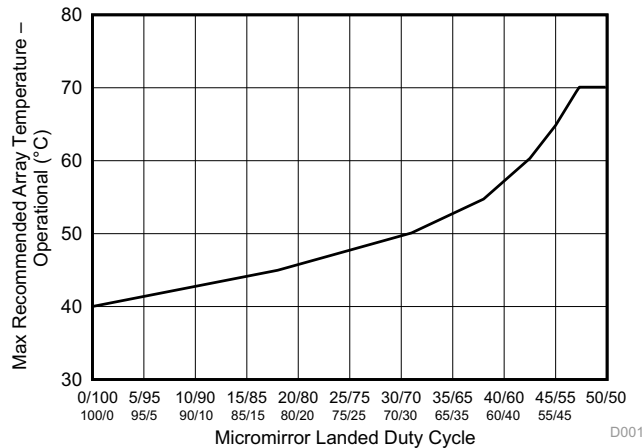


Figure 1. Maximum Recommended Array Temperature – Derating Curve

6.5 Thermal Information

| THERMAL METRIC ⁽¹⁾ | DLP2010 | UNIT |
|---|-------------|------|
| | FQJ Package | |
| | 40 PINS | |
| Thermal resistance Active area to test point 1 (TP1) ⁽¹⁾ | 7.9 | °C/W |

(1) The DMD is designed to conduct absorbed and dissipated heat to the back of the package. The cooling system must be capable of maintaining the package within the temperature range specified in the [Recommended Operating Conditions](#). The total heat load on the DMD is largely driven by the incident light absorbed by the active area; although other contributions include light energy absorbed by the window aperture and electrical power dissipation of the array. Optical systems should be designed to minimize the light energy falling outside the window clear aperture since any additional thermal load in this area can significantly degrade the reliability of the device.

6.6 Electrical Characteristics

Over operating free-air temperature range (unless otherwise noted)⁽¹⁾

| PARAMETER | TEST CONDITIONS ⁽²⁾ | MIN | TYP | MAX | UNIT |
|---|--------------------------------|-----|------|------|------|
| CURRENT | | | | | |
| I _{DD} Supply current: VDD ⁽³⁾⁽⁴⁾ | VDD = 1.95 V | | | 34.7 | mA |
| | VDD = 1.8 V | | 27.5 | | |
| I _{DDI} Supply current: VDDI ⁽³⁾⁽⁴⁾ | VDDI = 1.95 V | | | 9.4 | mA |
| | VDD = 1.8 V | | 6.6 | | |
| I _{OFFSET} Supply current: VOFFSET ⁽⁵⁾⁽⁶⁾ | VOFFSET = 10.5 V | | | 1.7 | mA |
| | VOFFSET = 10 V | | 0.9 | | |
| I _{BIAS} Supply current: VBIAS ⁽⁵⁾⁽⁶⁾ | VBIAS = 18.5 V | | | 0.4 | mA |
| | VBIAS = 18 V | | 0.2 | | |
| I _{RESET} Supply current: VRESET ⁽⁶⁾ | VRESET = -14.5 V | | | 2 | mA |
| | VRESET = -14 V | | 1.2 | | |
| POWER⁽⁷⁾ | | | | | |
| P _{DD} Supply power dissipation: VDD ⁽³⁾⁽⁴⁾ | VDD = 1.95 V | | | 67.7 | mW |
| | VDD = 1.8 V | | 49.5 | | |

- (1) Device electrical characteristics are over [Recommended Operating Conditions](#) unless otherwise noted.
- (2) All voltage values are with respect to the ground pins (VSS).
- (3) To prevent excess current, the supply voltage delta |VDDI – VDD| must be less than specified limit.
- (4) Supply power dissipation based on non-compressed commands and data.
- (5) To prevent excess current, the supply voltage delta |VBIAS – VOFFSET| must be less than specified limit.
- (6) Supply power dissipation based on 3 global resets in 200 μs.
- (7) The following power supplies are all required to operate the DMD: VSS, VDD, VDDI, VOFFSET, VBIAS, VRESET.

Electrical Characteristics (continued)

Over operating free-air temperature range (unless otherwise noted)⁽¹⁾

| PARAMETER | | TEST CONDITIONS ⁽²⁾ | MIN | TYP | MAX | UNIT |
|------------------------------------|---|---------------------------------------|-----------|------|-----------|------|
| P _{DDI} | Supply power dissipation: VDDI ⁽³⁾⁽⁴⁾ | VDDI = 1.95 V | | | 18.3 | mW |
| | | VDD = 1.8 V | | 11.9 | | |
| P _{OFFSET} | Supply power dissipation: VOFFSET ⁽⁵⁾⁽⁶⁾ | VOFFSET = 10.5 V | | | 17.9 | mW |
| | | VOFFSET = 10 V | | 9 | | |
| P _{BIAS} | Supply power dissipation: VBIAS ⁽⁵⁾⁽⁶⁾ | VBIAS = 18.5 V | | | 7.4 | mW |
| | | VBIAS = 18 V | | 3.6 | | |
| P _{RESET} | Supply power dissipation: VRESET ⁽⁶⁾ | VRESET = -14.5 V | | | 29 | mW |
| | | VRESET = -14 V | | 16.8 | | |
| P _{TOTAL} | Supply power dissipation: Total | | | 90.8 | 140.3 | mW |
| LPSDR INPUT⁽⁸⁾ | | | | | | |
| V _{IH(DC)} | DC input high voltage ⁽⁹⁾ | | 0.7 × VDD | | VDD + 0.3 | V |
| V _{IL(DC)} | DC input low voltage ⁽⁹⁾ | | -0.3 | | 0.3 × VDD | V |
| V _{IH(AC)} | AC input high voltage ⁽⁹⁾ | | 0.8 × VDD | | VDD + 0.3 | V |
| V _{IL(AC)} | AC input low voltage ⁽⁹⁾ | | -0.3 | | 0.2 × VDD | V |
| ΔV _T | Hysteresis (V _{T+} - V _{T-}) | Figure 10 | 0.1 × VDD | | 0.4 × VDD | V |
| I _{IL} | Low-level input current | VDD = 1.95 V; V _I = 0 V | -100 | | | nA |
| I _{IH} | High-level input current | VDD = 1.95 V; V _I = 1.95 V | | | 100 | nA |
| LPSDR OUTPUT⁽¹⁰⁾ | | | | | | |
| V _{OH} | DC output high voltage | I _{OH} = -2 mA | 0.8 × VDD | | | V |
| V _{OL} | DC output low voltage | I _{OL} = 2 mA | | | 0.2 × VDD | V |
| CAPACITANCE | | | | | | |
| C _{IN} | Input capacitance LPSDR | f = 1 MHz | | | 10 | pF |
| | Input capacitance SubLVDS | f = 1 MHz | | | 20 | |
| C _{OUT} | Output capacitance | f = 1 MHz | | | 10 | pF |
| C _{RESET} | Reset group capacitance | f = 1 MHz; (480 × 108) micromirrors | 95 | | 113 | pF |

(8) LPSDR specifications are for pins LS_CLK and LS_WDATA.

(9) Low-speed interface is LPSDR and adheres to the Electrical Characteristics and AC/DC Operating Conditions table in JEDEC Standard No. 209B, *Low-Power Double Data Rate (LPDDR)* [JESD209B](#).

(10) LPSDR specification is for pin LS_RDATA.

6.7 Timing Requirements

Device electrical characteristics are over *Recommended Operating Conditions* unless otherwise noted.

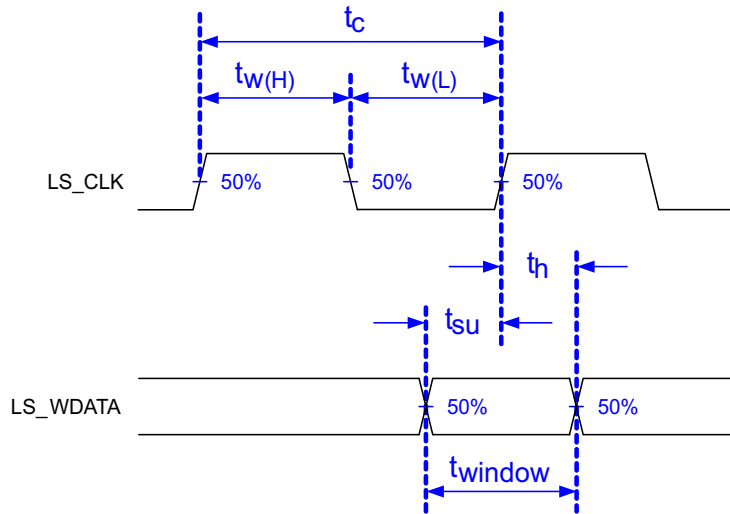
| | | | MIN | NOM | MAX | UNIT |
|--------------------------|--|--|------|------|------|------|
| LPSDR | | | | | | |
| t_R | Rise slew rate ⁽¹⁾ | (30% to 80%) × VDD, Figure 3 | 1 | | 3 | V/ns |
| t_V | Fall slew rate ⁽¹⁾ | (70% to 20%) × VDD, Figure 3 | 1 | | 3 | V/ns |
| t_R | Rise slew rate ⁽²⁾ | (20% to 80%) × VDD, Figure 3 | 0.25 | | | V/ns |
| t_F | Fall slew rate ⁽²⁾ | (80% to 20%) × VDD, Figure 3 | 0.25 | | | V/ns |
| t_C | Cycle time LS_CLK, | Figure 2 | 7.7 | 8.3 | | ns |
| $t_{W(H)}$ | Pulse duration LS_CLK high | 50% to 50% reference points, Figure 2 | 3.1 | | | ns |
| $t_{W(L)}$ | Pulse duration LS_CLK low | 50% to 50% reference points, Figure 2 | 3.1 | | | ns |
| t_{SU} | Setup time | LS_WDATA valid before LS_CLK ↑, Figure 2 | 1.5 | | | ns |
| t_H | Hold time | LS_WDATA valid after LS_CLK ↑, Figure 2 | 1.5 | | | ns |
| t_{WINDOW} | Window time ⁽¹⁾⁽³⁾ | Setup time + Hold time, Figure 2 | 3.0 | | | ns |
| $t_{DERATING}$ | Window time derating ⁽¹⁾⁽³⁾ | For each 0.25 V/ns reduction in slew rate below 1 V/ns, Figure 5 | | 0.35 | | ns |
| SubLVDS | | | | | | |
| t_R | Rise slew rate | 20% to 80% reference points, Figure 4 | 0.7 | 1 | | V/ns |
| t_F | Fall slew rate | 80% to 20% reference points, Figure 4 | 0.7 | 1 | | V/ns |
| t_C | Cycle time LS_CLK, | Figure 6 | 1.61 | 1.67 | | ns |
| $t_{W(H)}$ | Pulse duration DCLK high | 50% to 50% reference points, Figure 6 | 0.71 | | | ns |
| $t_{W(L)}$ | Pulse duration DCLK low | 50% to 50% reference points, Figure 6 | 0.71 | | | ns |
| t_{SU} | Setup time | D(0:3) valid before DCLK ↑ or DCLK ↓, Figure 6 | | | | |
| t_H | Hold time | D(0:3) valid after DCLK ↑ or DCLK ↓, Figure 6 | | | | |
| t_{WINDOW} | Window time | Setup time + Hold time, Figure 6 , Figure 7 | 3.0 | | | ns |
| $t_{LVDS-ENABLE+REFGEN}$ | Power-up receiver ⁽⁴⁾ | | | | 2000 | ns |

(1) Specification is for LS_CLK and LS_WDATA pins. Refer to LPSDR input rise slew rate and fall slew rate in [Figure 3](#).

(2) Specification is for DMD_DEN_ARSTZ pin. Refer to LPSDR input rise and fall slew rate in [Figure 3](#).

(3) Window time derating example: 0.5-V/ns slew rate increases the window time by 0.7 ns, from 3 to 3.7 ns.

(4) Specification is for SubLVDS receiver time only and does not take into account commanding and latency after commanding.



- A. Low-speed interface is LPSDR and adheres to the *Electrical Characteristics* and AC/DC Operating Conditions table in JEDEC Standard No. 209B, *Low Power Double Data Rate (LPDDR) JESD209B*.

