DLP3010 0.3 720p DMD

1 Features

- 0.3-Inch (7.93-mm) Diagonal Micromirror Array
  - 1280 × 720 Array of Aluminum Micrometer-Sized Mirrors, in an Orthogonal Layout
  - 5.4-µm Micromirror Pitch
  - ±17° Micromirror Tilt (Relative to Flat Surface)
  - Side Illumination for Optimal Efficiency and Optical Engine Size
  - Polarization Independent Aluminum Micromirror Surface
- 8-Bit SubLVDS Input Data Bus
- Dedicated DLPC3433 or DLPC3438 Display Controller and DLPA200x/DLPA3000 PMIC/LED Driver for Reliable Operation

2 Applications

- Battery Powered Mobile Accessory HD Projector
- Battery Powered Smart HD Projector
- Digital Signage
- Interactive Surface Projection
- Low-Latency Gaming Display
- Interactive Display

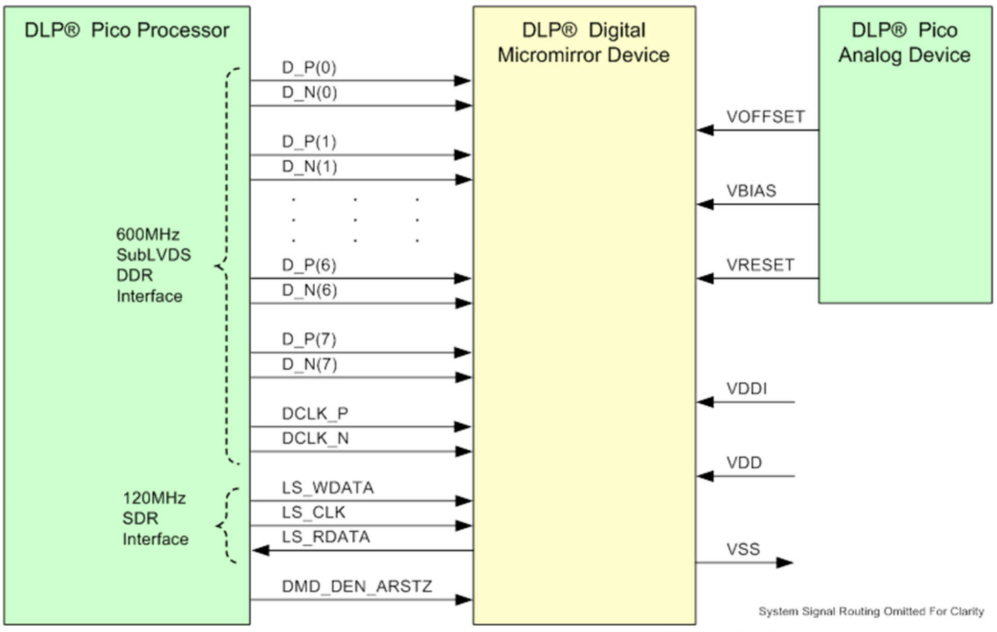
3 Description

The DLP3010 digital micromirror device (DMD) is a digitally controlled micro-opto-electromechanical system (MOEMS) spatial light modulator (SLM). When coupled to an appropriate optical system, the DLP3010 DMD displays a very crisp and high quality image or video. DLP3010 is part of the chipset comprising of the DLP3010 DMD, DLPC3433 or DLPC3438 display controller and DLPA200x/DLPA3000 PMIC/LED driver. The compact physical size of the DLP3010 coupled with the controller and the PMIC/LED driver provides a complete system solution that enables small form factor, low-power, and high-resolution HD displays.

Device Information

PART NUMBER	PACKAGE(1)	BODY SIZE (NOM)
DLP3010	FQK (57)	18.20-mm × 7.00-mm

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



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DLP® DLP3010 0.3 720p Chipset

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4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision B (May 2022) to Revision C (July 2023)	Page
• Added "ILLUMINATION" to *Recommended Operating Conditions*	7
• Updated *Micromirror Array Temperature Calculation*	23
• Added *Micromirror Power Density Calculation*	24

Changes from Revision A (October 2021) to Revision B (May 2022)	Page
• Updated Absolute Maximum Ratings disclosure to the latest TI standard	6
• Updated *Micromirror Array Optical Characteristics*	18
• Added *Third-Party Products Disclaimer*	37

Changes from Revision * (February 2018) to Revision A (October 2021)	Page
• Updated the numbering format for tables, figures, and cross-references throughout the document	1
• Updated $\lvert T_{DELTA} \rvert$ MAX from 30°C to 15°C	7

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5 Pin Configuration and Functions

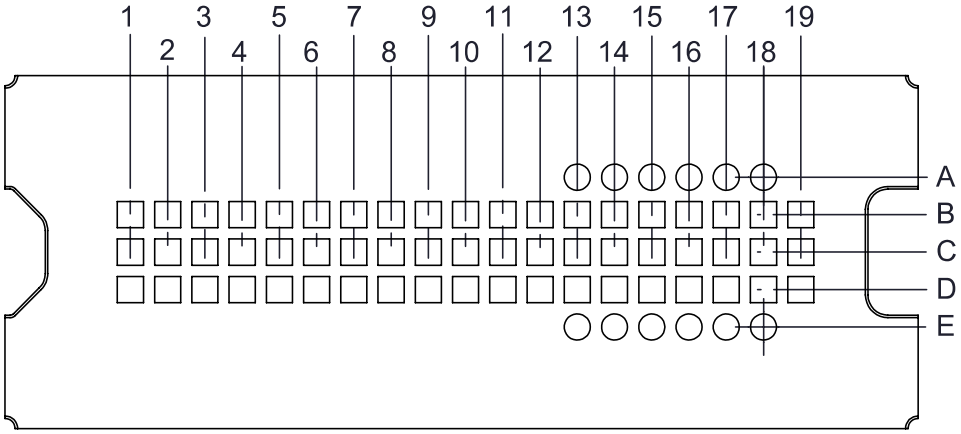


Figure 5-1. FQK Package. 57-Pin LGA. BOTTOM VIEW.

Table 5-1. Pin Functions – Connector Pins

PIN[1]		TYPE	SIGNAL	DATA RATE	DESCRIPTION	PACKAGE NET LENGTH[2] (mm)
NAME	NO.					
DATA INPUTS						
D_N(0)	C9	I	SubLVDS	Double	Data, Negative	10.54
D_P(0)	B9	I	SubLVDS	Double	Data, Positive	10.54
D_N(1)	D10	I	SubLVDS	Double	Data, Negative	13.14
D_P(1)	D11	I	SubLVDS	Double	Data, Positive	13.14
D_N(2)	C11	I	SubLVDS	Double	Data, Negative	14.24
D_P(2)	B11	I	SubLVDS	Double	Data, Positive	14.24
D_N(3)	D12	I	SubLVDS	Double	Data, Negative	14.35
D_P(3)	D13	I	SubLVDS	Double	Data, Positive	14.35
D_N(4)	D4	I	SubLVDS	Double	Data, Negative	5.89
D_P(4)	D5	I	SubLVDS	Double	Data, Positive	5.89
D_N(5)	C5	I	SubLVDS	Double	Data, Negative	5.45
D_P(5)	B5	I	SubLVDS	Double	Data, Positive	5.45
D_N(6)	D6	I	SubLVDS	Double	Data, Negative	8.59
D_P(6)	D7	I	SubLVDS	Double	Data, Positive	8.59
D_N(7)	C7	I	SubLVDS	Double	Data, Negative	7.69
D_P(7)	B7	I	SubLVDS	Double	Data, Positive	7.69
DCLK_N	D8	I	SubLVDS	Double	Clock, Negative	8.10
DCLK_P	D9	I	SubLVDS	Double	Clock, Positive	8.10
CONTROL INPUTS						
LS_WDATA	C12	I	LPSDR[1]	Single	Write data for low-speed interface.	7.16
LS_CLK	C13	I	LPSDR	Single	Clock for low-speed interface.	7.89
DMD_DEN_ARSTZ	C14	I	LPSDR		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.	
LS_RDATA	C15	O	LPSDR	Single	Read data for low-speed interface.	
POWER						
VBIAS[3]	C1	Power			Supply voltage for positive bias level at micromirrors.	
VBIAS[3]	C18	Power				

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Table 5-1. Pin Functions – Connector Pins (continued)

PIN[1]		TYPE	SIGNAL	DATA RATE	DESCRIPTION	PACKAGE NET LENGTH[2] (mm)
NAME	NO.					
VOFFSET[3]	D1	Power			Supply voltage for HVCMOS core logic. Supply voltage for stepped high level at micromirror address electrodes. Supply voltage for offset level at micromirrors.	
VOFFSET[3]	D17	Power				
VRESET	B1	Power			Supply voltage for negative reset level at micromirrors.	
VRESET	B18	Power				
VDD	B6	Power			Supply voltage for LVCMOS core logic. Supply voltage for LPSDR inputs. Supply voltage for normal high level at micromirror address electrodes.	
VDD	B10	Power				
VDD	B19	Power				
VDD[3]	C6	Power				
VDD	C10	Power				
VDD	C19	Power				
VDD	D2	Power				
VDD	D18	Power				
VDD	D19	Power				
VDDI	B2	Power			Supply voltage for SubLVDS receivers.	
VDDI	C2	Power				
VDDI	C3	Power				
VDDI	D3	Power				
VSS	B3	Ground			Common return. Ground for all power.	
VSS	B4	Ground				
VSS	B8	Ground				
VSS	B12	Ground				
VSS	B13	Ground				
VSS	B14	Ground				
VSS	B15	Ground				
VSS	B16	Ground				
VSS	B17	Ground				
VSS	C4	Ground				
VSS	C8	Ground				
VSS	C16	Ground				
VSS	C17	Ground				
VSS	D14	Ground				
VSS	D15	Ground				
VSS	D16	Ground				

(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 FQK ceramic package is 9.8.
Propagation speed = 11.8 / sqrt (9.8) = 3.769 in/ns.
Propagation delay = 0.265 ns/in = 265 ps/in = 10.43 ps/mm.
(3) The following power supplies are all required to operate the DMD: VSS, VDD, VDDI, VOFFSET, VBIAS, VRESET.

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Table 5-2. Pin Functions – Test Pads

NUMBER	SYSTEM BOARD
A13	Do not connect
A14	Do not connect
A15	Do not connect
A16	Do not connect
A17	Do not connect
A18	Do not connect
E13	Do not connect
E14	Do not connect
E15	Do not connect
E16	Do not connect
E17	Do not connect
E18	Do not connect

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6 Specifications

6.1 Absolute Maximum Ratings

See (1)

			MIN	MAX	UNIT
Supply voltage	VDD	Supply voltage for LVCMOS core logic(2) Supply voltage for LPSDR low-speed interface	–0.5	2.3	V
	VDDI	Supply voltage for SubLVDS receivers(2)	–0.5	2.3	
	VOFFSET	Supply voltage for HVCMOS and micromirror electrode(2) (3)	–0.5	11	
	VBIAS	Supply voltage for micromirror electrode(2)	–0.5	19	
	VRESET	Supply voltage for micromirror electrode(2)	–15	0.5	
	|VDDI–VDD|	Supply voltage delta (absolute value)(4)		0.3	
	|VBIAS–VOFFSET|	Supply voltage delta (absolute value)(5)		11	
	|VBIAS–VRESET|	Supply voltage delta (absolute value)(6)		34	
Input voltage	Input voltage for other inputs LPSDR(2)		–0.5	VDD + 0.5	V
	Input voltage 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		10	mA
Clock frequency	f_{clock}	Clock frequency for low-speed interface LS_CLK		130	MHz
	f_{clock}	Clock frequency for high-speed interface DCLK		560	
Environmental	T_{ARRAY} and T_{WINDOW}	Temperature – operational(8)	–20	90	°C
		Temperature – non-operational(8)	–40	90	
	T_{DP}	Dew point temperature – operating and non-operating (non-condensing)		81	
	$\|T_{DELTA}\|$	Absolute temperature delta between any point on the window edge and the ceramic test point TP1(9)		30	

(1) Operation outside the Absolute Maximum Ratings may cause permanent device damage. Absolute Maximum Ratings do not imply functional operation of the device at these or any other conditions beyond those listed under Recommended Operating Conditions. If used outside the Recommended Operating Conditions but within the Absolute Maximum Ratings, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.
(2) 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.
(3) VOFFSET supply transients must fall within specified voltages.
(4) Exceeding the recommended allowable absolute voltage difference between VDDI and VDD may result in excessive current draw.
(5) Exceeding the recommended allowable absolute voltage difference between VBIAS and VOFFSET may result in excessive current draw.
(6) Exceeding the recommended allowable absolute voltage difference between VBIAS and VRESET may result in excessive current draw.
(7) 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.
(8) The highest temperature of the active array (as calculated by the *Section 7.6*) or of any point along the window edge as defined in Figure 7-1. The locations of thermal test points TP2 and TP3 in Figure 7-1 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.
(9) Temperature delta is the highest difference between the ceramic test point 1 (TP1) and anywhere on the window edge as shown in Figure 7-1. The window test points TP2 and TP3 shown in Figure 7-1 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.