Figure 2. LPSDR Switching Parameters

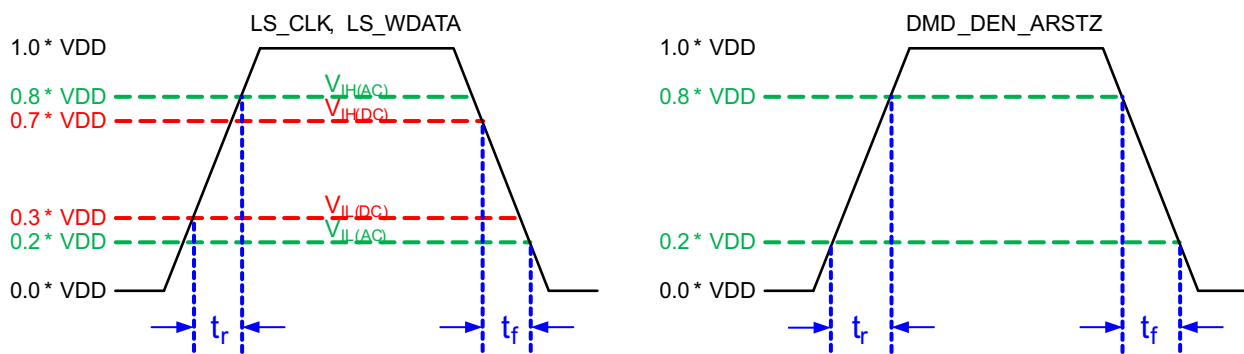


Figure 3. LPSDR Input Rise and Fall Slew Rate

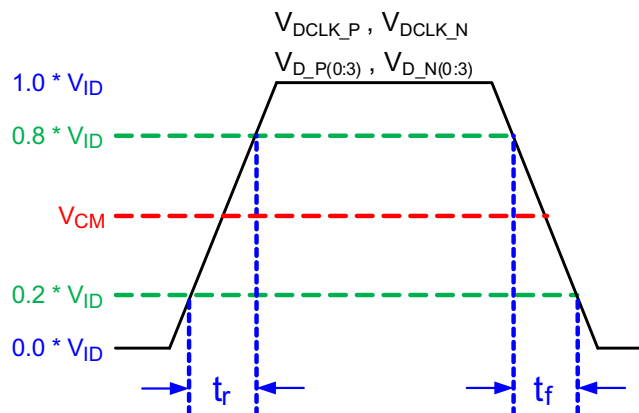


Figure 4. SubLVDS Input Rise and Fall Slew Rate

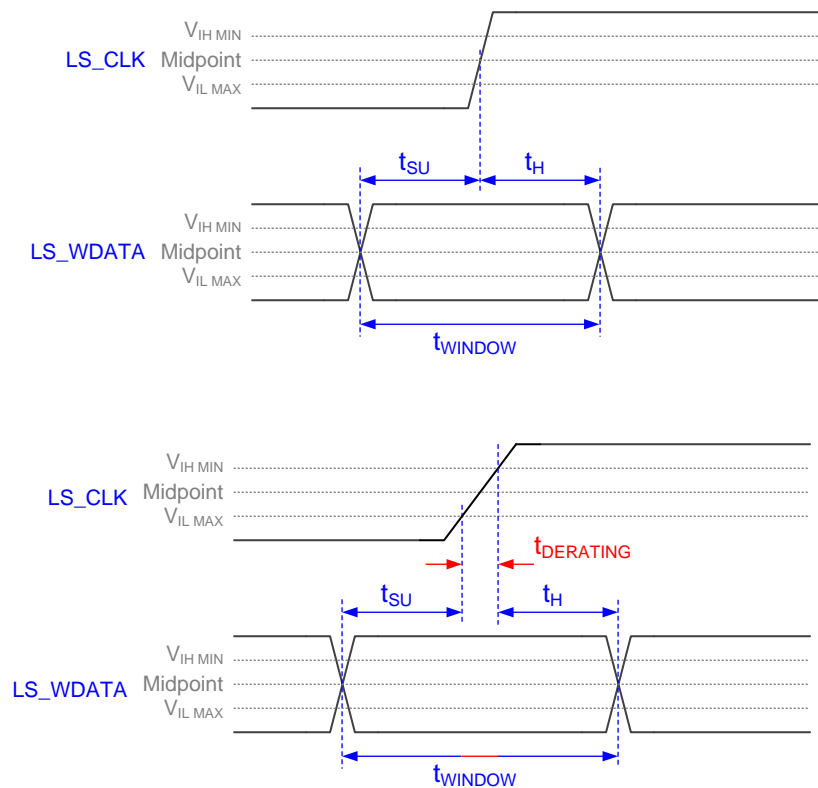


Figure 5. Window Time Derating Concept

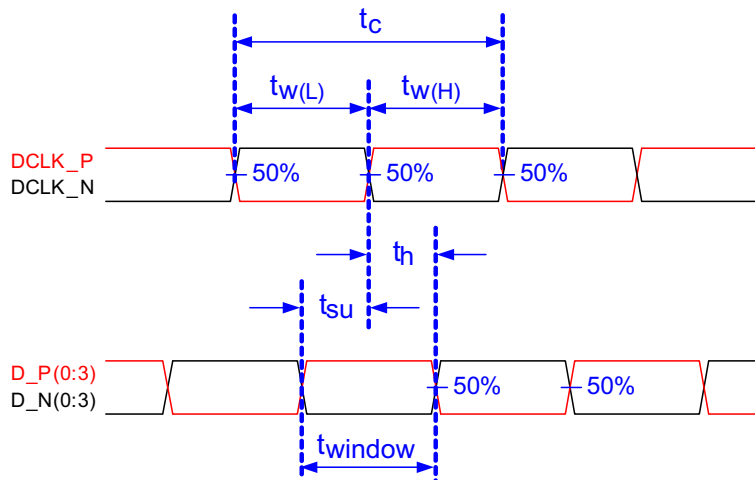
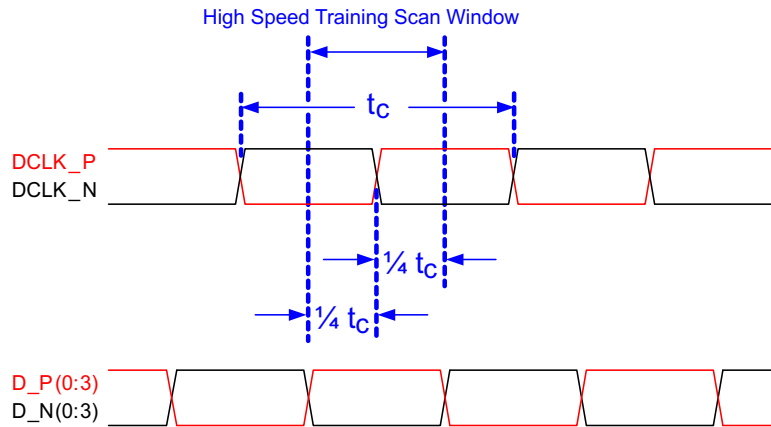


Figure 6. SubLVDS Switching Parameters



Note: Refer to *High-Speed Interface* for details.

Figure 7. High-Speed Training Scan Window

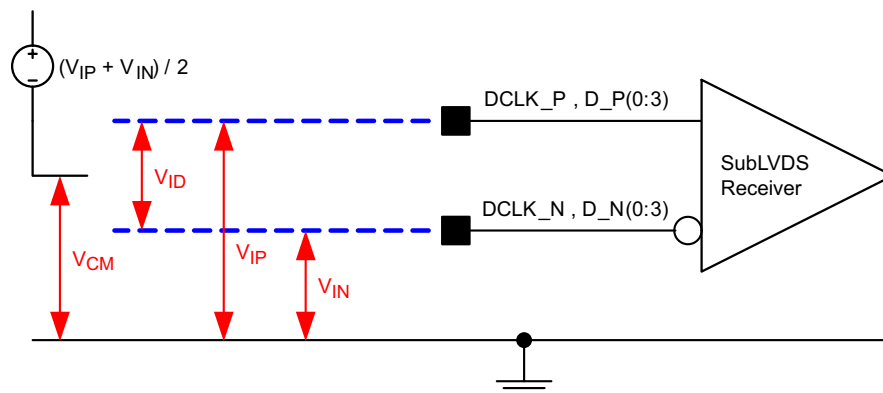


Figure 8. SubLVDS Voltage Parameters

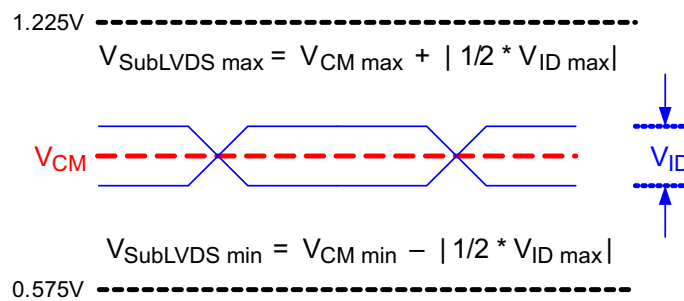


Figure 9. SubLVDS Waveform Parameters

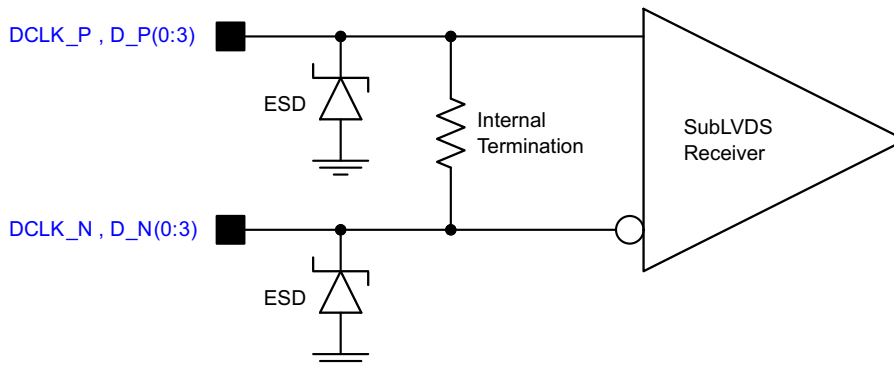


Figure 10. SubLVDS Equivalent Input Circuit

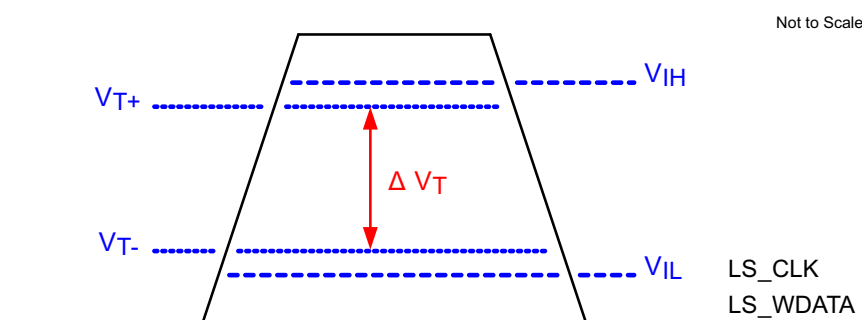


Figure 11. LPSDR Input Hysteresis

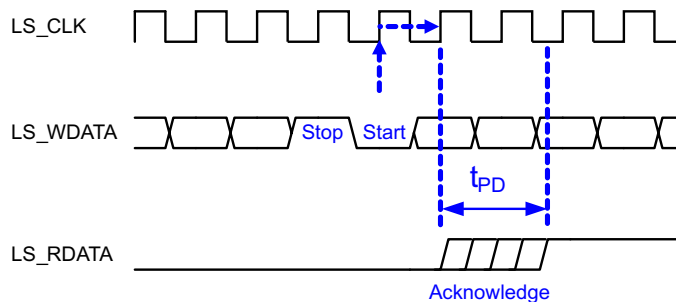
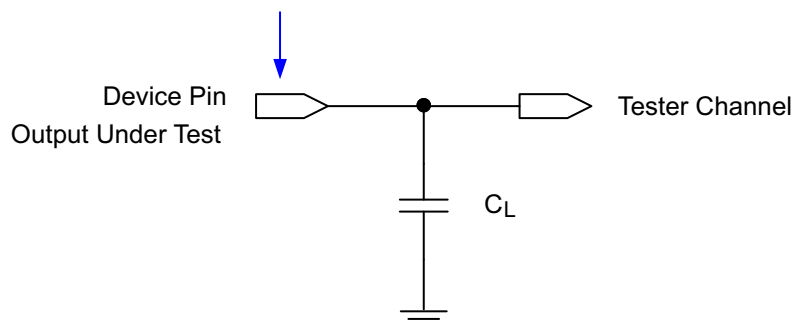


Figure 12. LPSDR Read Out

Data Sheet Timing Reference Point



A. See [Timing](#) for more information.

Figure 13. Test Load Circuit for Output Propagation Measurement

6.8 Switching Characteristics⁽¹⁾

Over operating free-air temperature range (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|-----------------------|-----|-----|-----|------|
| t_{PD} Output propagation, Clock to Q, rising edge of LS_CLK input to LS_RDATA output. Figure 12 | $C_L = 45 \text{ pF}$ | | | 15 | ns |
| Slew rate, LS_RDATA | | 0.5 | | | V/ns |
| Output duty cycle distortion, LS_RDATA | | 40% | | 60% | |

(1) Device electrical characteristics are over *Recommended Operating Conditions* unless otherwise noted.

6.9 System Mounting Interface Loads

| PARAMETER | MIN | NOM | MAX | UNIT |
|---|-----|-----|-----|------|
| Maximum system mounting interface load to be applied to the: | | | | |
| Connector area (see Figure 14) | | | 45 | N |
| DMD mounting area uniformly distributed over 4 areas (see Figure 14) | | | 100 | N |

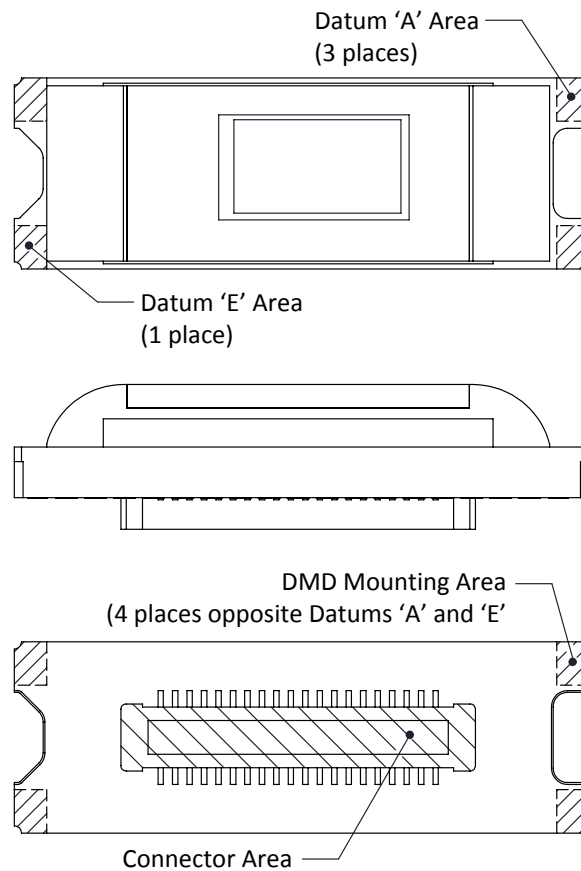


Figure 14. System Interface Loads

6.10 Physical Characteristics of the Micromirror Array

| PARAMETER | | VALUE | UNIT |
|--------------------------------------|--|--------|-------------------|
| Number of active columns | See Figure 15 | 854 | micromirrors |
| Number of active rows | See Figure 15 | 480 | micromirrors |
| ϵ Micromirror (pixel) pitch | See Figure 16 | 5.4 | μm |
| Micromirror active array width | Micromirror pitch \times number of active columns; see Figure 15 | 4.6116 | mm |
| Micromirror active array height | Micromirror pitch \times number of active rows; see Figure 15 | 2.592 | mm |
| Micromirror active border | Pond of micromirror (POM) ⁽¹⁾ | 20 | micromirrors/side |

(1) The structure and qualities of the border around the active array includes a band of partially functional micromirrors called the POM. These micromirrors are structurally and/or electrically prevented from tilting toward the bright or ON state, but still require an electrical bias to tilt toward OFF.