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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

(1) The average over time (including storage and operating) that the device is not in the elevated dew point temperature range.
(2) 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)					
V_{DD}	Supply voltage for LVCMOS core logic Supply voltage for LPSDR low-speed interface	1.65	1.8	1.95	V
V_{DDI}	Supply voltage for SubLVDS receivers	1.65	1.8	1.95	V
V_{OFFSET}	Supply voltage for HVCMOS and micromirror electrode(5)	9.5	10	10.5	V
V_{BIAS}	Supply voltage for mirror electrode	17.5	18	18.5	V
V_{RESET}	Supply voltage for micromirror electrode	–14.5	–14	–13.5	V
$\lvert V_{DDI}–V_{DD}\rvert$	Supply voltage delta (absolute value)(6)			0.3	V
$\lvert V_{BIAS}–V_{OFFSET}\rvert$	Supply voltage delta (absolute value)(7)			10.5	V
$\lvert V_{BIAS}–V_{RESET}\rvert$	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		540	MHz
	Duty cycle distortion DCLK	44%		56%	
SUBLVDS INTERFACE(10)					
$\lvert V_{ID}\rvert$	SubLVDS input differential voltage (absolute value), see Figure 6-8 and Figure 6-9	150	250	350	mV
V_{CM}	Common mode voltage, see Figure 6-8, Figure 6-8, and Figure 6-9	700	900	1100	mV
$V_{SUBLVDS}$	SubLVDS voltage, see Figure 6-8 and Figure 6-9	575		1225	mV
Z_{LINE}	Line differential impedance (PWB/trace)	90	100	110	Ω
Z_{IN}	Internal differential termination resistance, see Figure 6-10	80	100	120	Ω
	100-Ω differential PCB trace	6.35		152.4	mm
ENVIRONMENTAL					
T_{ARRAY}	Array temperature – long-term operational(11) (13) (14) (15)	0		40 to 70	°C
	Array temperature – short-term operational, 25 hr maximum(13) (16)	–20		–10	
	Array temperature – short-term operational, 500 hr maximum(13) (16)	–10		0	
	Array temperature – short-term operational, 500 hr maximum(13) (16)	70		75	

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6.4 Recommended Operating Conditions (continued)

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

		MIN	NOM	MAX	UNIT
$\lvert T_{DELTA} \rvert$	Absolute temperature delta between any point on the window edge and the ceramic test point TP1(17)			15	°C
T_{WINDOW}	Window temperature – operational(11) (18)			90	°C
T_{DP-AVG}	Average dew point temperature (non-condensing)(20)			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
ILLUMINATION					
ILL_{UV}	Illumination power at wavelengths < 410 nm(11)			10	mW/cm^2
ILL_{VIS}	Illumination power at wavelengths ≥ 410 nm and ≤ 800 nm(21)			26.1	W/cm^2
ILL_{IR}	Illumination power at wavelengths > 800 nm			10	mW/cm^2
ILL_{BLU}	Illumination power at wavelengths ≥ 410 nm and ≤ 475 nm(21)			8.3	W/cm^2
ILL_{BLU1}	Illumination power at wavelengths ≥ 410 nm and ≤ 445 nm(21)			1.5	W/cm2
ILL_{θ}	Illumination marginal ray angle(12)			55	deg

(1) The following power supplies are all required to operate the DMD: VSS, VDD, VDDI, VOFFSET, VBIAS, and VRESET.
(2) *Section 6.4* are applicable after the DMD is installed in the final product.
(3) The functional performance of the device specified in this data sheet is achieved when operating the device within the limits defined by the *Section 6.4*. No level of performance is implied when operating the device above or below the *Section 6.4* limits.
(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 *Section 6.7*.
(11) Simultaneous exposure of the DMD to the maximum *Section 6.4* for temperature and UV illumination will reduce device lifetime.
(12) 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.
(13) The array temperature cannot be measured directly and must be computed analytically from the temperature measured at test point 1 (TP1) shown in Figure 7-1 and the package thermal resistance using *Section 7.6*.
(14) Per Figure 6-1, 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 *Section 7.8* for a definition of micromirror landed duty cycle.
(15) Long-term is defined as the usable life of the device
(16) Short-term is the total cumulative time over the useful life of the device.
(17) Temperature delta is the highest difference between the ceramic test point 1 (TP1) and anywhere on the window edge shown in Figure 7-1. The window test points TP2 and TP3 shown in Figure 7-1 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.
(18) Window temperature is the highest temperature on the window edge shown in Figure 7-1. The locations of thermal test points TP2 and TP3 in Figure 7-1 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.
(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 average over time (including storage and operating) that the device is not in the elevated dew point temperature range.
(21) The maximum allowable optical power incident on the DMD is limited by the maximum optical power density for each wavelength range specified and the micromirror array temperature (T_{ARRAY}).

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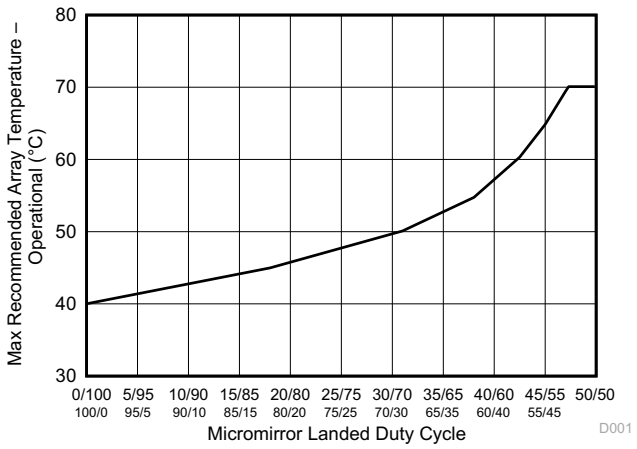


Figure 6-1. Maximum Recommended Array Temperature – Derating Curve

6.5 Thermal Information

THERMAL METRIC[1]		DLP3010 FQK (LGA) 57 PINS	UNIT
Thermal resistance	Active area to test point 1 (TP1)[1]	5.4	°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[3]	MIN	TYP	MAX	UNIT
CURRENT						
I_{DD}	Supply current: VDD[4] [6]	VDD = 1.95 V			60.5	mA
		VDD = 1.8 V		54		
I_{DDI}	Supply current: VDDI[4] [6]	VDDI = 1.95 V			16.5	mA
		VDD = 1.8 V		11.3		
I_{OFFSET}	Supply current: VOFFSET[5] [7]	VOFFSET = 10.5 V			2.2	mA
		VOFFSET = 10 V		1.5		
I_{BIAS}	Supply current: VBIAS[5] [7]	VBIAS = 18.5 V			0.6	mA
		VBIAS = 18 V		0.3		
I_{RESET}	Supply current: VRESET[7]	VRESET = –14.5 V			2.4	mA
		VRESET = –14 V		1.7		
POWER[2]						
P_{DD}	Supply power dissipation: VDD[4] [6]	VDD = 1.95 V			118	mW
		VDD = 1.8 V		97.2		
P_{DDI}	Supply power dissipation: VDDI[4] [6]	VDDI = 1.95 V			32	mW
		VDD = 1.8 V		20		
P_{OFFSET}	Supply power dissipation: VOFFSET[5] [7]	VOFFSET = 10.5 V			23	mW
		VOFFSET = 10 V		15		
P_{BIAS}	Supply power dissipation: VBIAS[5] [7]	VBIAS = 18.5 V			11	mW
		VBIAS = 18 V		6		
P_{RESET}	Supply power dissipation: VRESET[7]	VRESET = –14.5 V			35	mW
		VRESET = –14 V		24		
P_{TOTAL}	Supply power dissipation: Total			162.2	219	mW
LPSDR INPUT[8]						
$V_{IH(DC)}$	DC input high voltage[10]		0.7 × VDD		VDD + 0.3	V
$V_{IL(DC)}$	DC input low voltage[10]		–0.3		0.3 × VDD	V
$V_{IH(AC)}$	AC input high voltage[10]		0.8 × VDD		VDD + 0.3	V
$V_{IL(AC)}$	AC input low voltage[10]		–0.3		0.2 × VDD	V
ΔV_T	Hysteresis ($V_{T+} – V_{T–}$)	See Figure 6-10	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[9]						
V_{OH}	DC output high voltage	I_{OH} = –2 mA	0.8 × VDD			V

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6.6 Electrical Characteristics (continued)

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

PARAMETER		TEST CONDITIONS(3)	MIN	TYP	MAX	UNIT
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			10	
C_{OUT}	Output capacitance	f = 1 MHz			10	pF
C_{RESET}	Reset group capacitance	f = 1 MHz; (720 × 160) micromirrors	200		220	pF

(1) Device electrical characteristics are over *Recommended Operating Conditions* unless otherwise noted.
(2) The following power supplies are all required to operate the DMD: VSS, VDD, VDDI, VOFFSET, VBIAS, VRESET.
(3) All voltage values are with respect to the ground pins (VSS).
(4) To prevent excess current, the supply voltage delta |VDDI – VDD| must be less than specified limit.
(5) To prevent excess current, the supply voltage delta |VBIAS – VOFFSET| must be less than specified limit.
(6) Supply power dissipation based on non–compressed commands and data.
(7) Supply power dissipation based on 3 global resets in 200 µs.
(8) LPSDR specifications are for pins LS_CLK and LS_WDATA.
(9) LPSDR specification is for pin LS_RDATA.
(10) 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.

6.7 Timing Requirements

Device electrical characteristics are over *Section 6.4* unless otherwise noted.

			MIN	NOM	MAX	UNIT
LPSDR						
t_r	Rise slew rate(1)	(30% to 80%) × VDD, see Figure 6-3	1		3	V/ns
t_f	Fall slew rate(1)	(70% to 20%) × VDD, see Figure 6-3	1		3	V/ns
t_r	Rise slew rate(2)	(20% to 80%) × VDD, see Figure 6-3	0.25			V/ns
t_f	Fall slew rate(2)	(80% to 20%) × VDD, see Figure 6-3	0.25			V/ns
t_c	Cycle time LS_CLK,	See Figure 6-2	7.7	8.3		ns
$t_{W(H)}$	Pulse duration LS_CLK high	50% to 50% reference points, see Figure 6-2	3.1			ns
$t_{W(L)}$	Pulse duration LS_CLK low	50% to 50% reference points, see Figure 6-2	3.1			ns
t_{su}	Setup time	LS_WDATA valid before LS_CLK ↑, see Figure 6-2	1.5			ns
t_h	Hold time	LS_WDATA valid after LS_CLK ↑, see Figure 6-2	1.5			ns
t_{WINDOW}	Window time(1) (4)	Setup time + hold time, see Figure 6-2	3			ns
$t_{DERATING}$	Window time derating(1) (4)	For each 0.25-V/ns reduction in slew rate below 1 V/ns, see Figure 6-5		0.35		ns
SubLVDS						
t_r	Rise slew rate	20% to 80% reference points, see Figure 6-4	0.7	1		V/ns
t_f	Fall slew rate	80% to 20% reference points, see Figure 6-4	0.7	1		V/ns
t_c	Cycle time DCLK,	See Figure 6-6	1.79	1.85		ns
$t_{W(H)}$	Pulse duration DCLK high	50% to 50% reference points, see Figure 6-6	0.79			ns
$t_{W(L)}$	Pulse duration DCLK low	50% to 50% reference points, see Figure 6-6	0.79			ns
t_{su}	Setup time	D(0:3) valid before DCLK ↑ or DCLK ↓, see Figure 6-6				
t_h	Hold time	D(0:3) valid after DCLK ↑ or DCLK ↓, see Figure 6-6				
t_{WINDOW}	Window time	Setup time + hold time, see Figure 6-6 and Figure 6-7			0.3	ns

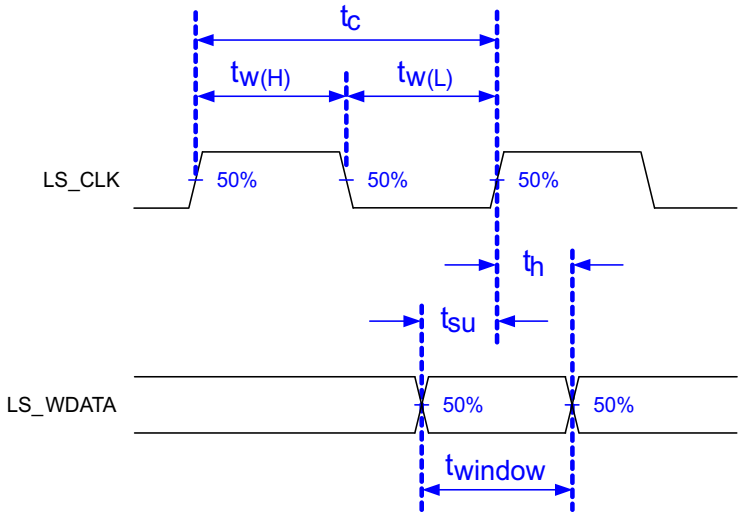
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6.7 Timing Requirements (continued)

Device electrical characteristics are over *Section 6.4* unless otherwise noted.

			MIN	NOM	MAX	UNIT
$t_{LVDS-ENABLE+REFGEN}$	Power-up receiver(3)				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 6-3.
(2) Specification is for DMD_DEN_ARSTZ pin. Refer to LPSDR input rise and fall slew rate in Figure 6-3.
(3) Specification is for SubLVDS receiver time only and does not take into account commanding and latency after commanding.
(4) Window time derating example: 0.5-V/ns slew rate increases the window time by 0.7 ns, from 3 ns to 3.7 ns.



Low-speed interface is LPSDR and adheres to the *Section 6.6* and AC/DC Operating Conditions table in JEDEC Standard No. 209B, *Low Power Double Data Rate (LPDDR)* JESD209B.

Figure 6-2. LPSDR Switching Parameters

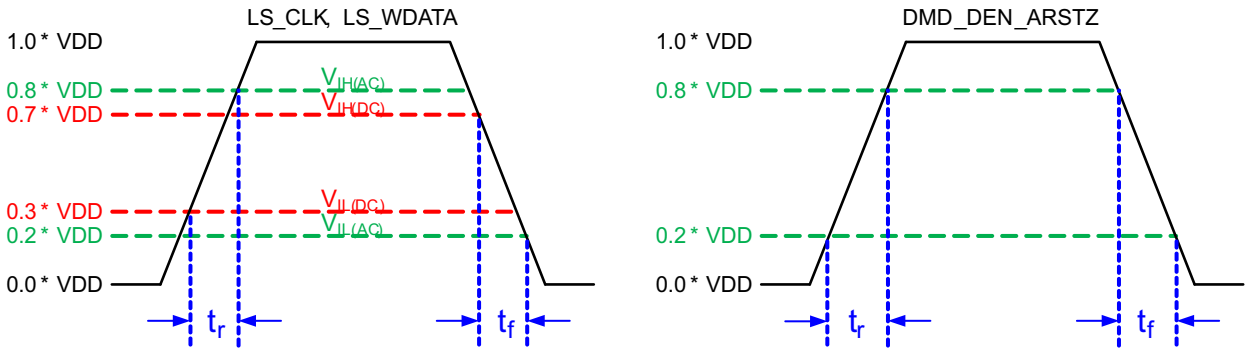


Figure 6-3. LPSDR Input Rise and Fall Slew Rate

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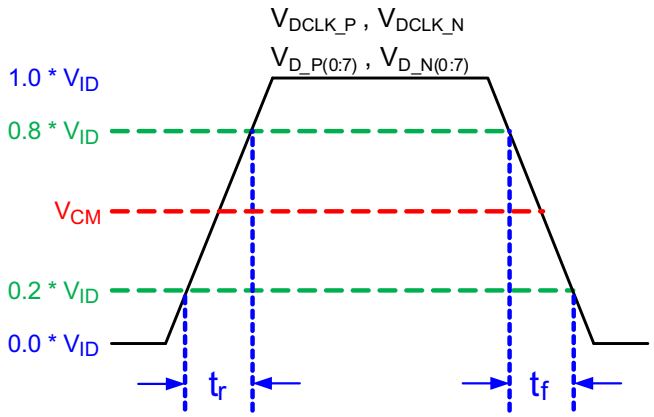


Figure 6-4. SubLVDS Input Rise and Fall Slew Rate

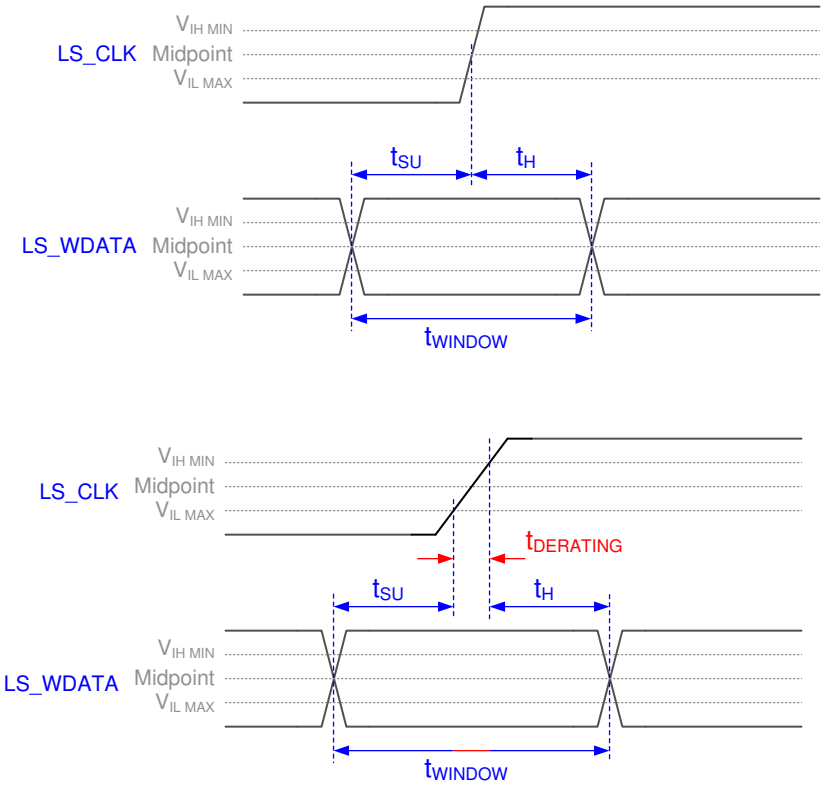


Figure 6-5. Window Time Derating Concept

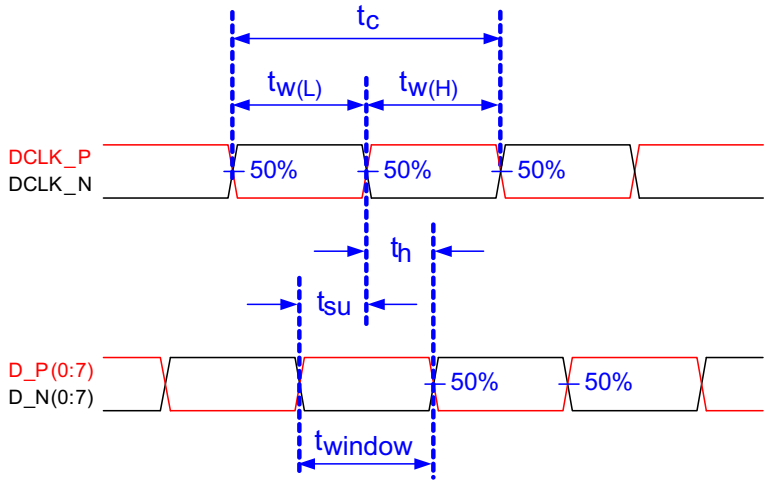
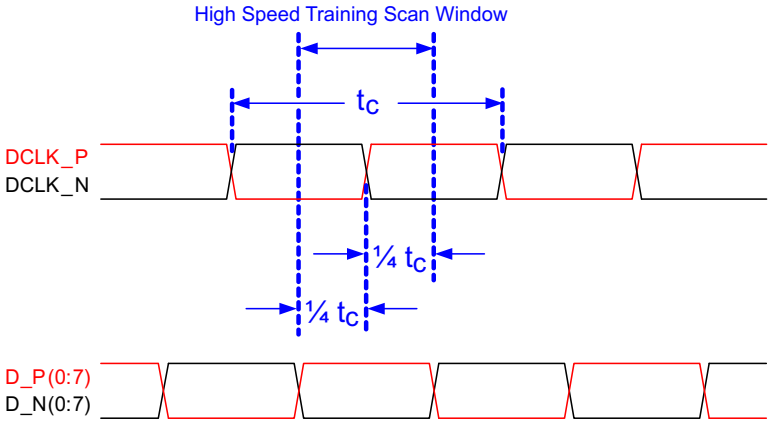


Figure 6-6. SubLVDS Switching Parameters



Note: Refer to *Section 7.3.3* for details.

Figure 6-7. High-Speed Training Scan Window

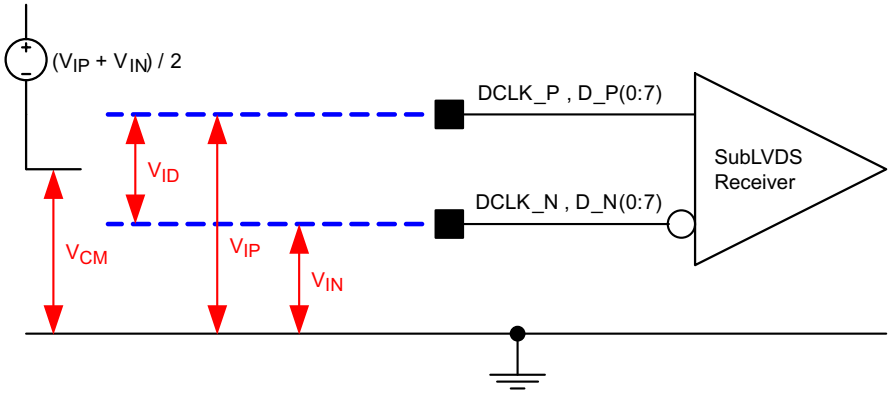


Figure 6-8. SubLVDS Voltage Parameters

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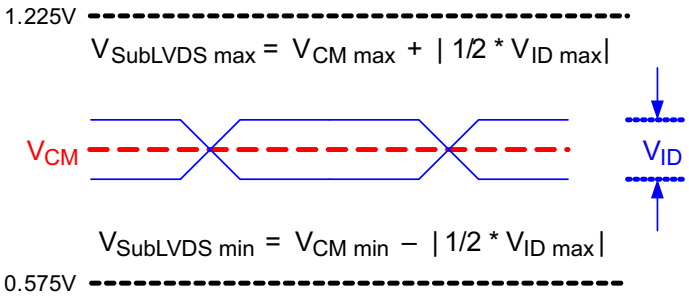


Figure 6-9. SubLVDS Waveform Parameters

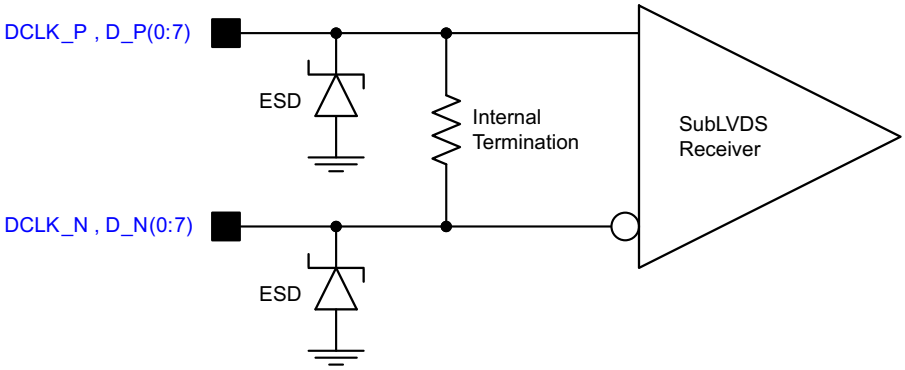


Figure 6-10. SubLVDS Equivalent Input Circuit

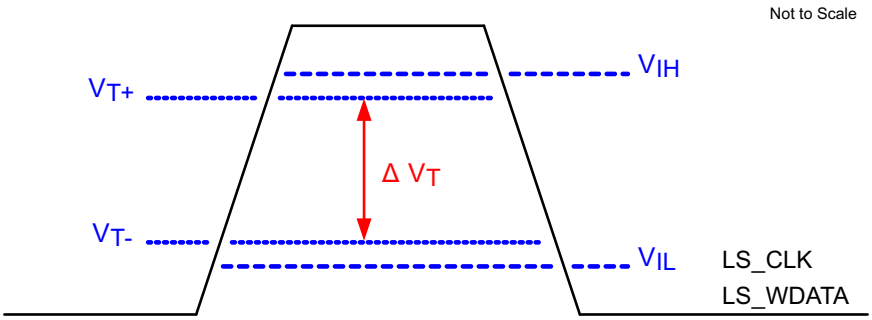


Figure 6-11. LPSDR Input Hysteresis

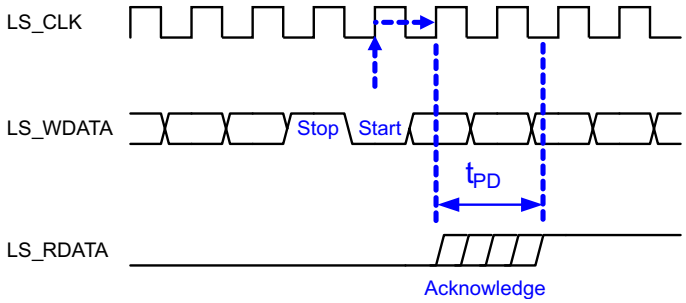
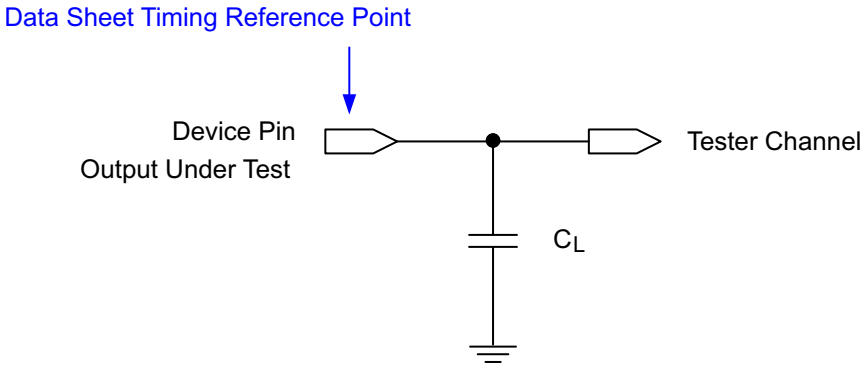


Figure 6-12. LPSDR Read Out



See *Section 7.3.4* for more information.