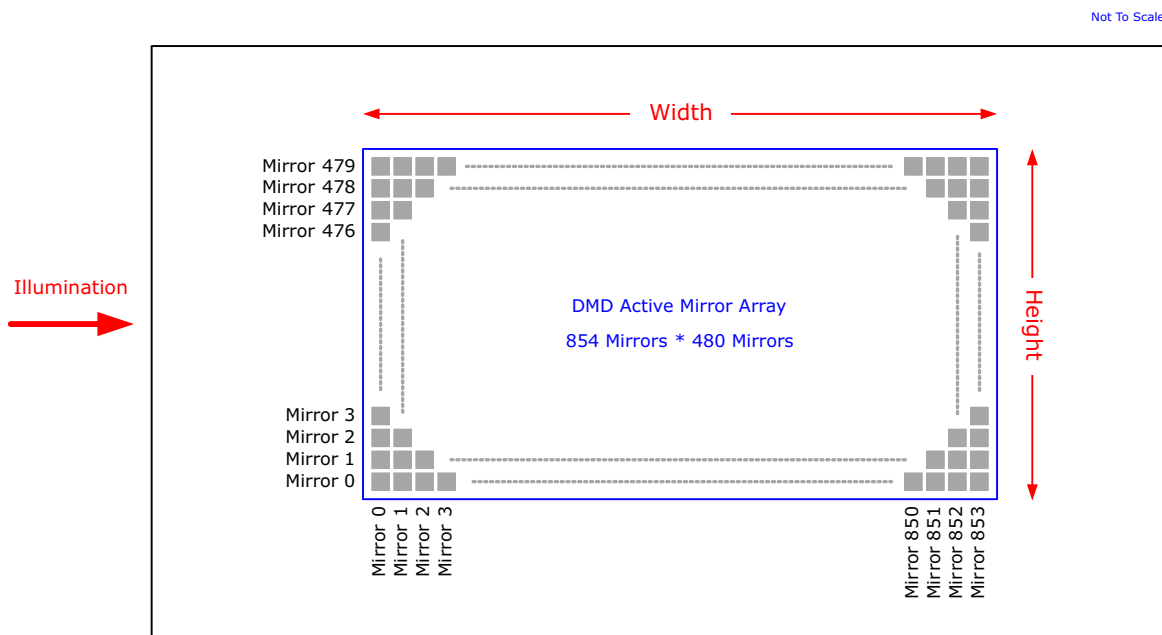


Figure 15. Micromirror Array Physical Characteristics

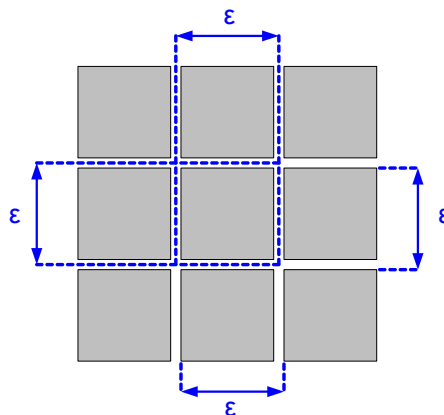


Figure 16. Mirror (Pixel) Pitch

6.11 Micromirror Array Optical Characteristics

| PARAMETER | TEST CONDITIONS | MIN | NOM | MAX | UNIT |
|---|---------------------------------|------|-----|-----|--------------|
| Micromirror tilt angle | DMD landed state ⁽¹⁾ | | 17 | | degrees |
| Micromirror tilt angle tolerance ⁽²⁾⁽³⁾⁽⁴⁾⁽⁵⁾ | | -1.4 | | 1.4 | degrees |
| Micromirror tilt direction ⁽⁶⁾⁽⁷⁾ | Landed ON state | | 180 | | degrees |
| | Landed OFF state | | 270 | | |
| Micromirror crossover time ⁽⁸⁾ | Typical Performance | | 1 | 3 | μs |
| Micromirror switching time ⁽⁹⁾ | Typical Performance | 10 | | | |
| Number of out-of-specification micromirrors ⁽¹⁰⁾ | Adjacent micromirrors | | | 0 | micromirrors |
| | Non-adjacent micromirrors | | | 10 | |

- (1) Measured relative to the plane formed by the overall micromirror array.
- (2) Additional variation exists between the micromirror array and the package datums.
- (3) Represents the landed tilt angle variation relative to the nominal landed tilt angle.
- (4) Represents the variation that can occur between any two individual micromirrors, located on the same device or located on different devices.
- (5) For some applications, it is critical to account for the micromirror tilt angle variation in the overall system optical design. With some system optical designs, the micromirror tilt angle variation within a device may result in perceivable non-uniformities in the light field reflected from the micromirror array. With some system optical designs, the micromirror tilt angle variation between devices may result in colorimetry variations, system efficiency variations or system contrast variations.
- (6) When the micromirror array is landed (not parked), the tilt direction of each individual micromirror is dictated by the binary contents of the CMOS memory cell associated with each individual micromirror. A binary value of 1 results in a micromirror landing in the ON state direction. A binary value of 0 results in a micromirror landing in the OFF state direction.
- (7) Micromirror tilt direction is measured as in a typical polar coordinate system: Measuring counter-clockwise from a 0° reference which is aligned with the +X Cartesian axis.
- (8) The time required for a micromirror to nominally transition from one landed state to the opposite landed state.
- (9) The minimum time between successive transitions of a micromirror.
- (10) An out-of-specification micromirror is defined as a micromirror that is unable to transition between the two landed states within the specified Micromirror Switching Time.

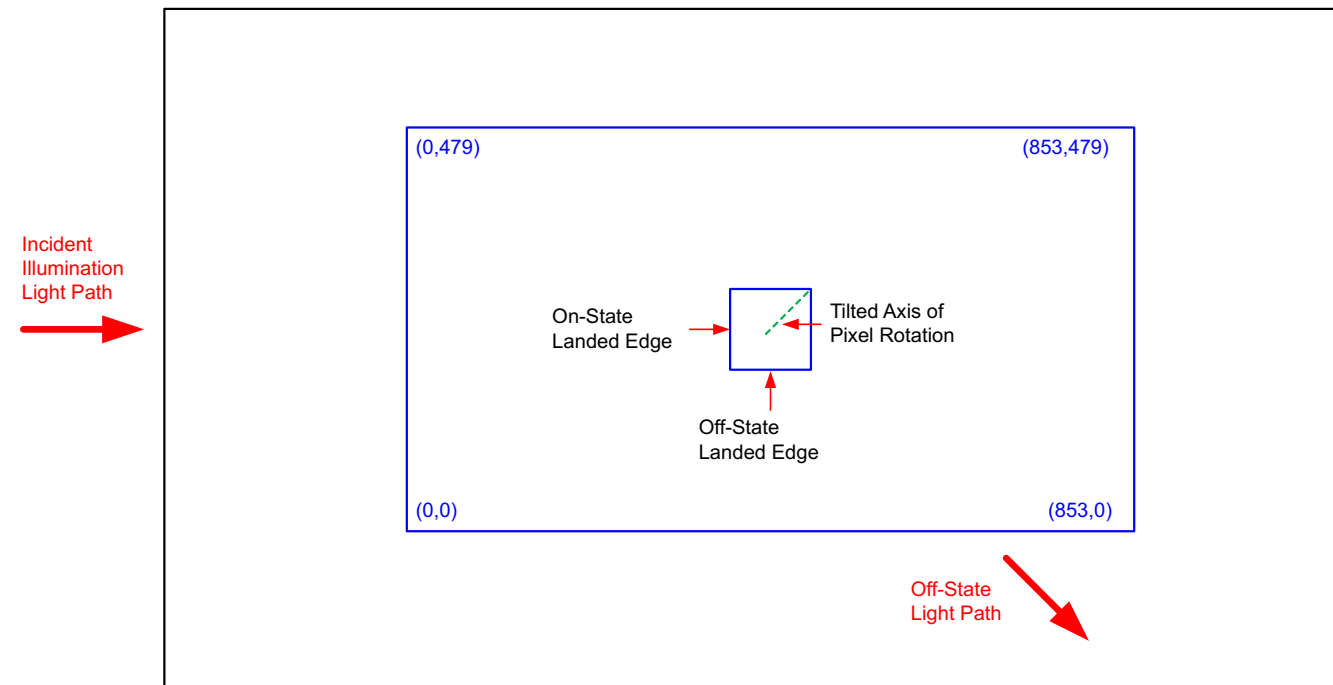


Figure 17. Landed Pixel Orientation and Tilt

6.12 Window Characteristics

| PARAMETER ⁽¹⁾ | | MIN | NOM | MAX | UNIT |
|---|---|------------------|-----|-----|--------------------|
| Window material designation | | Corning Eagle XG | | | |
| Window refractive index | at wavelength 546.1 nm | 1.5119 | | | |
| Window aperture ⁽²⁾ | | | | | See ⁽²⁾ |
| Illumination overfill ⁽³⁾ | | | | | See ⁽³⁾ |
| Window transmittance, single-pass through both surfaces and glass | Minimum within the wavelength range 420 to 680 nm. Applies to all angles 0° to 30° AOI. | 97% | | | |
| Window Transmittance, single-pass through both surfaces and glass | Average over the wavelength range 420 to 680 nm. Applies to all angles 30° to 45° AOI. | 97% | | | |

(1) See [Optical Interface and System Image Quality Considerations](#) for more information.

(2) See the package mechanical characteristics for details regarding the size and location of the window aperture.

(3) The active area of the DLP2010 device is surrounded by an aperture on the inside of the DMD window surface that masks structures of the DMD device assembly from normal view. The aperture is sized to anticipate several optical conditions. Overfill light illuminating the area outside the active array can scatter and create adverse effects to the performance of an end application using the DMD. The illumination optical system should be designed to limit light flux incident outside the active array to less than 10% of the average flux level in the active area. Depending on the particular system's optical architecture and assembly tolerances, the amount of overfill light on the outside of the active array may cause system performance degradation.

6.13 Chipset Component Usage Specification

The DLP2010 is a component of one or more DLP chipsets. Reliable function and operation of the DLP2010 requires that it be used in conjunction with the other components of the applicable DLP chipset, including those components that contain or implement TI DMD control technology. TI DMD control technology is the TI technology and devices for operating or controlling a DLP DMD.

NOTE

TI assumes no responsibility for image quality artifacts or DMD failures caused by optical system operating conditions exceeding limits described previously.

6.14 Software Requirements

CAUTION

The DLP2010 DMD has mandatory software requirements. Refer to [Software Requirements for TI DLP® Pico™ TRP Digital Micromirror Devices](#) application report for additional information. Failure to use the specified software will result in failure at power up.

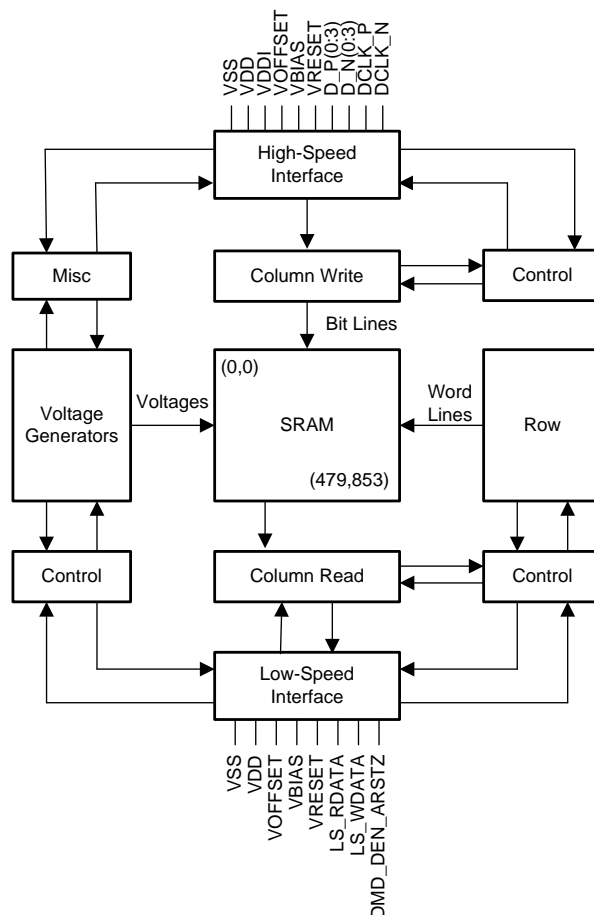
7 Detailed Description

7.1 Overview

The DLP2010 is a 0.2 inch diagonal spatial light modulator of aluminum micromirrors. Pixel array size is 854 columns by 480 rows in a square grid pixel arrangement. The electrical interface is sub low voltage differential signaling (SubLVDS) data.