Figure 6-13. Test Load Circuit for Output Propagation Measurement

6.8 Switching Characteristics

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{PD}	Output propagation, clock to Q, rising edge of LS_CLK input to LS_RDATA output, see Figure 6-12	C_L = 5 pF			11.1	ns
		C_L = 10 pF			11.3	
		C_L = 85 pF			15	
	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:	Electrical interface area, see Figure 6-14			125	N
	Clamping and thermal interface area, see Figure 6-14			67	

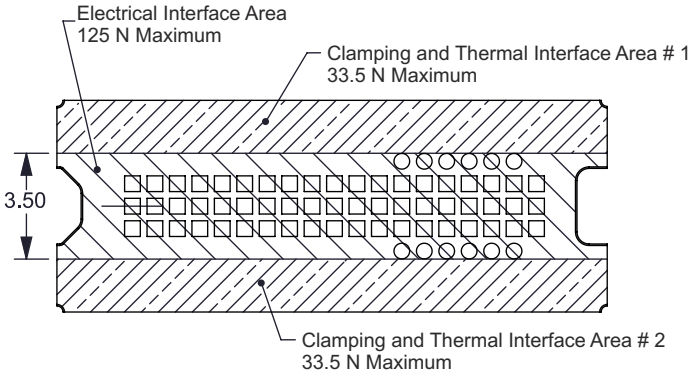


Figure 6-14. System Interface Loads

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6.10 Micromirror Array Physical Characteristics

PARAMETER		VALUE	UNIT
Number of active columns	See Figure 6-15	1280	micromirrors
Number of active rows	See Figure 6-15	720	micromirrors
Micromirror (pixel) pitch	See Figure 6-16	5.4	µm
Micromirror active array width	Micromirror pitch × number of active columns; see Figure 6-15	6.912	mm
Micromirror active array height	Micromirror pitch × number of active rows; see Figure 6-15	3.888	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.

Not To Scale

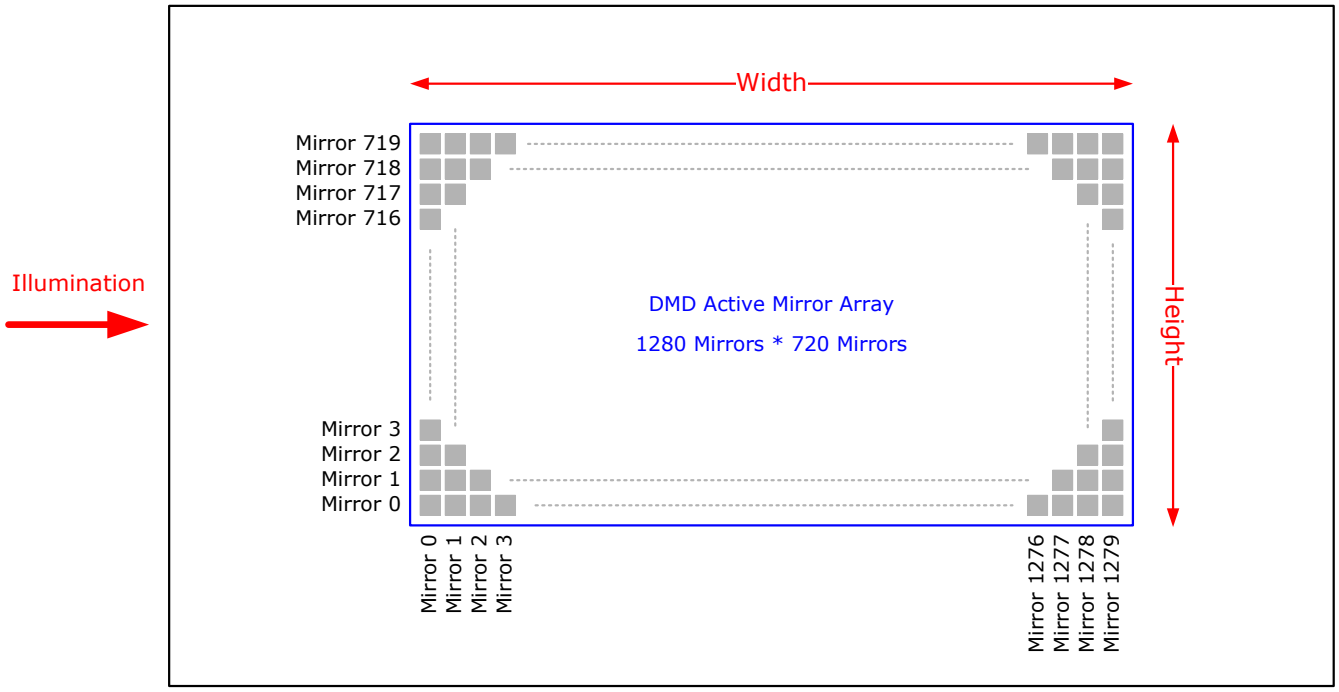


Figure 6-15. Micromirror Array Physical Characteristics

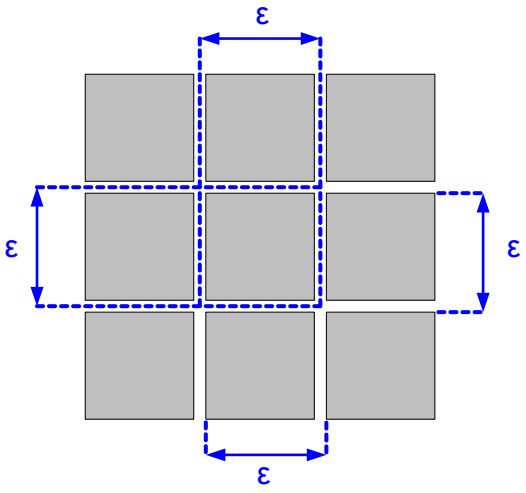


Figure 6-16. Mirror (Pixel) Pitch

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6.11 Micromirror Array Optical Characteristics

PARAMETER		TEST CONDITIONS	MIN	NOM	MAX	UNIT
Micromirror tilt angle		DMD landed state(1)		17		degree
Micromirror tilt angle tolerance(2) (3) (4) (5)			–1.4		1.4	degree
Micromirror tilt direction (6) (7)		Landed ON state		180		degree
		Landed OFF state		270		
Micromirror crossover time(8)		Typical performance		1	3	µs
Micromirror switching time(9)		Typical performance	10			
Image performance (10)	Bright pixel(s) in active area (11)	Gray 10 Screen (12)			0	micromirrors
	Bright pixel(s) in the POM (13)	Gray 10 Screen (12)			1	
	Dark pixel(s) in the active area (14)	White Screen			4	
	Adjacent pixel(s) (15)	Any Screen			0	
	Unstable pixel(s) in active area (16)	Any Screen			0	

(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. See Figure 6-17.
(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) Conditions of Acceptance: All DMD image quality returns will be evaluated using the following projected image test conditions:
Test set degamma shall be linear
Test set brightness and contrast shall be set to nominal
The diagonal size of the projected image shall be a minimum of 20 inches
The projections screen shall be 1X gain
The projected image shall be inspected from a 38 inch minimum viewing distance
The image shall be in focus during all image quality tests
(11) Bright pixel definition: A single pixel or mirror that is stuck in the ON position and is visibly brighter than the surrounding pixels
(12) Gray 10 screen definition: All areas of the screen are colored with the following settings:
Red = 10/255
Green = 10/255
Blue = 10/255
(13) POM definition: Rectangular border of off-state mirrors surrounding the active area
(14) Dark pixel definition: A single pixel or mirror that is stuck in the OFF position and is visibly darker than the surrounding pixels
(15) Adjacent pixel definition: Two or more stuck pixels sharing a common border or common point, also referred to as a cluster
(16) Unstable pixel definition: A single pixel or mirror that does not operate in sequence with parameters loaded into memory. The unstable pixel appears to be flickering asynchronously with the image

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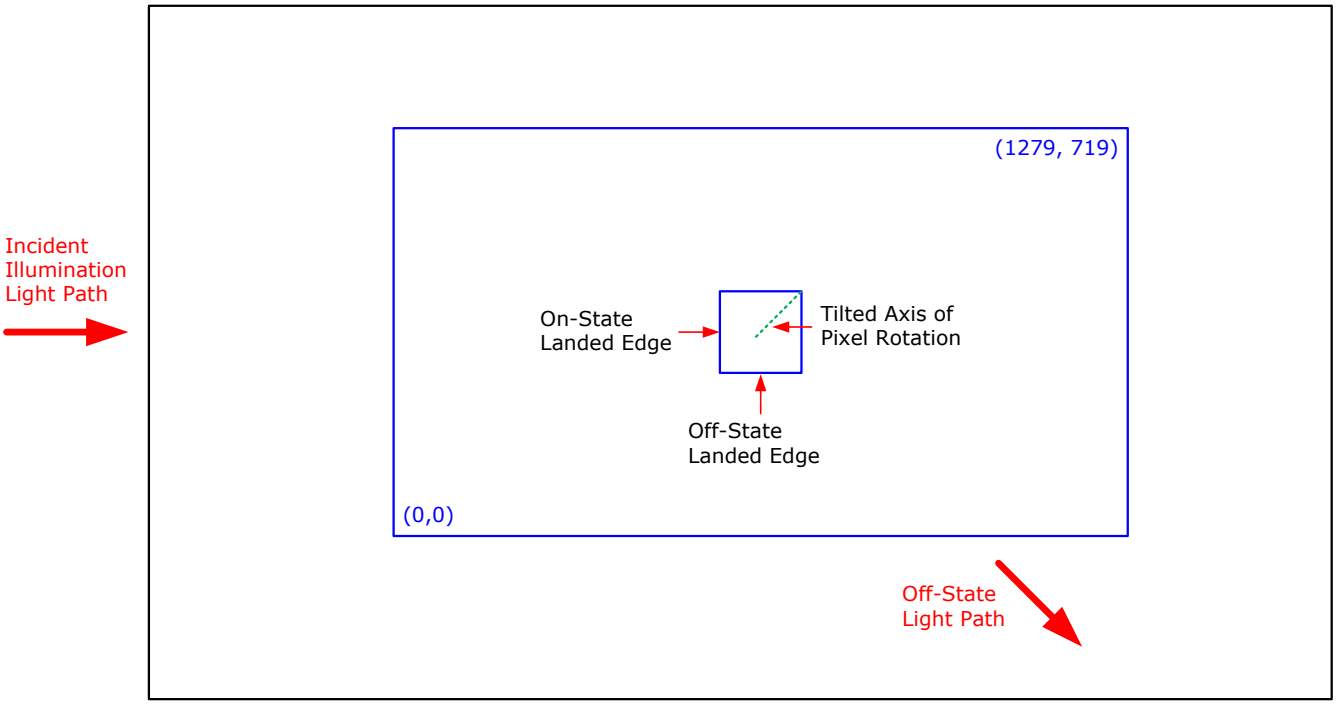


Figure 6-17. Landed Pixel Orientation and Tilt

6.12 Window Characteristics

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

(1) See the package mechanical characteristics for details regarding the size and location of the window aperture.
(2) The active area of the DLP3010 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.
(3) See *Optical Interface and System Image Quality Considerations* for more information.

6.13 Chipset Component Usage Specification

Note

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

The DLP3010 is a component of one or more DLP® chipsets. Reliable function and operation of the DLP3010 requires that it be used in conjunction with the other components of the applicable DLP chipset, including

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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.

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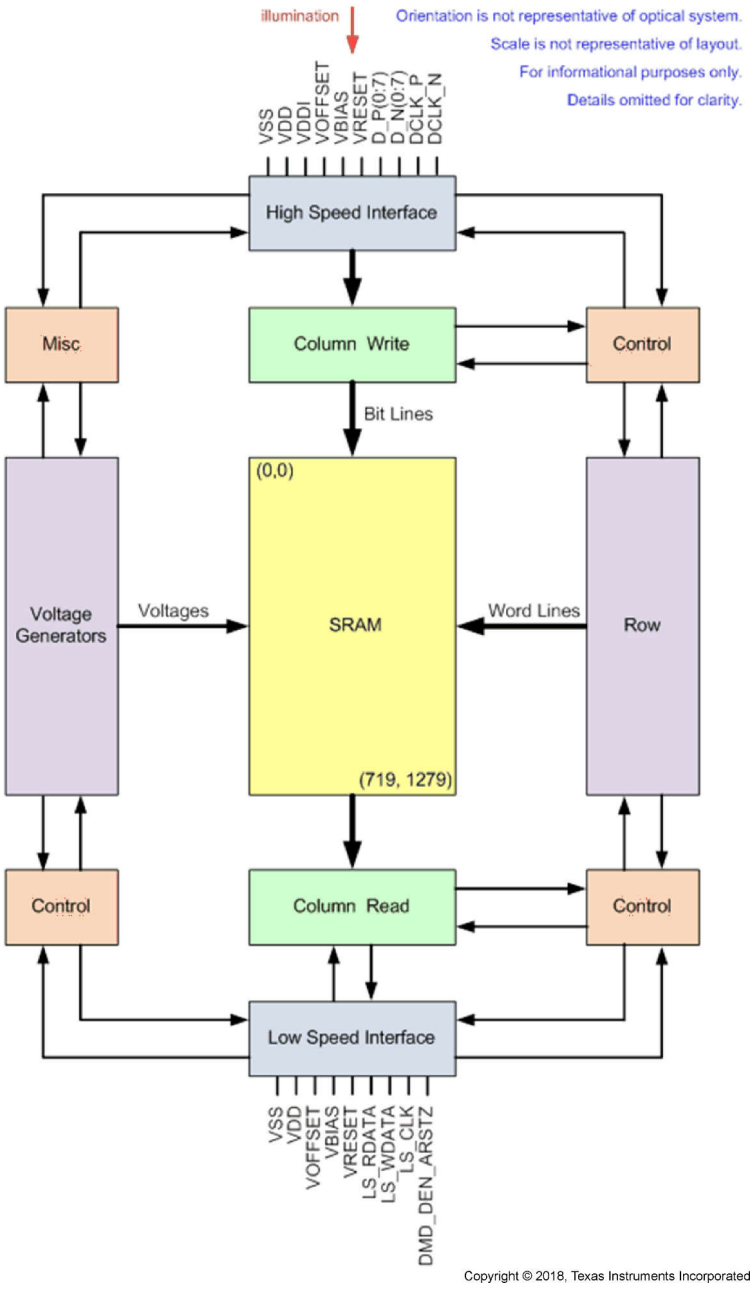
7 Detailed Description

7.1 Overview

The DLP3010 is a 0.3-in diagonal spatial light modulator of aluminum micromirrors. Pixel array size is 1280 columns by 720 rows in a square grid pixel arrangement. The electrical interface is sub low voltage differential signaling (SubLVDS) data.

DLP3010 is part of the chipset comprising of the DLP3010 DMD, DLPC3433 or DLPC3438 display controller and DLPA200x/DLPA3000 PMIC/LED driver. To ensure reliable operation, DLP3010 DMD must always be used with DLPC3433 or DLPC3438 display controller and DLPA200x/DLPA3000 PMIC/LED driver.

7.2 Functional Block Diagram



A. Details omitted for clarity.

7.3 Feature Description

7.3.1 Power Interface

The power management IC, DLPA200x/DLPA3000, contains 3 regulated DC supplies for the DMD reset circuitry: VBIAS, VRESET and VOFFSET, as well as the two regulated DC supplies for the DLPC3433 or DLPC3438 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 is composed of differential SubLVDS receivers for inputs, with a dedicated clock.

7.3.4 Timing

The data sheet provides timing at the device pin. For output timing analysis, the tester pin electronics and its transmission line effects must be taken into account. Figure 6-13 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. System designers should use IBIS or other simulation tools to correlate the timing reference load to a system environment. The load capacitance value stated is only for characterization and measurement of AC timing signals. 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 DLPC3433 or DLPC3438 controller. See the DLPC3430 or DLPC3435 controller data sheet or contact a TI applications engineer.

7.5 Optical Interface and System Image Quality Considerations

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 Numerical Aperture and Stray Light Control

The angle defined by the numerical aperture of the illumination and projection optics at the DMD optical area should be the same. This angle should not exceed the nominal device micromirror tilt angle unless appropriate apertures are added in the illumination and/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 could occur.

7.5.2 Pupil Match

TI's 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's border and/or active area, which may require additional system apertures to control, especially if the numerical aperture of the system exceeds the pixel tilt angle.

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7.5.3 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. The illumination optical system should be designed to limit 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 system's optical architecture, overfill light may have to be further reduced below the suggested 10% level in order to be acceptable.

7.6 Micromirror Array Temperature Calculation

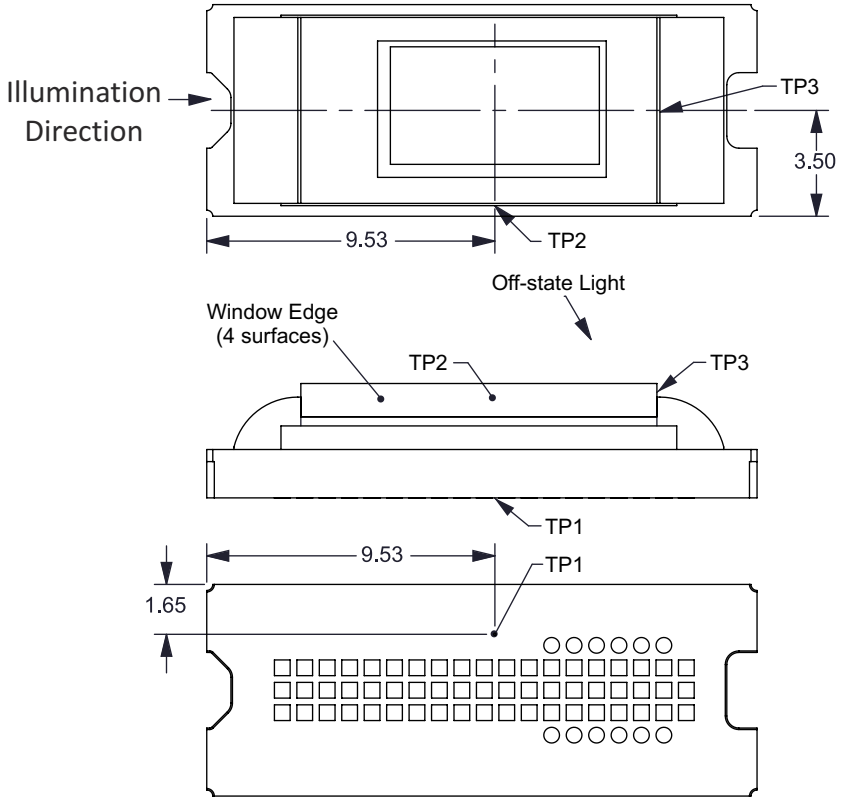


Figure 7-1. DMD Thermal Test Points

Micromirror array temperature cannot be measured directly, therefore it must be computed analytically from measurement points on the outside of the package, the package thermal resistance, the electrical power, and the illumination heat load. The relationship between array temperature and the reference ceramic temperature (thermal test TP1 in Figure 7-1) is provided by the following equations:

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

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

where

- T_{ARRAY} = Computed array temperature (°C)
- $T_{CERAMIC}$ = Measured ceramic temperature (°C) (TP1 location)
- $R_{ARRAY\text{-}TO\text{-}CERAMIC}$ = Thermal resistance of package specified in *Section 6.5* from array to ceramic TP1 (°C/Watt)

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- Q_{ARRAY} = Total DMD power on the array (W) (electrical + absorbed)
- $Q_{ELECTRICAL}$ = Nominal electrical power (W)
- $Q_{INCIDENT}$ = Incident illumination optical power (W)
- $Q_{ILLUMINATION}$ = (DMD average thermal absorptivity × $Q_{INCIDENT}$) (W)
- DMD average thermal absorptivity = 0.4

The 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 0.10 Watts. The absorbed power from the illumination source is variable and depends on the operating state of the micromirrors and the intensity of the light source. The equations shown above are valid for a single chip or multichip DMD system. It assumes an illumination distribution of 83.7% on the active array, and 16.3% on the array border.

The sample calculation for a typical projection application is as follows:

$Q_{INCIDENT}$ = 2.2 W (measured)

$T_{CERAMIC}$ = 55.0°C (measured)

$Q_{ELECTRICAL}$ = 0.10 W

Q_{ARRAY} = 0.10 W + (0.40 × 2.2 W) = 0.98 W

T_{ARRAY} = 55.0°C + (0.98 W × 5.4°C/W) = 60.3°C

7.7 Micromirror Power Density Calculation

The calculation of the optical power density of the illumination on the DMD in the different wavelength bands uses the total measured optical power on the DMD, percent illumination overfill, area of the active array, and ratio of the spectrum in the wavelength band of interest to the total spectral optical power.

- $ILL_{UV} = [OP_{UV\text{-}RATIO} \times Q_{INCIDENT}] \times 1000 \div A_{ILL}$ (mW/cm^2)
- $ILL_{VIS} = [OP_{VIS\text{-}RATIO} \times Q_{INCIDENT}] \div A_{ILL}$ (W/cm^2)
- $ILL_{IR} = [OP_{IR\text{-}RATIO} \times Q_{INCIDENT}] \times 1000 \div A_{ILL}$ (mW/cm^2)
- $ILL_{BLU} = [OP_{BLU\text{-}RATIO} \times Q_{INCIDENT}] \div A_{ILL}$ (W/cm^2)
- $ILL_{BLU1} = [OP_{BLU1\text{-}RATIO} \times Q_{INCIDENT}] \div A_{ILL}$ (W/cm^2)
- $A_{ILL} = A_{ARRAY} \div (1 - OV_{ILL})$ (cm^2)

where:

- ILL_{UV} = UV illumination power density on the DMD (mW/cm^2)
- ILL_{VIS} = VIS illumination power density on the DMD (W/cm^2)
- ILL_{IR} = IR illumination power density on the DMD (mW/cm^2)
- ILL_{BLU} = BLU illumination power density on the DMD (W/cm^2)
- ILL_{BLU1} = BLU1 illumination power density on the DMD (W/cm^2)
- A_{ILL} = illumination area on the DMD (cm^2)
- $Q_{INCIDENT}$ = total incident optical power on DMD (W) (measured)
- A_{ARRAY} = area of the array (cm ^{2}) (data sheet)
- OV_{ILL} = percent of total illumination on the DMD outside the array (%) (optical model)

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- $OP_{UV-RATIO}$ = ratio of the optical power for wavelengths <410 nm to the total optical power in the illumination spectrum (spectral measurement)
- $OP_{VIS-RATIO}$ = ratio of the optical power for wavelengths ≥410 and ≤800 nm to the total optical power in the illumination spectrum (spectral measurement)
- $OP_{IR-RATIO}$ = ratio of the optical power for wavelengths >800 nm to the total optical power in the illumination spectrum (spectral measurement)
- $OP_{BLU-RATIO}$ = ratio of the optical power for wavelengths ≥410 and ≤475 nm to the total optical power in the illumination spectrum (spectral measurement)
- $OP_{BLU1-RATIO}$ = ratio of the optical power for wavelengths ≥410 and ≤445 nm to the total optical power in the illumination spectrum (spectral measurement)

The illumination area varies and depends on the illumination overfill. The total illumination area on the DMD is the array area and overfill area around the array. The optical model is used to determine the percent of the total illumination on the DMD that is outside the array (OV_{ILL}) and the percent of the total illumination that is on the active array. From these values the illumination area (A_{ILL}) is calculated. The illumination is assumed to be uniform across the entire array.

From the measured illumination spectrum, the ratio of the optical power in the wavelength bands of interest to the total optical power is calculated.