This DMD is part of the chipset that is composed of the DLP2010 DMD, DLPC3430, DLPC3435, or DLPC3470 display controller and the DLPA2000 PMIC and LED driver. To ensure reliable operation, the DLP2010 DMD must always be used with the DLPC3430, DLPC3435, or DLPC3470 display controller and the DLPA2000 PMIC and LED driver.

7.2 Functional Block Diagram



Details omitted for clarity.

7.3 Feature Description

7.3.1 Power Interface

The power management component DLPA2000, contains three 3 regulated DC supplies for the DMD reset circuitry: VBIAS, VRESET and VOFFSET, as well as the two regulated DC supplies for the DLPC3430, DLPC3435, or DLPC3470 controller.

7.3.2 Low-Speed Interface

The low speed interface handles instructions that configure the DMD and control reset operation. LS_CLK is the low-speed clock, and LS_WDATA is the low speed data input.

7.3.3 High-Speed Interface

The purpose of the high-speed interface is to transfer pixel data rapidly and efficiently, making use of high speed DDR transfer and compression techniques to save power and time. The high-speed interface uses differential SubLVDS receivers for inputs, with a dedicated clock.

7.3.4 Timing

The data sheet provides timing test results at the device pin. For output timing analysis, the tester pin electronics and its transmission line effects must be considered. [Figure 13](#) shows an equivalent test load circuit for the output under test. Timing reference loads are not intended as a precise representation of any particular system environment or depiction of the actual load presented by a production test. TI recommends that system designers use IBIS or other simulation tools to correlate the timing reference load to a system environment. The load capacitance value stated is intended for characterization and measurement of AC timing signals only. This load capacitance value does not indicate the maximum load the device is capable of driving.

7.4 Device Functional Modes

DMD functional modes are controlled by the DLPC3430, DLPC3435, or DLPC3470 controller. See the [DLPC3430](#) or [DLPC3435](#) or [DLPC3470](#) controller data sheet or contact a TI applications engineer.

7.5 Optical Interface and System Image Quality Considerations

NOTE

TI assumes no responsibility for image quality artifacts or DMD failures caused by optical system operating conditions exceeding limits described previously.

7.5.1 Optical Interface and System Image Quality

TI assumes no responsibility for end-equipment optical performance. Achieving the desired end-equipment optical performance involves making trade-offs between numerous component and system design parameters. Optimizing system optical performance and image quality strongly relate to optical system design parameter trades. Although it is not possible to anticipate every conceivable application, projector image quality and optical performance is contingent on compliance to the optical system operating conditions described in the following sections.

7.5.1.1 Numerical Aperture and Stray Light Control

The angle defined by the numerical aperture of the illumination and projection optics at the DMD optical area is typically the same. Ensure this angle does not exceed the nominal device micromirror tilt angle unless appropriate apertures are added in the illumination or projection pupils to block out flat-state and stray light from the projection lens. The micromirror tilt angle defines DMD capability to separate the "ON" optical path from any other light path, including undesirable flat-state specular reflections from the DMD window, DMD border structures, or other system surfaces near the DMD such as prism or lens surfaces. If the numerical aperture exceeds the micromirror tilt angle, or if the projection numerical aperture angle is more than two degrees larger than the illumination numerical aperture angle (and vice versa), contrast degradation and objectionable artifacts in the display border and/or active area may occur.

Optical Interface and System Image Quality Considerations (continued)

7.5.1.2 Pupil Match

The optical and image quality specifications assume that the exit pupil of the illumination optics is nominally centered within 2° of the entrance pupil of the projection optics. Misalignment of pupils can create objectionable artifacts in the display border and/or active area. These artifacts may require additional system apertures to control, especially if the numerical aperture of the system exceeds the pixel tilt angle.

7.5.1.3 Illumination Overfill

The active area of the device is surrounded by an aperture on the inside DMD window surface that masks structures of the DMD chip assembly from normal view, and is sized to anticipate several optical operating conditions. Overfill light illuminating the window aperture can create artifacts from the edge of the window aperture opening and other surface anomalies that may be visible on the screen. Be sure to design an illumination optical system that limits light flux incident anywhere on the window aperture from exceeding approximately 10% of the average flux level in the active area. Depending on the particular optical architecture, overfill light may require further reduction below the suggested 10% level in order to be acceptable.

7.6 Micromirror Array Temperature Calculation

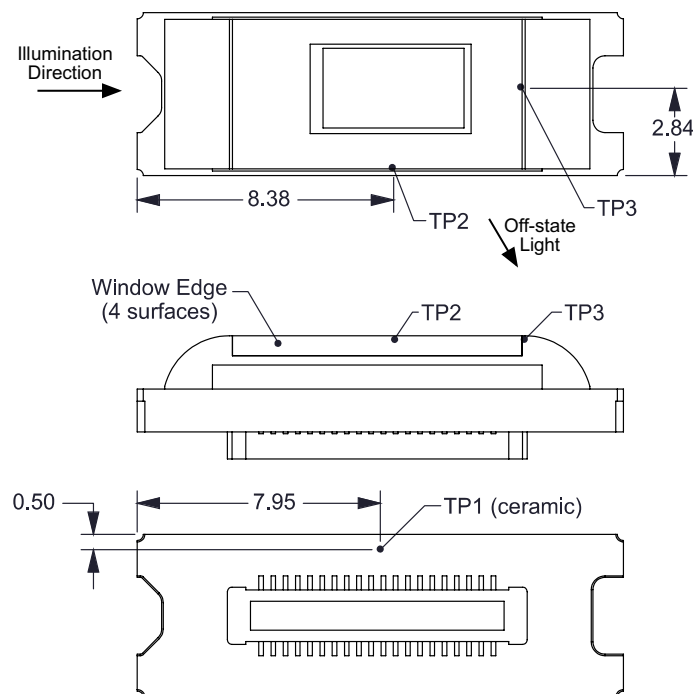


Figure 18. DMD Thermal Test Points

Micromirror array temperature can be computed analytically from measurement points on the outside of the package, the ceramic package thermal resistance, the electrical power dissipation, and the illumination heat load. The relationship between micromirror array temperature and the reference ceramic temperature is provided by the following equations:

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

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

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

where

- T_{ARRAY} = Computed DMD array temperature (°C)
- T_{CERAMIC} = Measured ceramic temperature (°C), TP1 location in [Figure 18](#)
- $R_{\text{ARRAY-TO-CERAMIC}}$ = DMD package thermal resistance from array to outside ceramic (°C/W) specified in [Thermal Information](#)

Micromirror Array Temperature Calculation (continued)

- Q_{ARRAY} = Total DMD power; electrical plus absorbed (calculated) (W)
- $Q_{\text{ELECTRICAL}}$ = Nominal DMD electrical power dissipation (W)
- C_{L2W} = Conversion constant for screen lumens to absorbed optical power on the DMD (W/lm) specified below
- SL = Measured ANSI screen lumens (lm)

Electrical power dissipation of the DMD is variable and depends on the voltages, data rates and operating frequencies. A nominal electrical power dissipation to use when calculating array temperature is 0.07 W. Absorbed optical power from the illumination source varies and depends on the operating state of the micromirrors and the intensity of the light source. Equation 1 through are valid for a 1-chip DMD system with total projection efficiency through the projection lens from DMD to the screen of 87%.

The conversion constant CL2W is based on the DMD micromirror array characteristics. It assumes a spectral efficiency of 300 lm/W for the projected light and illumination distribution of 83.7% on the DMD active array, and 16.3% on the DMD array border and window aperture. The conversion constant is calculated to be 0.00266 W/lm.

The following is a sample calculation for typical projection application:

$$T_{\text{CERAMIC}} = 55^{\circ}\text{C (measured)}$$

$$\text{SL} = 150 \text{ lm (measured)}$$

$$Q_{\text{ELECTRICAL}} = 0.070 \text{ W}$$

$$C_{\text{L2W}} = 0.00266 \text{ W/lm}$$

$$Q_{\text{ARRAY}} = 0.070 \text{ W} + (0.00266 \text{ W/lm} \times 150 \text{ lm}) = 0.469 \text{ W}$$

$$T_{\text{ARRAY}} = 55^{\circ}\text{C} + (0.469 \text{ W} \times 7.9^{\circ}\text{C/W}) = 58.7^{\circ}\text{C}$$

7.7 Micromirror Landed-On/Landed-Off Duty Cycle

7.7.1 Definition of Micromirror Landed-On and Landed-Off Duty Cycle

The micromirror landed-on/landed-off duty cycle (landed duty cycle) denotes the amount of time (as a percentage) that an individual micromirror is landed in the ON state versus the amount of time the same micromirror is landed in the OFF state.

As an example, a landed duty cycle of 75/25 indicates that the referenced pixel is in the ON state 75% of the time (and in the OFF state 25% of the time), whereas 25/75 indicates that the pixel is in the OFF state 75% of the time. Likewise, 50/50 indicates that the pixel is ON 50% of the time and OFF 50% of the time.

When assessing landed duty cycle, the time spent switching from the current state to the opposite state is considered negligible and is thus ignored.

Because a micromirror can only be landed in one state or the other (ON or OFF), the two numbers (percentages) nominally add to 100. In practice, image processing algorithms in the DLP chipset can result a total of less than 100.

7.7.2 Landed Duty Cycle and Useful Life of the DMD

Knowing the long-term average landed duty cycle (of the end product or application) is important because subjecting all (or a portion) of the DMD's micromirror array (also called the active array) to an asymmetric landed duty cycle for a prolonged period of time can reduce the DMD's usable life.

It is the symmetry or asymmetry of the landed duty cycle that is relevant. The symmetry of the landed duty cycle is determined by how close the two numbers (percentages) are to being equal. For example, a landed duty cycle of 50/50 is perfectly symmetrical whereas a landed duty cycle of 100/0 or 0/100 is perfectly asymmetrical.

7.7.3 Landed Duty Cycle and Operational DMD Temperature

Operational DMD temperature and landed duty cycle interact to affect the usable life of the DMD. This interaction can be used to reduce the impact that an asymmetrical landed duty cycle has on the usable life of the DMD. Figure 1 describes this relationship. The importance of this curve is that:

Micromirror Landed-On/Landed-Off Duty Cycle (continued)

- All points along this curve represent the same usable life.
- All points above this curve represent lower usable life (and the further away from the curve, the lower the usable life).
- All points below this curve represent higher usable life (and the further away from the curve, the higher the usable life).

In practice, this curve specifies the maximum operating DMD temperature that the DMD should be operated at for a give long-term average landed duty cycle.

7.7.4 Estimating the Long-Term Average Landed Duty Cycle of a Product or Application

During a given period of time, the landed duty cycle of a given pixel depends on the image content being displayed by that pixel.

In the simplest case for example, when the system displays pure-white on a given pixel for a given time period, that pixel operates very close to a 100/0 landed duty cycle during that time period. Likewise, when the system displays pure-black, the pixel operates very close to a 0/100 landed duty cycle.

Between the two extremes (ignoring for the moment color and any image processing that may be applied to an incoming image), the landed duty cycle tracks one-to-one with the gray scale value, as shown in [Table 1](#).

Table 1. Grayscale Value and Landed Duty Cycle

| Grayscale Value | Nominal Landed Duty Cycle |
|-----------------|---------------------------|
| 0% | 0/100 |
| 10% | 10/90 |
| 20% | 20/80 |
| 30% | 30/70 |
| 40% | 40/60 |
| 50% | 50/50 |
| 60% | 60/40 |
| 70% | 70/30 |
| 80% | 80/20 |
| 90% | 90/10 |
| 100% | 100/0 |

To account for color rendition (and continuing to ignore image processing for this example) requires knowing both the color intensity (from 0% to 100%) for each constituent primary color (red, green, and/or blue) for the given pixel as well as the color cycle time for each primary color, where *color cycle time* describes the total percentage of the frame time that a given primary must be displayed in order to achieve the desired white point.

During a given period of time, the nominal landed duty cycle of a given pixel can be calculated as shown in [Equation 3](#):

$$\text{Landed Duty Cycle} = (\text{Red_Cycle_}\% \times \text{Red_Scale_Value}) + (\text{Green_Cycle_}\% \times \text{Green_Scale_Value}) + (\text{Blue_Cycle_}\% \times \text{Blue_Scale_Value})$$

where

- Red_Cycle_% represents the percentage of the frame time that red displays to achieve the desired white point
 - Green_Cycle_% represents the percentage of the frame time that green displays to achieve the desired white point
 - Blue_Cycle_% represents the percentage of the frame time that blue displays to achieve the desired white point
- (3)

For example, assume that the ratio of red, green and blue color cycle times are as listed in [Table 2](#) (in order to achieve the desired white point) then the resulting nominal landed duty cycle for various combinations of red, green, blue color intensities are as shown in [Table 3](#).