Sample calculation:

$Q_{INCIDENT}$ = 2.20 W (measured)

A_{ARRAY} = (0.6912× 0.3888) = 0.2687 cm^2 (data sheet)

OV_{ILL} = 16.3% (optical model)

$OP_{UV-RATIO}$ = 0.00021 (spectral measurement)

$OP_{VIS-RATIO}$ = 0.99977 (spectral measurement)

$OP_{IR-RATIO}$ = 0.00002 (spectral measurement)

$OP_{BLU-RATIO}$ = 0.28100 (spectral measurement)

$OP_{BLU1-RATIO}$ = 0.03200 (spectral measurement)

A_{ILL} = 0.2687 ÷ (1 - 0.163) = 0.3211 cm^2

ILL_{UV} = [0.00021 × 2.20W] × 1000 ÷ 0.3211 cm^2 = 1.439 mW/cm^2

ILL_{VIS} = [0.99977 × 2.20W] ÷ 0.3211 cm^2 = 6.85 W/cm^2

ILL_{IR} = [0.00002 × 2.20W] × 1000 ÷ 0.3211 cm^2 = 0.137 mW/cm^2

ILL_{BLU} = [0.28100 × 2.20W] ÷ 0.3211 cm^2 = 1.93 W/cm^2

ILL_{BLU1} = [0.03200 × 2.20W] ÷ 0.3211 cm^2 = 0.219 W/cm^2

7.8 Micromirror Landed-On/Landed-Off Duty Cycle

7.8.1 Definition of Micromirror Landed-On/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.

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As an example, a landed duty cycle of 100/0 indicates that the referenced pixel is in the ON state 100% of the time (and in the OFF state 0% of the time), whereas 0/100 would indicate that the pixel is in the OFF state 100% of the time. Likewise, 50/50 indicates that the pixel is ON 50% of the time and OFF 50% of the time.

Note that when assessing landed duty cycle, the time spent switching from one state (ON or OFF) to the other state (OFF or ON) is considered negligible and is thus ignored.

Since a micromirror can only be landed in one state or the other (ON or OFF), the two numbers (percentages) always add to 100.

7.8.2 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.

Note that it is the symmetry/asymmetry of the landed duty cycle that is of relevance. 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.

7.8.3 Landed Duty Cycle and Operational DMD Temperature

Operational DMD temperature and landed duty cycle interact to affect the DMD's usable life, and this interaction can be exploited to reduce the impact that an asymmetrical landed duty cycle has on the DMD's usable life. This is quantified in the de-rating curve shown in Figure 6-1. The importance of this curve is that:

- 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 given long-term average landed duty cycle.

7.8.4 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 follows from the image content being displayed by that pixel.

For example, in the simplest case, when displaying pure-white on a given pixel for a given time period, that pixel will experience a 100/0 landed duty cycle during that time period. Likewise, when displaying pure-black, the pixel will experience 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 grayscale value, as shown in Table 7-1.

Table 7-1. Grayscale Value and Landed Duty Cycle

Grayscale Value	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

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Table 7-1. Grayscale Value and Landed Duty Cycle (continued)

Grayscale Value	Landed Duty Cycle
80%	80/20
90%	90/10
100%	100/0

Accounting for color rendition (but still ignoring image processing) 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” is 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 landed duty cycle of a given pixel can be calculated as follows:

Landed Duty Cycle = (Red_Cycle_% × Red_Scale_Value) + (Green_Cycle_% × Green_Scale_Value) + (Blue_Cycle_% × Blue_Scale_Value)

where

Red_Cycle_%, Green_Cycle_%, and Blue_Cycle_% represent the percentage of the frame time that red, green, and blue are displayed (respectively) to achieve the desired white point.

For example, assume that the red, green and blue color cycle times are 50%, 20%, and 30% respectively (in order to achieve the desired white point), then the landed duty cycle for various combinations of red, green, blue color intensities would be as shown in Table 7-2.

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Table 7-2. Example Landed Duty Cycle for Full-Color Pixels

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

Red Scale Value	Green Scale Value	Blue Scale Value	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 account for in estimating the landed duty cycle is any applied image processing. Within the DLP Controller DLPC3433/DLPC3438, the two functions which affect landed duty cycle are Gamma and IntelliBright™.

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

In the DLPC3430/DLPC3435 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 7-2.

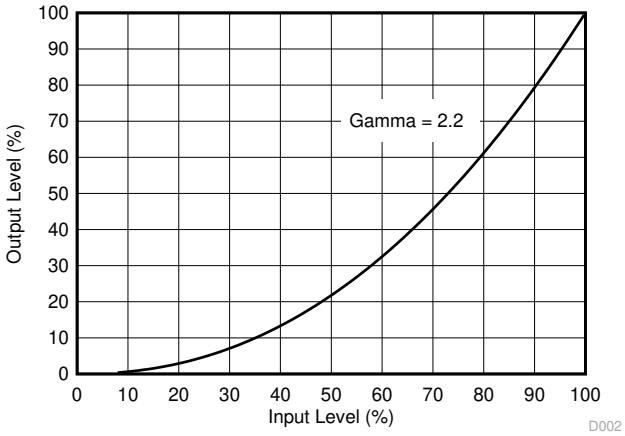


Figure 7-2. Example of Gamma = 2.2

From Figure 7-2, if the grayscale value of a given input pixel is 40% (before gamma is applied), then grayscale value will be 13% after gamma is applied. Therefore, since gamma has a direct impact on displayed grayscale level of a pixel, it also has a direct impact on the landed duty cycle of a pixel.

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

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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.

Consideration must also be given to any image processing which occurs before the DLPC3433 or DLPC3438 controller.

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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, as well as validating and testing their design implementation to confirm system functionality.

8.1 Application Information

CAUTION

The DLP3010 DMD has mandatory software requirements. Refer to *Software Requirements for TI DLP® Pico™ TRP Digital Micromirror Devices* application report for additional information.

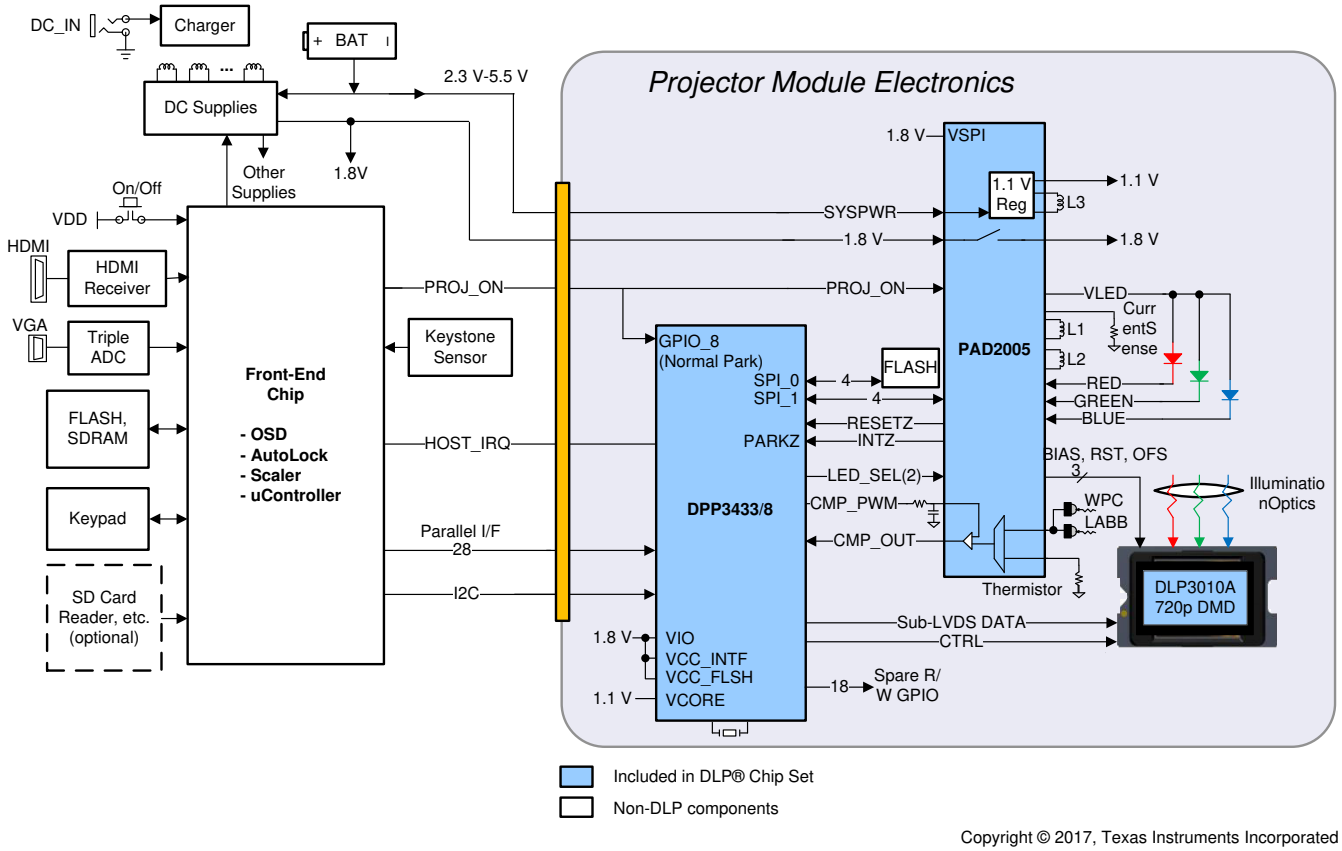
The DMDs are spatial light modulators which reflect incoming light from an illumination source to one of two directions, with the primary direction being into a projection or collection optic. Each application is derived primarily from the optical architecture of the system and the format of the data coming into the DLPC3433/DLPC3438 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 of interest include projection embedded in display devices like smartphones, tablets, cameras, and camcorders. Other applications include wearable (near-eye) displays, battery powered mobile accessory, interactive display, low-latency gaming display, and digital signage.

DMD power-up and power-down sequencing is strictly controlled by the DLPA200x/DLPA3000. Refer to *Power Supply Recommendations* for power-up and power-down specifications. To ensure reliable operation, DLP3010 DMD must always be used with DLPC3433 or DLPC3438 display controller and DLPA200x/DLPA3000 PMIC/LED driver.

8.2 Typical Application

A common application when using the DLPC3433/DLPC3438 is for creating a pico-projector that can be used as an accessory to a smartphone, tablet or a laptop. The DLPC3433/DLPC3438 in the pico-projector receives images from a multimedia front end within the product as shown in the following figure.

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Figure 8-1. Typical Application Diagram

8.2.1 Design Requirements

A pico-projector is created by using a DLP chip set comprised of DLP3010 DMD, a DLPC3433/DLPC3438 controller and a DLPA200x/DLPA3000 PMIC/LED driver. The DLPC3433/DLPC3438 controller does the digital image processing, the DLPA200x/DLPA3000 provides the needed analog functions for the projector, and DLP3010 DMD is the display device for producing the projected image.

In addition to the three DLP chips in the chip set, other chips may be needed. At a minimum a Flash part is needed to store the software and firmware to control the DLPC3433/DLPC3438 controller.

The illumination light that is applied to the DMD is typically from red, green, and blue LEDs. These 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.

For connecting the DLPC3433/DLPC3438 controller to the multimedia front end for receiving images, parallel interface is used. When the parallel interface is used, I2C should be connected to the multimedia front end for sending commands to the DLPC3433/DLPC3438 controller and configuring the DLPC3433/DLPC3438 controller for different features.

8.2.2 Detailed Design Procedure

For connecting together the DLPC3433/DLPC3438 controller, the DLPA200x/DLPA3000, and the DLP3010 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.

8.2.3 Application Curve

As the LED currents that are driven time-sequentially through the red, green, and blue LEDs are increased, the brightness of the projector increases. This increase is somewhat non-linear, and the curve for typical white screen lumens changes with LED currents is as shown in Figure 8-2. For the LED currents shown, it's assumed that the same current amplitude is applied to the red, green, and blue LEDs.

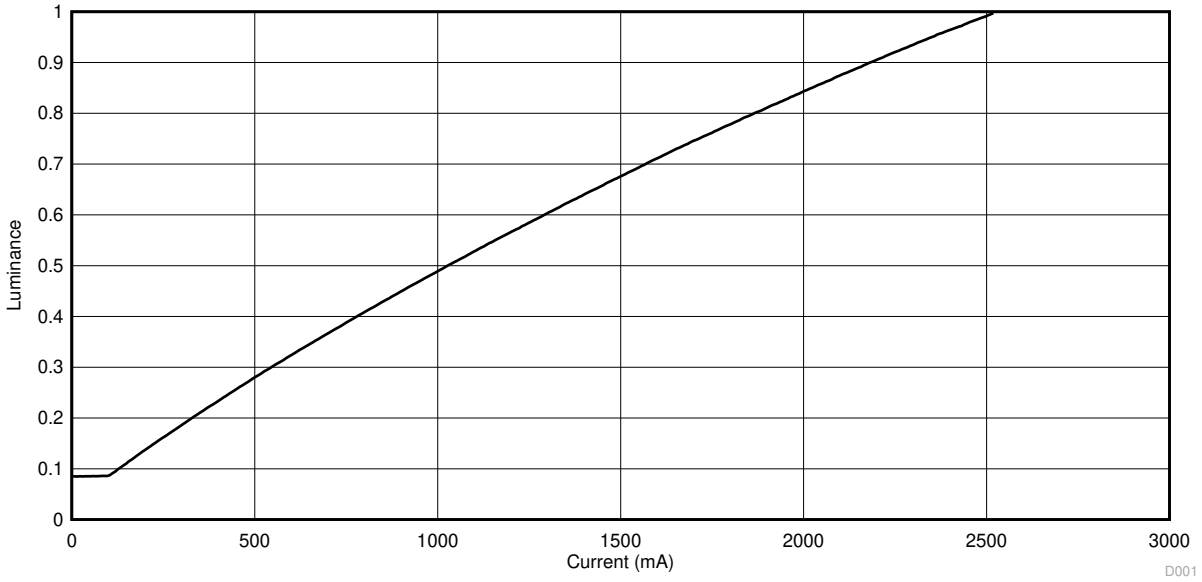


Figure 8-2. Luminance vs Current

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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 DLPA200x devices.

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 9-2. VSS must also be connected.

9.1 Power Supply Power-Up Procedure

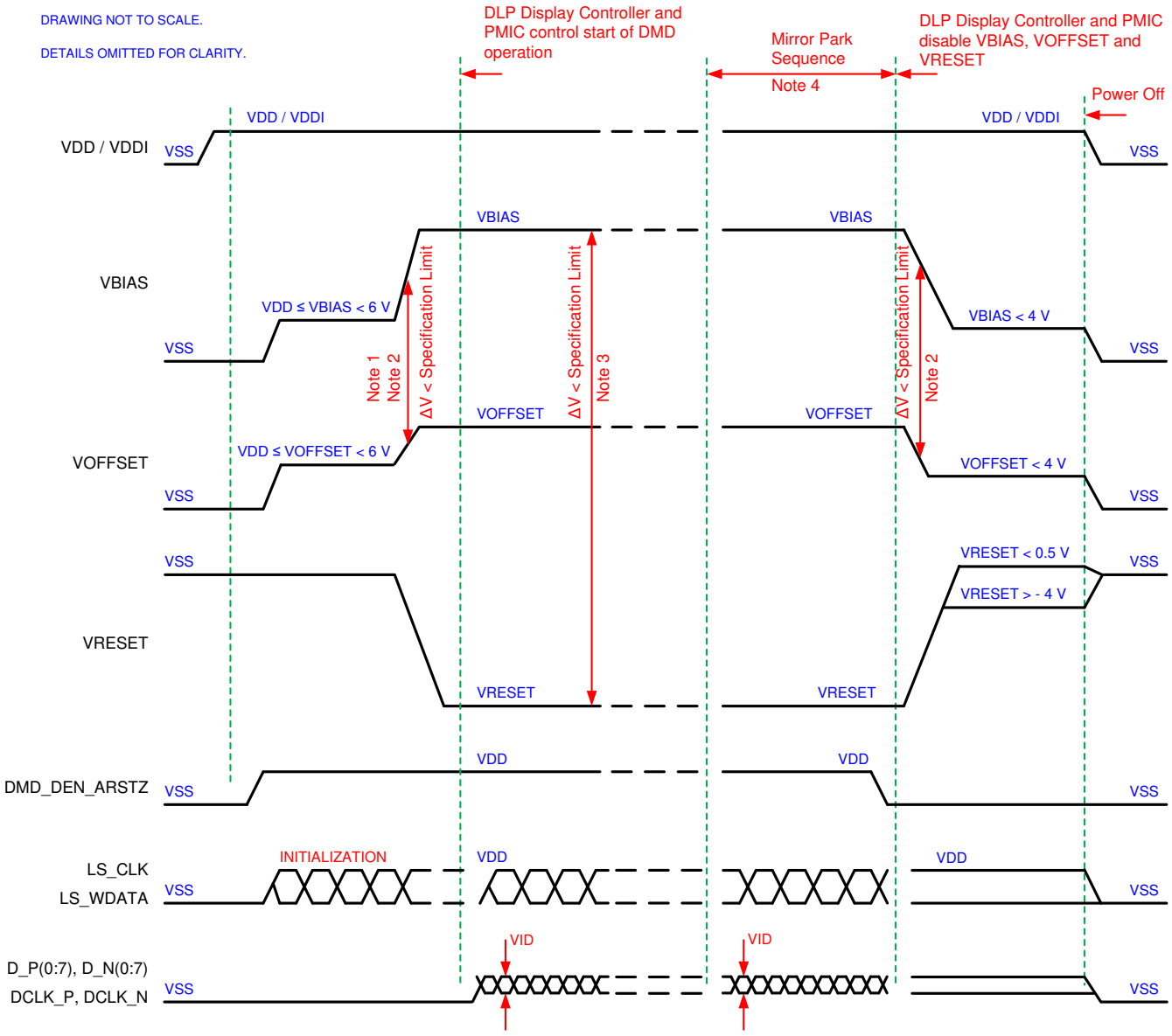
- During power-up, VDD and VDDI must always start and settle before VOFFSET, VBIAS, and VRESET voltages are applied to the DMD.
- During power-up, it is a strict requirement that the delta between VBIAS and VOFFSET must be within the specified limit shown in *Recommended Operating Conditions*. Refer to Table 9-1 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 9-1.

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 9-1).
- 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 9-1.

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9.3 Power Supply Sequencing Requirements



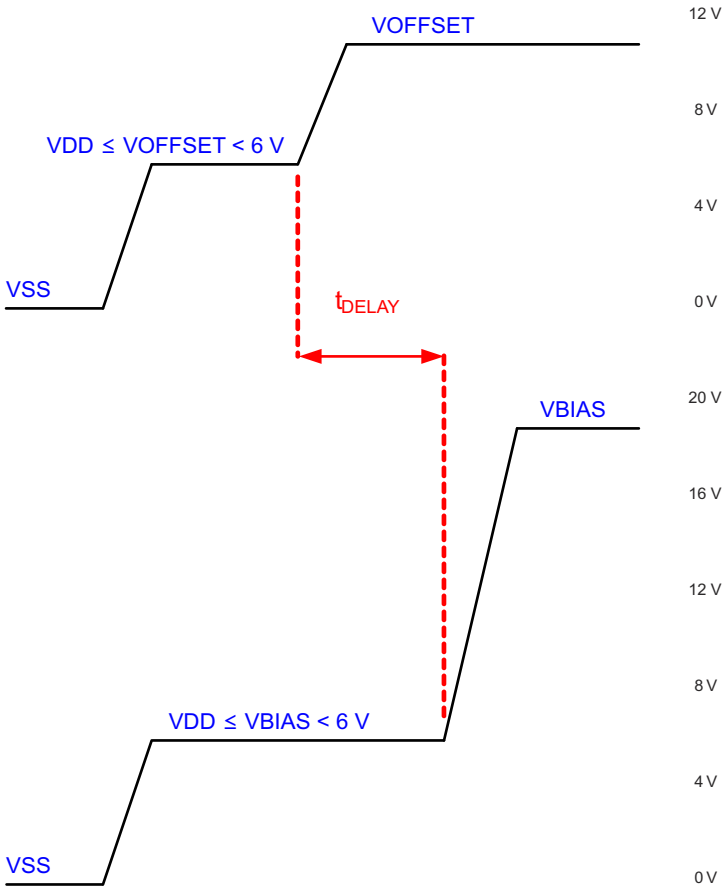
A. Refer to Table 9-1 and Figure 9-2 for critical power-up sequence delay requirements.
B. To prevent excess current, the supply voltage delta |VBIAS – VOFFSET| must be less than specified in *Section 6.4*. OEMs may find that the most reliable way to ensure this is to power VOFFSET prior to VBIAS during power-up and to remove VBIAS prior to VOFFSET during power-down. Refer to Table 9-1 and Figure 9-2 for power-up delay requirements.
C. To prevent excess current, the supply voltage delta |VBIAS – VRESET| must be less than specified limit shown in *Section 6.4*.
D. When system power is interrupted, the DLPA200x initiates hardware power-down that disables VBIAS, VRESET and VOFFSET after the Micromirror Park Sequence.
E. Drawing is not to scale and details are omitted for clarity.

Figure 9-1. Power Supply Sequencing Requirements (Power Up and Power Down)

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Table 9-1. 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 9-2)		6	V
V_{BIAS}	Supply voltage level during power–up sequence delay (see Figure 9-2)		6	V



A. Refer to Table 9-1 for VOFFSET and VBIAS supply voltage levels during power-up sequence delay.

Figure 9-2. Power-Up Sequence Delay Requirement

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10 Layout

10.1 Layout Guidelines

There are no specific layout guidelines for the DMD as typically DMD is connected using a board to board connector to a flex cable. Flex cable provides the interface of data and CTRL signals between the DLPC343x controller and the DLP3010 DMD. For detailed layout guidelines refer to the layout design files. Some layout guideline 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 10-1.
- Minimum of two 100-nF decoupling capacitor close to VBIAS. Capacitor C6 and C7 in Figure 10-1.
- Minimum of two 100-nF decoupling capacitor close to VRST. Capacitor C9 and C8 in Figure 10-1.
- Minimum of two 220-nF decoupling capacitor close to VOFS. Capacitor C5 and C4 in Figure 10-1.
- Minimum of four 100-nF decoupling capacitor close to Vcci and Vcc. Capacitor C1, C2, C3 and C10 in Figure 10-1.

10.2 Layout Example

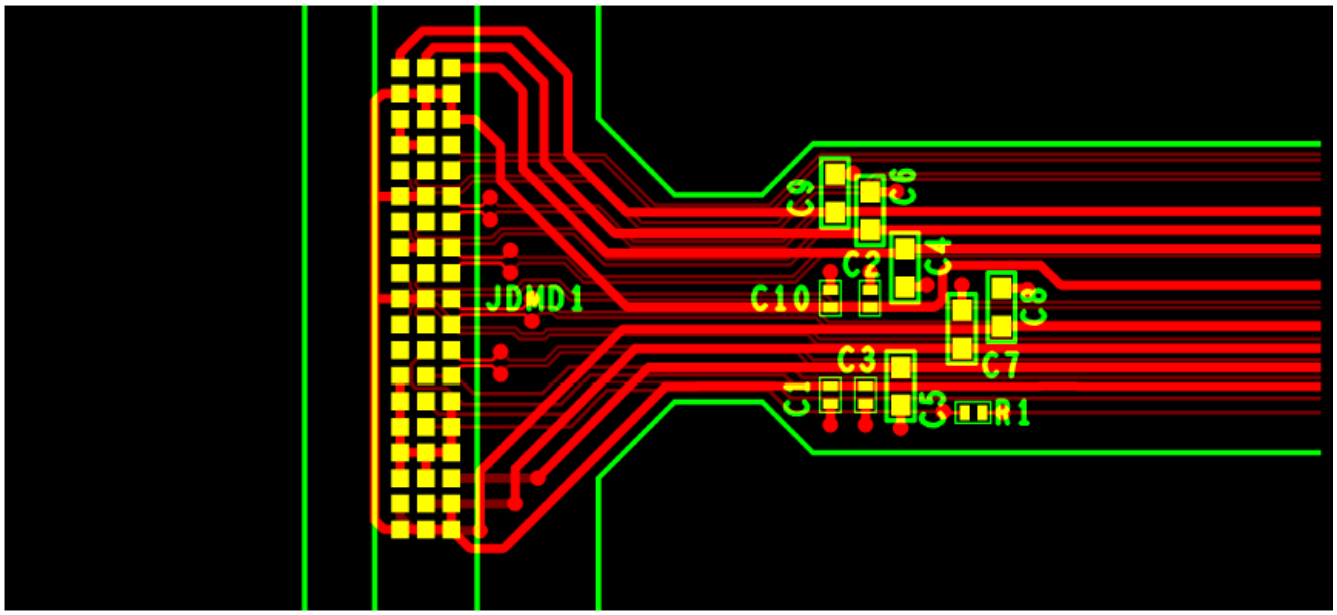


Figure 10-1. Power Supply Connections

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11 Device and Documentation Support

11.1 Device Support

11.1.1 Third-Party Products Disclaimer

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11.1.2 Device Nomenclature

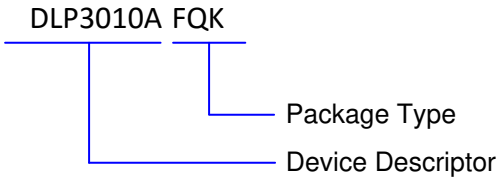


Figure 11-1. Part Number Description

11.1.3 Device Markings

The device marking includes the legible character string GHJJJJK DLP3010AFQK. GHJJJJK is the lot trace code. DLP3010AFQK is the device part number.