Table 2. Example Landed Duty Cycle for Full-Color Pixels

| Red Cycle Percentage | Green Cycle Percentage | Blue Cycle Percentage |
|----------------------|------------------------|-----------------------|
| 50% | 20% | 30% |

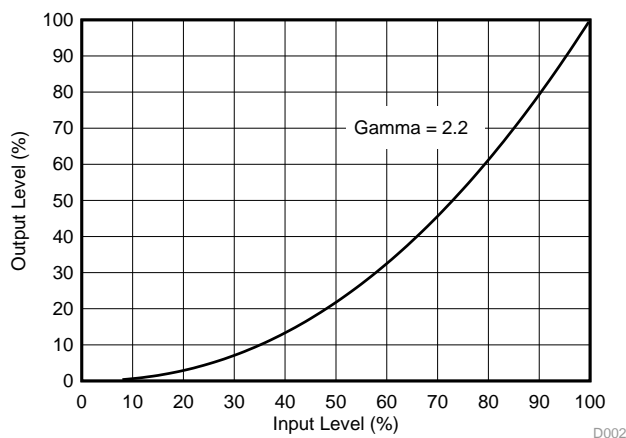
Table 3. Color Intensity Combinations

| Red Scale Value | Green Scale Value | Blue Scale Value | Nominal Landed Duty Cycle |
|-----------------|-------------------|------------------|---------------------------|
| 0% | 0% | 0% | 0/100 |
| 100% | 0% | 0% | 50/50 |
| 0% | 100% | 0% | 20/80 |
| 0% | 0% | 100% | 30/70 |
| 12% | 0% | 0% | 6/94 |
| 0% | 35% | 0% | 7/93 |
| 0% | 0% | 60% | 18/82 |
| 100% | 100% | 0% | 70/30 |
| 0% | 100% | 100% | 50/50 |
| 100% | 0% | 100% | 80/20 |
| 12% | 35% | 0% | 13/87 |
| 0% | 35% | 60% | 25/75 |
| 12% | 0% | 60% | 24/76 |
| 100% | 100% | 100% | 100/0 |

The last factor to consider when estimating the landed duty cycle is any applied image processing. Within the DLP Controller DLPC3430, DLPC3435, or DLPC3470, the two functions which influence the actual landed duty cycle are Gamma and IntelliBright™, and bitplane sequencing rules.

Gamma is a power function of the form $\text{Output_Level} = A \times \text{Input_Level}^{\text{Gamma}}$, where A is a scaling factor that is typically set to 1.

In the DLPC3430, DLPC3435, or DLPC3470 controller, gamma is applied to the incoming image data on a pixel-by-pixel basis. A typical gamma factor is 2.2, which transforms the incoming data as shown in [Figure 19](#).


Figure 19. Example of Gamma = 2.2

As shown in [Figure 19](#), when the gray scale value of a given input pixel is 40% (before gamma is applied), then gray scale value is 13% after gamma is applied. Because gamma has a direct impact on the displayed gray scale level of a pixel, it also has a direct impact on the landed duty cycle of a pixel.

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The IntelliBright algorithms content adaptive illumination control (CAIC) and local area brightness boost (LABB) also apply transform functions on the gray scale level of each pixel.

But while amount of gamma applied to every pixel (of every frame) is constant (the exponent, gamma, is constant), CAIC and LABB are both adaptive functions that can apply a different amounts of either boost or compression to every pixel of every frame.

Be sure to account for any image processing which occurs before the DLPC3430, DLPC3435, or DLPC3470 controller.

8 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

The DMDs are spatial light modulators which reflect incoming light from an illumination source to one of two directions, with the primary direction being into a projection or collection optic. Each application depends primarily on the optical architecture of the system and the format of the data coming into the DLPC3430, DLPC3435, or DLPC3470 controller. The new high-tilt pixel in the side-illuminated DMD increases brightness performance and enables a smaller system electronics footprint for thickness constrained applications. Applications include

like smartphones, tablets, cameras, and camcorders. Other applications include .

- projection embedded in display devices
 - smartphones
 - tablets
 - cameras
 - camcorders
- wearable (near-eye) displays
- battery powered mobile accessory
- interactive display
- low-latency gaming display
- digital signage

DMD power-up and power-down sequencing is strictly controlled by the DLPA2000. Refer to [Power Supply Recommendations](#) for power-up and power-down specifications. DLP2010 DMD reliability is specified when used with DLPC3430, DLPC3435, or DLPC3470 controller and DLPA2000 PMIC/LED driver only.

8.2 Typical Application

This section describes a pico-projector using a DLP chipset that includes a DLP2010 DMD, DLPC3430, DLPC3435, or DLPC3470 controller and DLPA2000 PMIC/LED driver. The DLPC3430, DLPC3435, or DLPC3470 controller does the digital image processing, the DLPA2000 provides the needed analog functions for the projector, and DMD is the display device for producing the projected image.

The DLPC3430 controller in the pico-projector embedded module typically receives images/video from a host processor within the product. DLPC3430 controller then drives the DLP2010 DMD synchronized with the R, G, B LEDs in the optical engine to display the image/video as output of the optical engine.

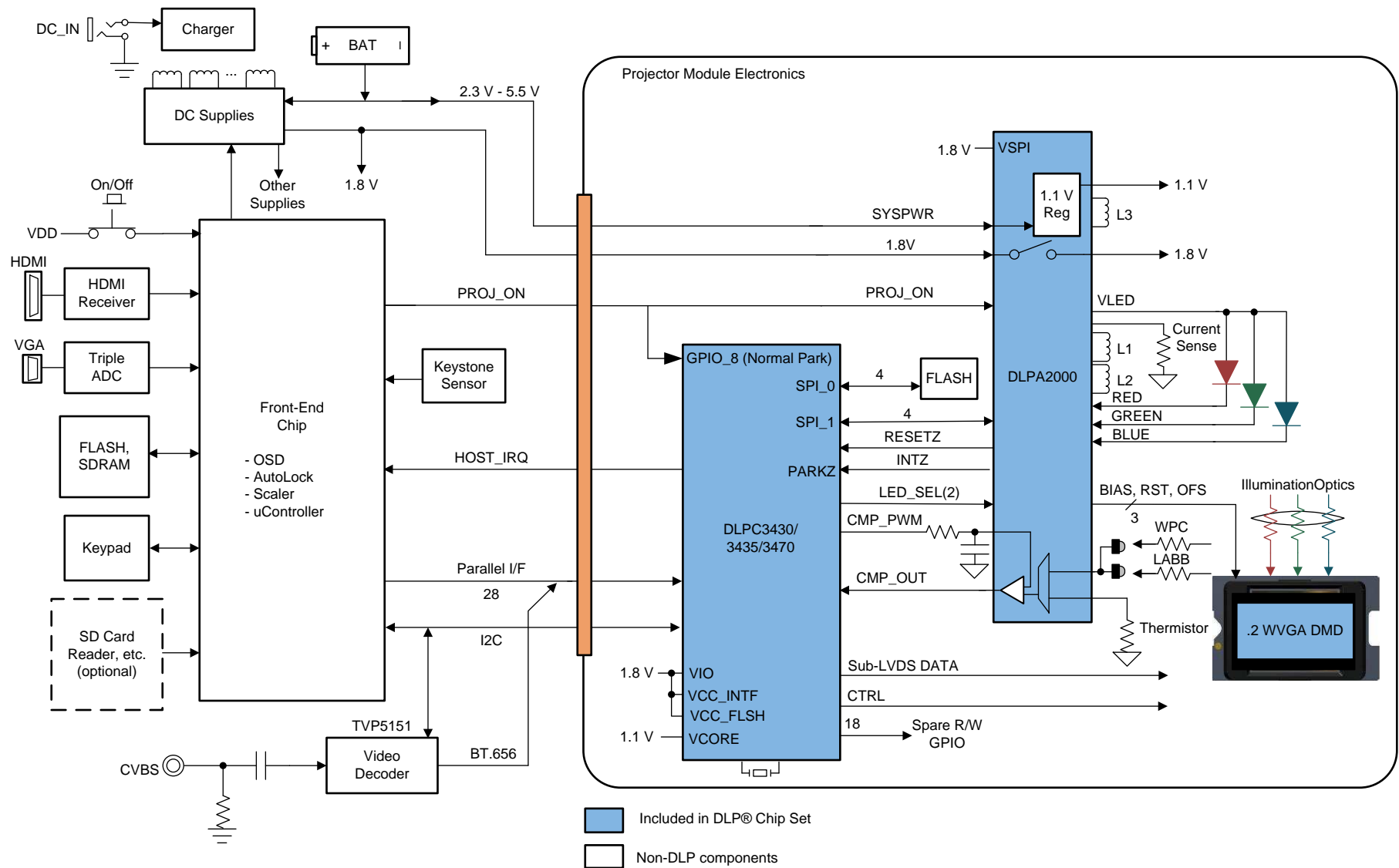


Figure 20. Typical Application

8.2.1 Design Requirements

In addition to the three DLP devices in the chipset, other IC components may be needed. At a minimum, this design requires a flash device to store the software and firmware to control the DLPC3430, DLPC3435, or DLPC3470 .

Red, green, and blue LEDs typically supply the illumination light that is applied to the DMD. These LEDs are often contained in three separate packages, but sometimes more than one color of LED die may be in the same package to reduce the overall size of the pico-projector.

A parallel interface connects the DLPC3430, DLPC3435, or DLPC3470 to the host processing for receiving images. When the parallel interface is used, use an I²C interface to the host processor for sending commands to the DLPC3430, DLPC3435, or DLPC3470.

The battery (SYSPWR) and a regulated 1.8-V supply are the only power supplies needed external to the projector.

8.2.2 Detailed Design Procedure

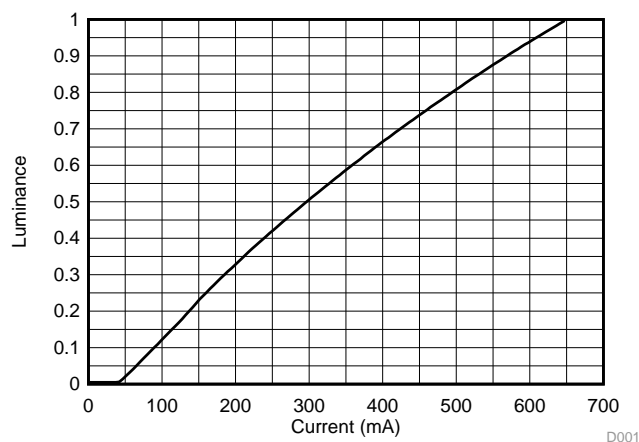
For connecting together the DLPC3430, DLPC3435, or DLPC3470 , the DLPA2000, and the DMD, see the reference design schematic. When a circuit board layout is created from this schematic a very small circuit board is possible. An example small board layout is included in the reference design data base. Layout guidelines should be followed to achieve a reliable projector.

The optical engine that has the LED packages and the DMD mounted to it is typically supplied by an optical OEM who specializes in designing optics for DLP projectors.

A miniature stepper motor can optionally be added to the optical engine for creating a motorized focus. Direct control and driving of the motor can be done by the DLPA2000, and software commands sent over I²C to the DLPC3430, DLPC3435, or DLPC3470 are available to move the motor to the desired position.

8.2.3 Application Curve

This device drives current time-sequentially through the LEDs. As the LED currents through the red, green, and blue LEDs increases, the brightness of the projector increases. This increase is somewhat non-linear, and the curve for typical white screen lumens changes with LED currents as shown in . For the LED currents shown, assumed that the same current amplitude is applied to the red, green, and blue.



$$I_{LED(red)} = I_{LED(green)} = I_{LED(blue)}$$

Figure 21. Luminance vs Current

9 Power Supply Recommendations

The following power supplies are all required to operate the DMD: VSS, VDD, VDDI, VOFFSET, VBIAS, and VRESET. DMD power-up and power-down sequencing is strictly controlled by the DLPxxxx device.

CAUTION

For reliable operation of the DMD, the following power supply sequencing requirements must be followed. Failure to adhere to the prescribed power-up and power-down procedures may affect device reliability.

VDD, VDDI, VOFFSET, VBIAS, and VRESET power supplies have to be coordinated during power-up and power-down operations. Failure to meet any of the below requirements will result in a significant reduction in the DMD's reliability and lifetime. Refer to [Figure 23](#). VSS must also be connected.

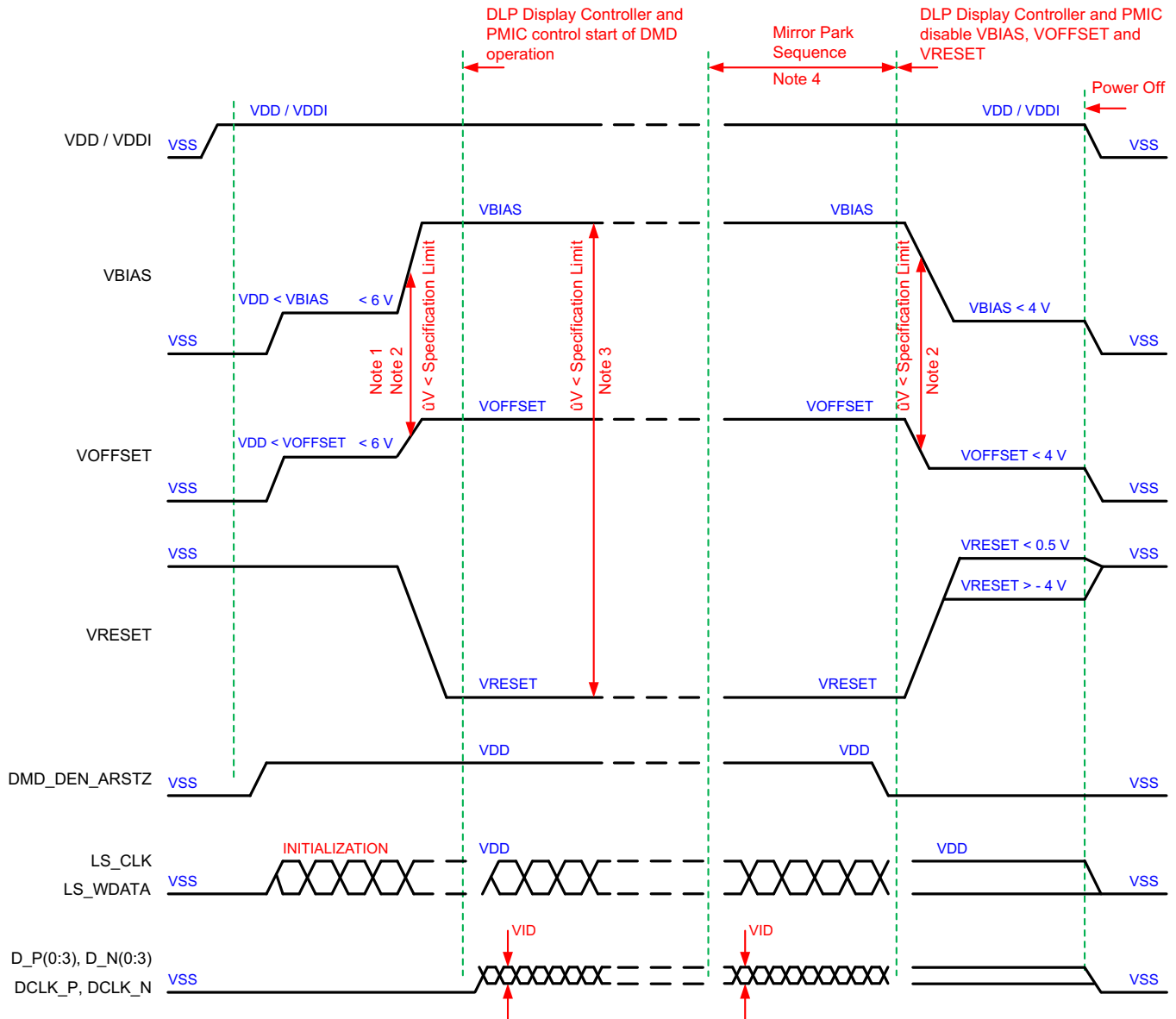
9.1 Power Supply Power-Up Procedure

- During power-up, VDD and VDDI must always start and settle before VOFFSET, VBIAS, and VRESET voltages are applied to the DMD.
- During power-up, it is a strict requirement that the delta between VBIAS and VOFFSET must be within the specified limit shown in *Recommended Operating Conditions*. Refer to [Table 4](#) and the *Layout Example* for power-up delay requirements.
- During power-up, the DMD's LPSDR input pins shall not be driven high until after VDD and VDDI have settled at operating voltage.
- During power-up, there is no requirement for the relative timing of VRESET with respect to VOFFSET and VBIAS. Power supply slew rates during power-up are flexible, provided that the transient voltage levels follow the requirements listed previously and in [Figure 22](#).

9.2 Power Supply Power-Down Procedure

- Power-down sequence is the reverse order of the previous power-up sequence. VDD and VDDI must be supplied until after VBIAS, VRESET, and VOFFSET are discharged to within 4 V of ground.
- During power-down, it is not mandatory to stop driving VBIAS prior to VOFFSET, but it is a strict requirement that the delta between VBIAS and VOFFSET must be within the specified limit shown in *Recommended Operating Conditions* (Refer to Note 2 for [Figure 22](#)).
- During power-down, the DMD's LPSDR input pins must be less than VDDI, the specified limit shown in *Recommended Operating Conditions*.
- During power-down, there is no requirement for the relative timing of VRESET with respect to VOFFSET and VBIAS.
- Power supply slew rates during power-down are flexible, provided that the transient voltage levels follow the requirements listed previously and in [Figure 22](#).

9.3 Power Supply Sequencing Requirements



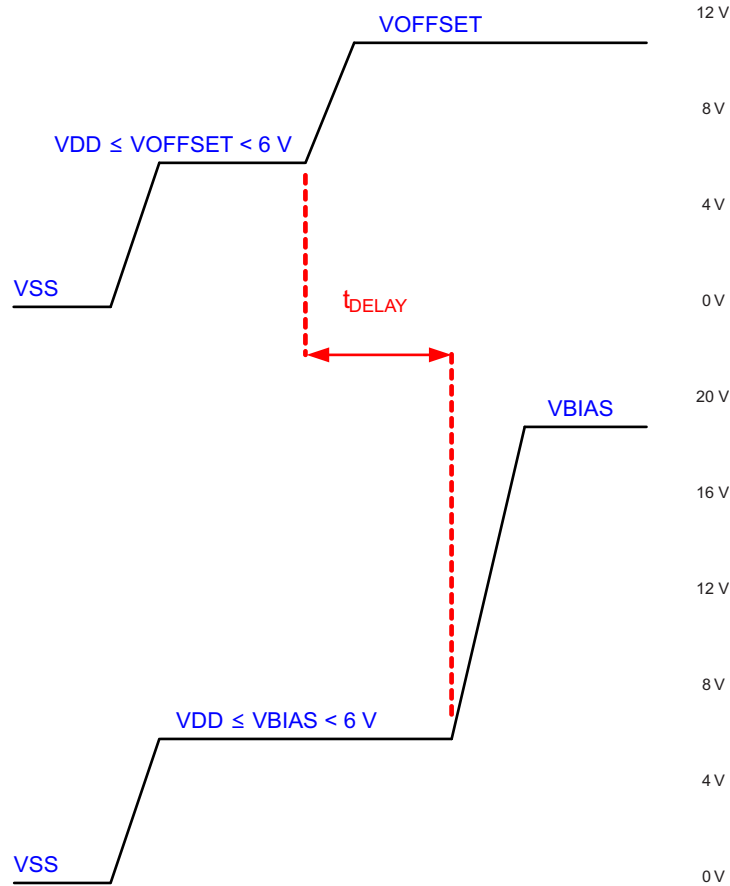
- (1) Refer to [Table 4](#) and [Figure 23](#) for critical power-up sequence delay requirements.
- (2) To prevent excess current, the supply voltage delta $|VBIAS - VOFFSET|$ must be less than specified in *Recommended Operating Conditions*. OEMs may find that the most reliable way to ensure this is to power VOFFSET prior to VBIAS during power-up and to remove VBIAS prior to VOFFSET during power-down. Refer to [Table 4](#) and [Figure 23](#) for power-up delay requirements.
- (3) To prevent excess current, the supply voltage delta $|VBIAS - VRESET|$ must be less than specified limit shown in *Recommended Operating Conditions*.
- (4) When system power is interrupted, the ASIC driver initiates hardware power-down that disables VBIAS, VRESET and VOFFSET after the Micromirror Park Sequence. Software power-down disables VBIAS, VRESET, and VOFFSET after the Micromirror Park Sequence through software control.
- (5) Drawing is not to scale and details are omitted for clarity.

Figure 22. Power Supply Sequencing Requirements (Power Up and Power Down)

Power Supply Sequencing Requirements (continued)

Table 4. Power-Up Sequence Delay Requirement

| PARAMETER | | MIN | MAX | UNIT |
|--------------|---|-----|-----|------|
| t_{DELAY} | Delay requirement from VOFFSET power up to VBIAS power up | 2 | | ms |
| V_{OFFSET} | Supply voltage level during power-up sequence delay (see Figure 23) | | 6 | V |
| V_{BIAS} | Supply voltage level during power-up sequence delay (see Figure 23) | | 6 | V |



A. Refer to Table 4 for VOFFSET and VBIAS supply voltage levels during power-up sequence delay.

Figure 23. Power-Up Sequence Delay Requirement

10 Layout

10.1 Layout Guidelines

There are no specific layout guidelines because in most cases the DMD is connected using a board-to-board connector to a flex cable. The flex cable provides the interface of data and control signals between the DLPC3430, DLPC3435, or DLPC3470 controller and the DLP2010 DMD. For detailed layout guidelines refer to the layout design files.

Layout guidelines for the flex cable interface with DMD are:

- Match lengths for the LS_WDATA and LS_CLK signals.
- Minimize vias, layer changes, and turns for the HS bus signals. Refer [Figure 24](#).
- Place a decoupling capacitor (minimum 100-nF) close to VBIAS. See capacitor C4 in [Figure 25](#).
- Place a decoupling capacitor (minimum 100-nF) close to VRST. See capacitor C6 in [Figure 25](#).
- Place a decoupling capacitor (minimum 220-nF) close to VOFS. See capacitor C7 in [Figure 25](#).
- Place the optional decoupling capacitor (minimum between 200-nF and 220-nF) to meet the ripple requirements of the DMD. See capacitor C5 in [Figure 25](#).
- Place a decoupling capacitor (minimum 100-nF) close to VDDI. See capacitor C1 in [Figure 25](#).
- Place a decoupling capacitor (minimum 100-nF) close to both groups of VDD pins, for a total of 200 nF for VDD. See capacitors C2 and C3 in [Figure 25](#).

10.2 Layout Example

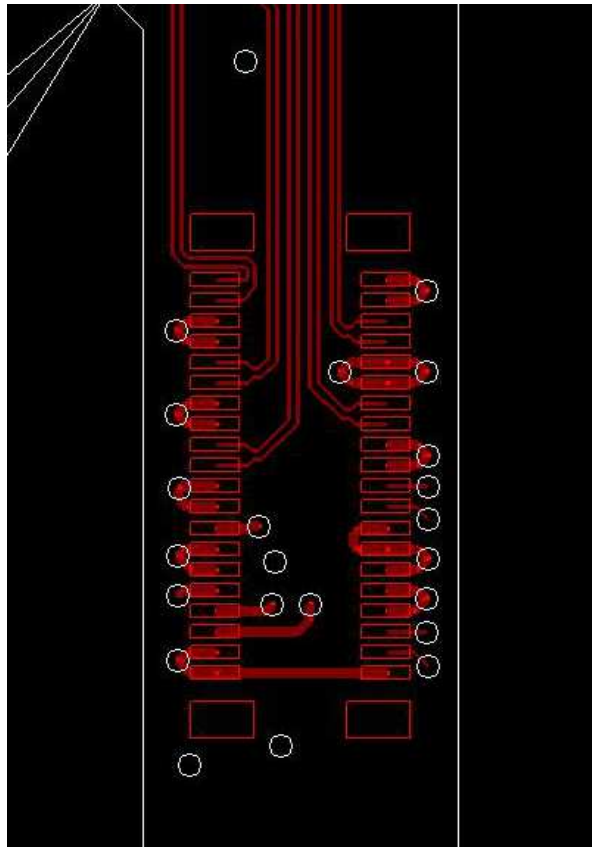


Figure 24. High-Speed (HS) Bus Connections

Layout Example (continued)

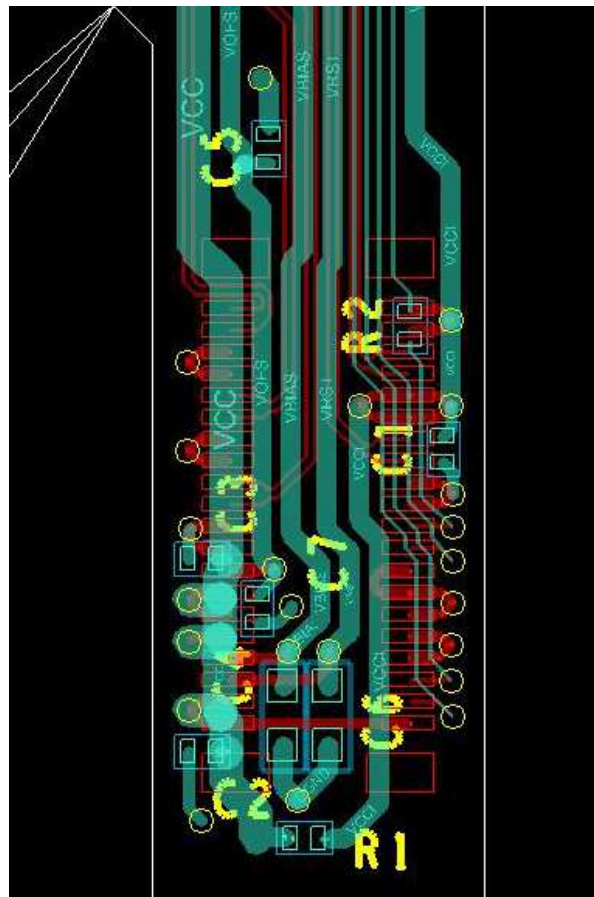


Figure 25. Power Supply Connections

11 Device and Documentation Support

11.1 Device Support

11.1.1 Device Nomenclature

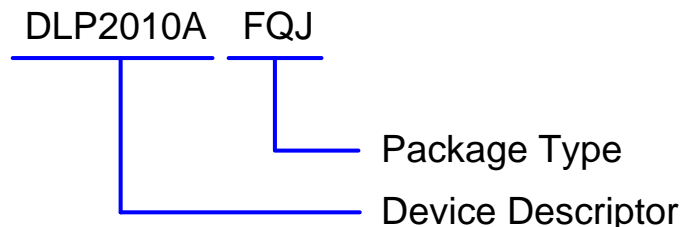


Figure 26. Part Number Description

11.1.2 Device Markings

Device Marking will include the human-readable character string GHJJJK VVVV on the electrical connector. GHJJJK is the lot trace code. VVVV is a 4 character encoded device part number.



Figure 27. DMD Marking

11.2 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

Table 5. Related Links

| PARTS | PRODUCT FOLDER | SAMPLE & BUY | TECHNICAL DOCUMENTS | TOOLS & SOFTWARE | SUPPORT & COMMUNITY |
|----------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| DLPC3430 | Click here | Click here | Click here | Click here | Click here |
| DLPC3435 | Click here | Click here | Click here | Click here | Click here |
| DLPC3470 | Click here | Click here | Click here | Click here | Click here |
| DLPA2000 | Click here | Click here | Click here | Click here | Click here |

11.3 Trademarks

Pico, IntelliBright are trademarks of Texas Instruments.
 DLP is a registered trademark of Texas Instruments.
 All other trademarks are the property of their respective owners.

11.4 Electrostatic Discharge Caution



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

11.5 Glossary

[SLYZ022](#) — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|------------------|---------------|--------------|-----------------|------|-------------|-----------------|-------------------------|----------------------|--------------|-------------------------|---------|
| DLP2010AFQJ | ACTIVE | CLGA | FQJ | 40 | 120 | RoHS & Green | Call TI | N / A for Pkg Type | | | Samples |

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

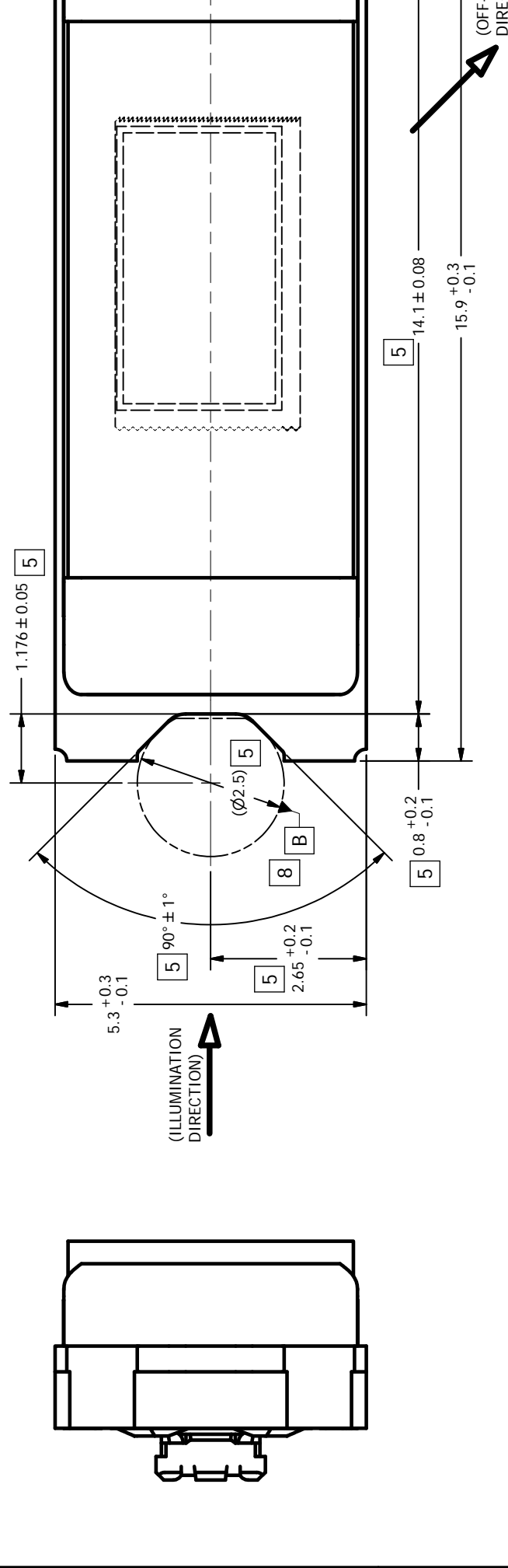
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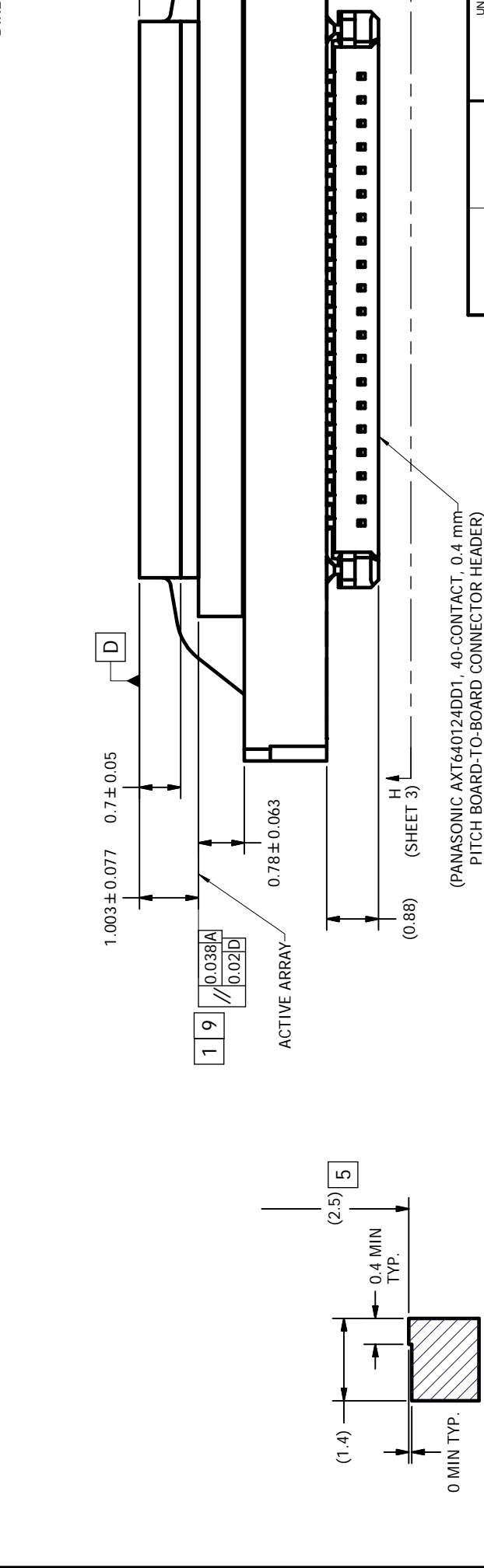
NOTES UNLESS OTHERWISE SPECIFIED:

- 1 DIE PARALLELISM TOLERANCE APPLIES TO DMD ACTIVE ARRAY ONLY.
- 2 ROTATION ANGLE OF DMD ACTIVE ARRAY IS A REFINEMENT OF THE LOCATION TOLERANCE AND HAS A MAXIMUM ALLOWED VALUE OF 0.6 DEGREES.
- 3 BOUNDARY MIRRORS SURROUNDING THE DMD ACTIVE ARRAY.
- 4 DMD MARKING TO APPEAR IN CONNECTOR RECESS.
- 5 NOTCH DIMENSIONS ARE DEFINED BY UPPERMOST LAYERS OF CERAMIC, AS SHOWN IN SECTION A-A.
- 6 ENCAPSULANT TO BE CONTAINED WITHIN DIMENSIONS SHOWN IN VIEW C (SHEET 2). NO ENCAPSULANT IS ALLOWED ON TOP OF THE WINDOW.
- 7 ENCAPSULANT NOT TO EXCEED THE HEIGHT OF THE WINDOW.
- 8 DATUM B IS DEFINED BY A DIA. 2.5 PIN, WITH A FLAT ON THE SIDE FACING TOWARD THE CENTER OF THE ACTIVE ARRAY, AS SHOWN IN VIEW B (SHEET 2).
- 9 WHILE ONLY THE THREE DATUM A TARGET AREAS A1, A2, AND A3 ARE USED FOR MEASUREMENT, ALL 4 CORNERS SHOULD BE CONTACTED, INCLUDING E1, TO SUPPORT MECHANICAL LOADS.

D



C



B



A

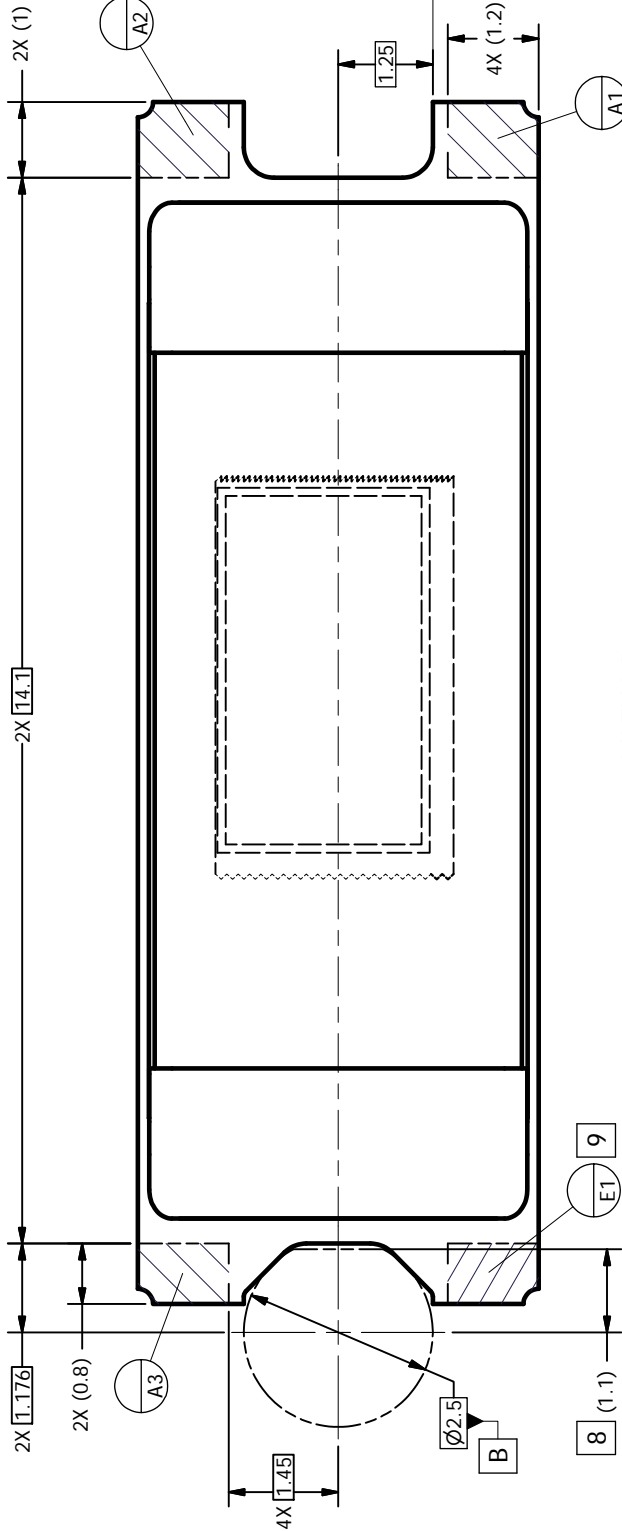
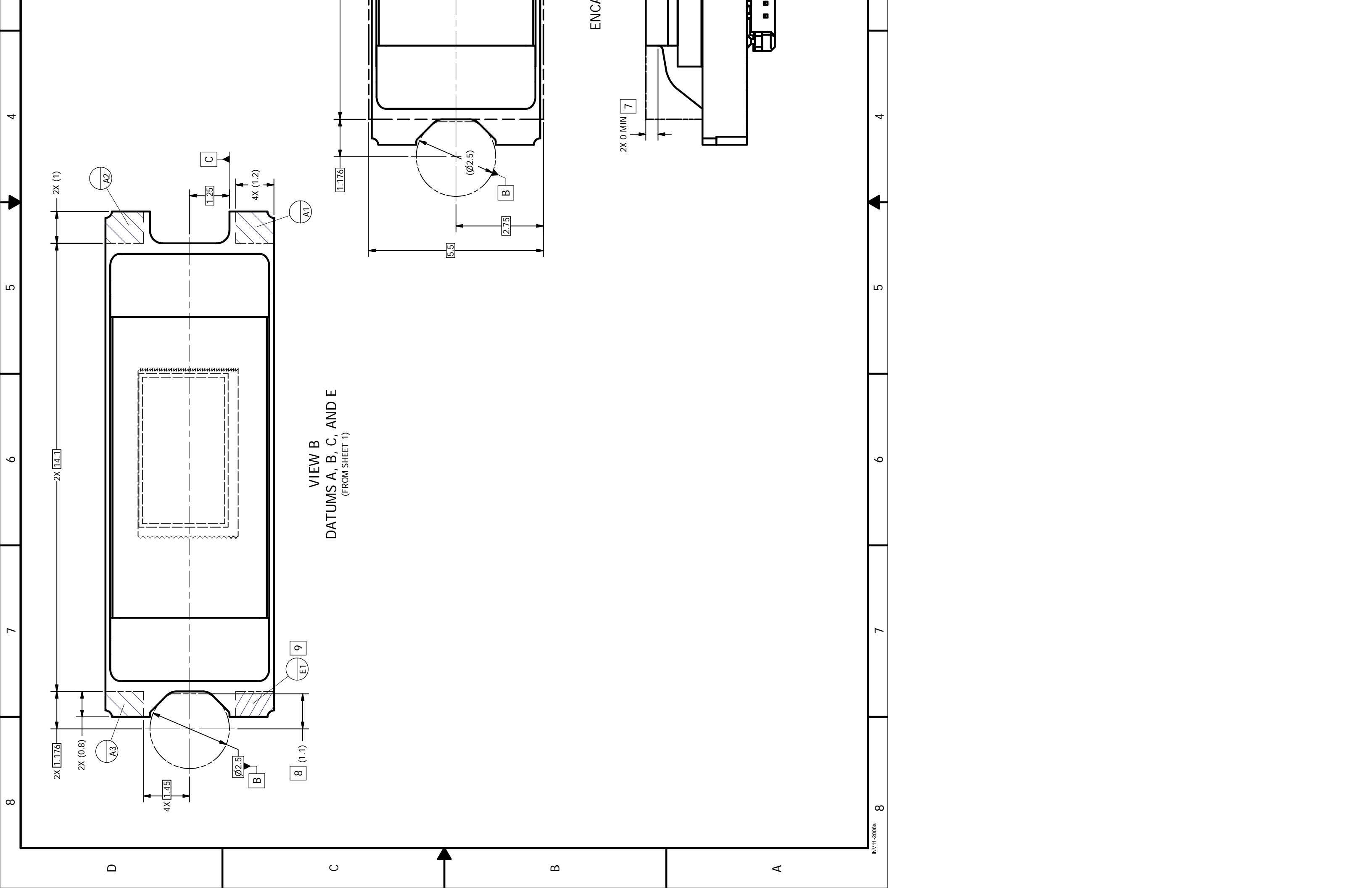
SECTION A-A
NOTCH OFFSETS

(PANASONIC AXT640124DD1, 40-CONTACT, 0.4 mm PITCH BOARD-TO-BOARD CONNECTOR HEADER) MATES WITH PANASONIC AXT540124DD1 OR EQUIVALENT CONNECTOR SOCKET

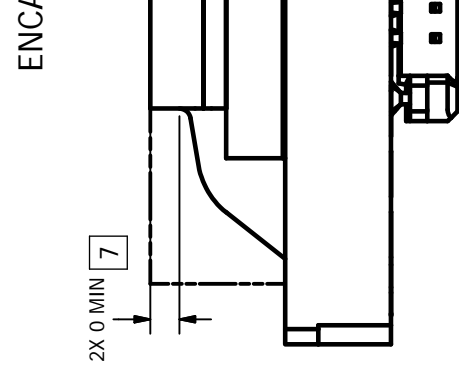
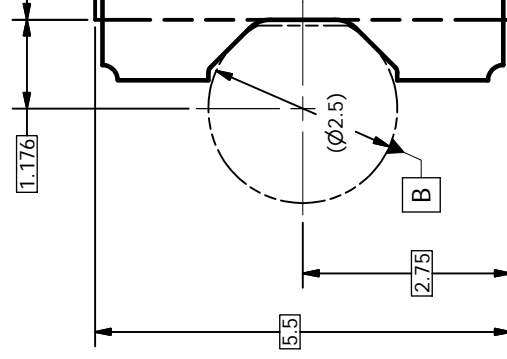
- UN
- DIMENSIONS
- TOLERANCES
- ANGLES
- 1 PLACE D
- 2 PLACE D
- INTERPRET D
- Y14.5M-1994
- AS SHOWN
- PARENTHETIC

| | | |
|-----------|---------|-------------|
| NEXT ASSY | USED ON | APPLICATION |
| | 0314DA | |

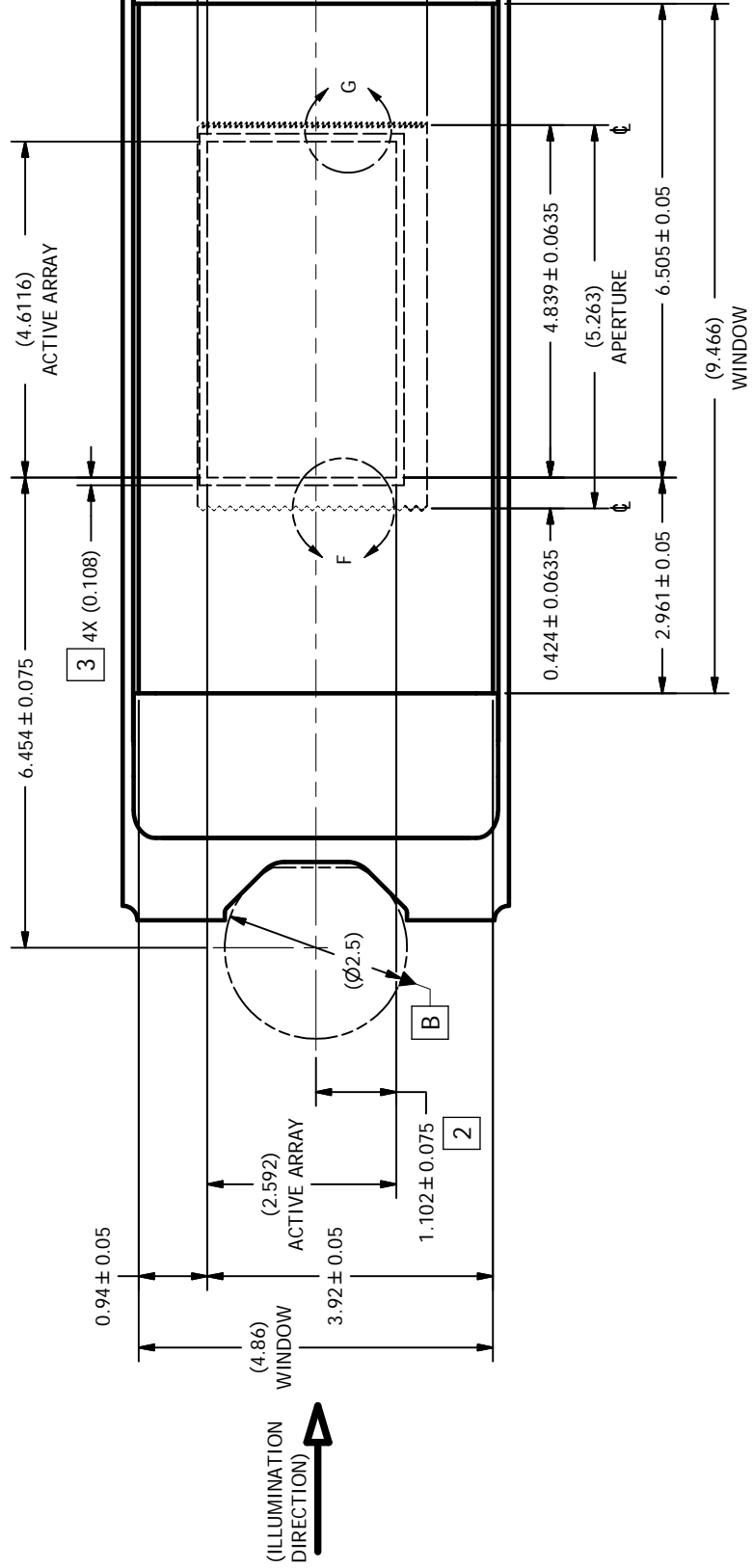
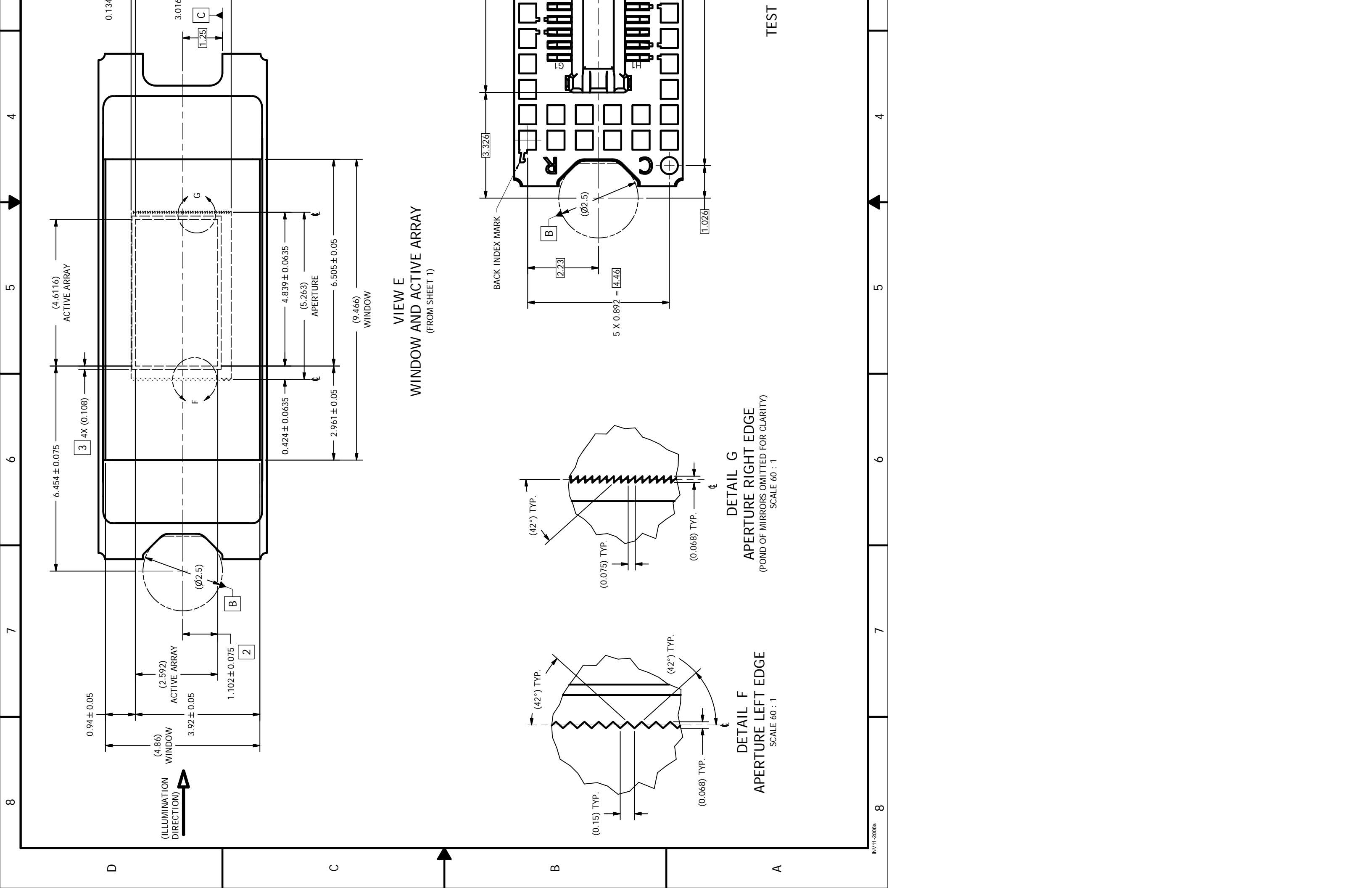




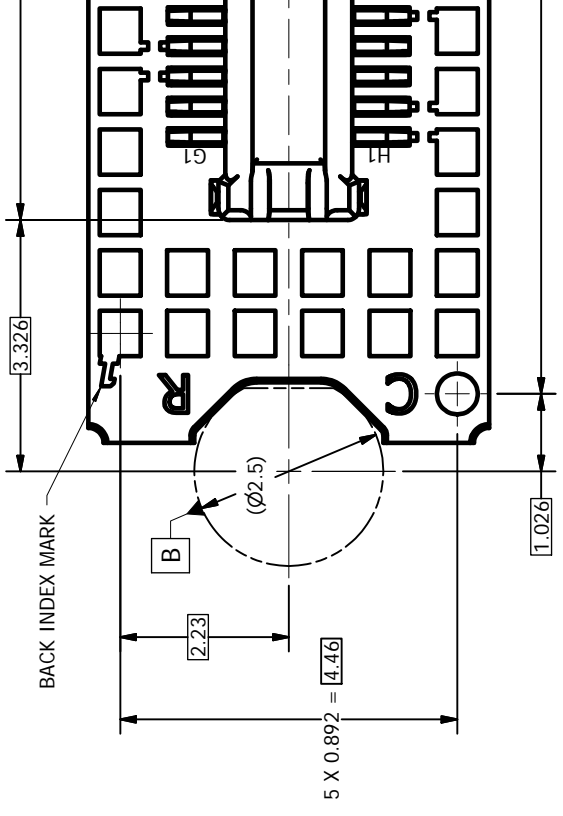
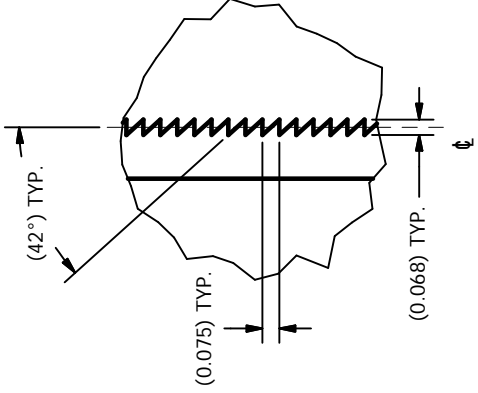
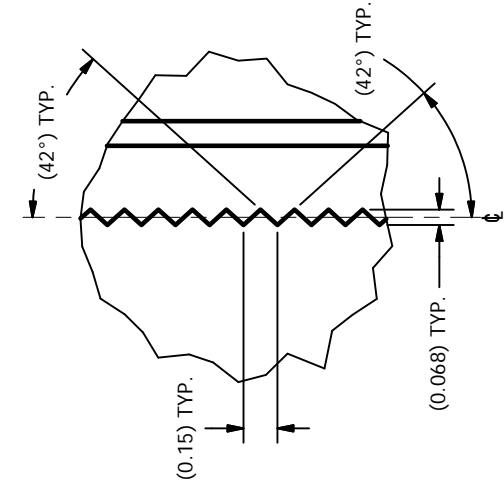
VIEW B
DATUMS A, B, C, AND E
(FROM SHEET 1)



| | | | | |
|---|---|---|---|---|
| 8 | 7 | 6 | 5 | 4 |
| D | C | B | A | |



VIEW E
WINDOW AND ACTIVE ARRAY
(FROM SHEET 1)



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