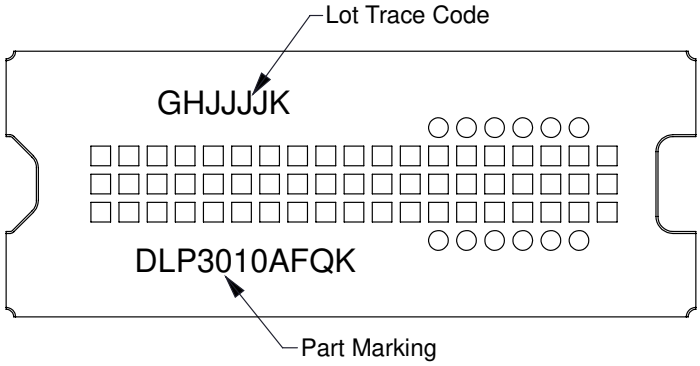


Figure 11-2. DMD Marking

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 11-1. Related Links

PARTS	PRODUCT FOLDER	SAMPLE & BUY	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
DLP3010A	Click here	Click here	Click here	Click here	Click here
DLPC3433	Click here	Click here	Click here	Click here	Click here
DLPC3438	Click here	Click here	Click here	Click here	Click here
DLPA2005	Click here	Click here	Click here	Click here	Click here
DLPA3000	Click here	Click here	Click here	Click here	Click here

11.3 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Subscribe to updates* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

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11.4 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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11.6 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

11.7 Glossary

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.

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PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
DLP3010AFQK	NRND	Production	null (null) |	120 | JEDEC TRAY (5+1)	Yes	NIAU	N/A for Pkg Type	0 to 70	
DLP3010AFQK.B	NRND	Production	null (null) |	120 | JEDEC TRAY (5+1)	Yes	NIAU	N/A for Pkg Type	0 to 70	
DLP3010FQK	Obsolete	Production	CLGA (FQK) | 57	-	-			-	

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

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

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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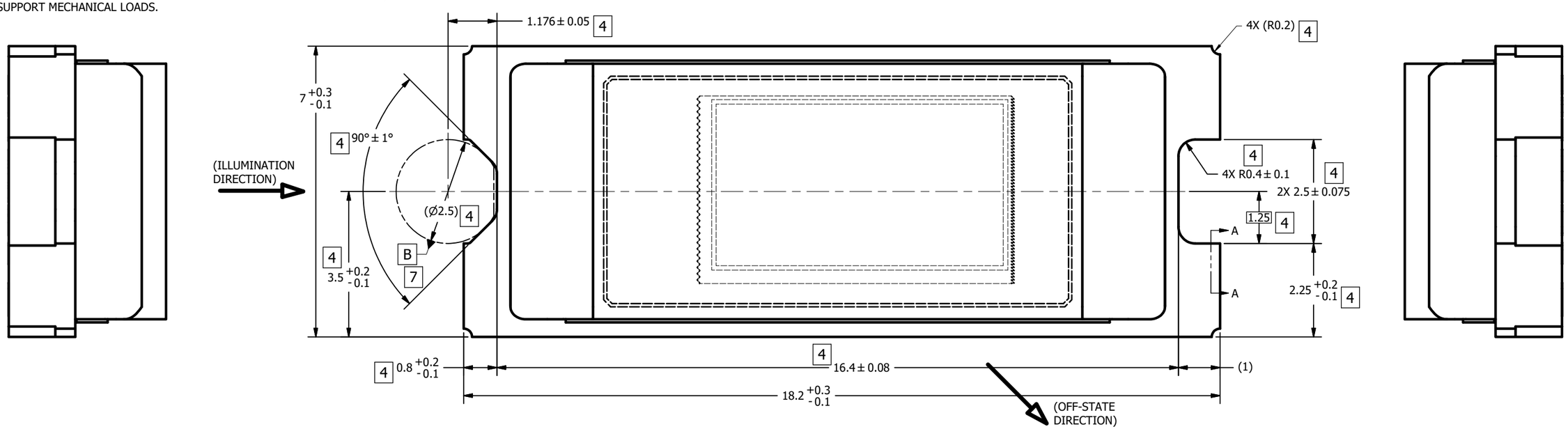
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

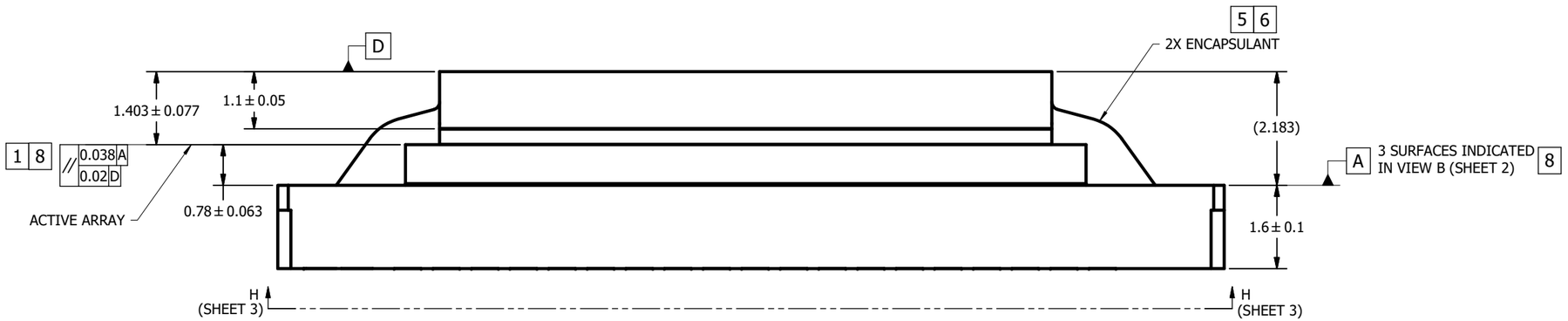
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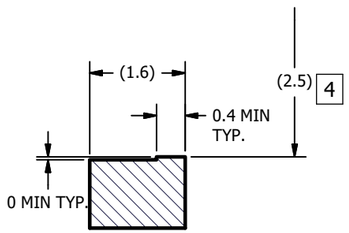
REVISIONS			
REV	DESCRIPTION	DATE	BY
A	ECO 2133835: INITIAL RELEASE	6/6/2013	BMH
B	ECO 2134093: CORRECT WINDOW THK TOL, ZONE B6	6/17/2013	BMH
C	ECO 2186947: ADD APERTURE SLOTS PICTORIALLY	4/8/2020	PPC

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. NOTCH DIMENSIONS ARE DEFINED BY UPPERMOST LAYERS OF CERAMIC, AS SHOWN IN SECTION A-A.
5. ENCAPSULANT TO BE CONTAINED WITHIN DIMENSIONS SHOWN IN VIEW C (SHEET 2). NO ENCAPSULANT IS ALLOWED ON TOP OF THE WINDOW.
6. ENCAPSULANT NOT TO EXCEED THE HEIGHT OF THE WINDOW.
7. 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).
8. 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.







SECTION A-A
NOTCH OFFSETS

	0314DA
NEXT ASSY	USED ON
APPLICATION	

THIRD ANGLE PROJECTION

UNLESS OTHERWISE SPECIFIED
- DIMENSIONS ARE IN MILLIMETERS
- TOLERANCES:
  - ANGLES ± 1°
  - 2 PLACE DECIMALS ± 0.25
  - 1 PLACE DECIMALS ± 0.50
- ~~DIMENSIONAL LIMITS APPLY BEFORE PROCESSES~~
- INTERPRET DIMENSIONS IN ACCORDANCE WITH ASME Y14.5M-1994
- ~~REMOVE ALL BURRS AND SHARP EDGES~~
- PARENTHETICAL INFORMATION FOR REFERENCE ONLY

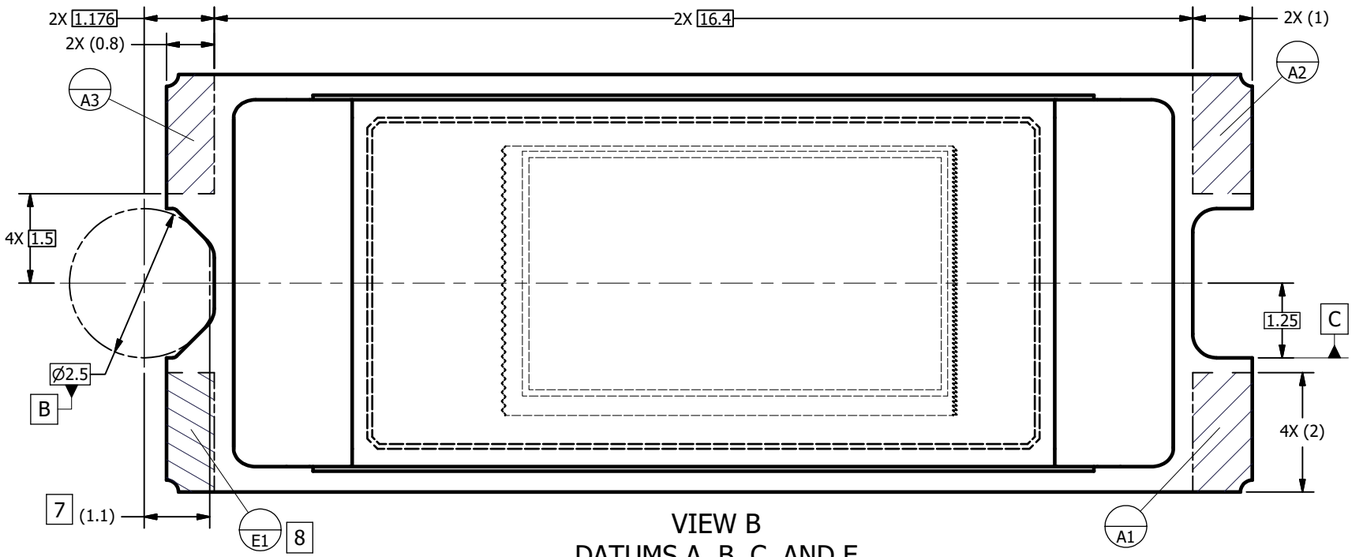
		DATE
DRAWN	B. HASKETT	6/6/2013
ENGINEER	B. HASKETT	6/6/2013
QA/CE	P. KONRAD	6/7/2013
CM	S. SUSI	6/6/2013
	S. CROFF	6/10/2013
APPROVED	R. LONG	6/6/2013

TEXAS INSTRUMENTS
Dallas Texas

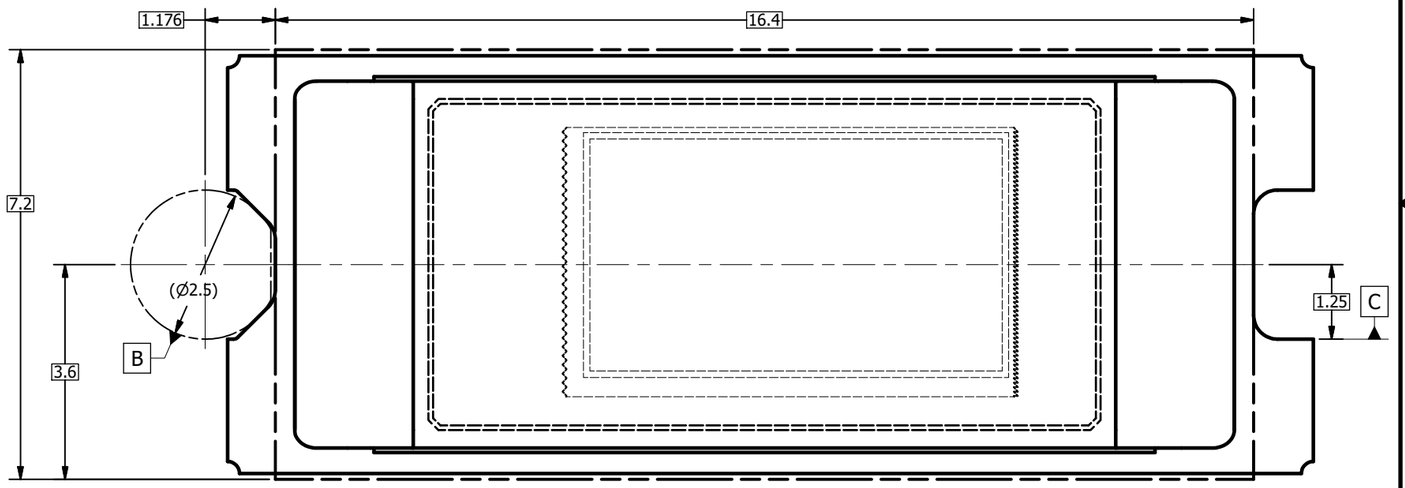
TITLE
ICD, MECHANICAL, DMD,
.3 720p SERIES 245
(FQK PACKAGE)

SIZE		DWG NO	REV
D		2512014	C
SCALE 20:1		SHEET 1 OF 3	

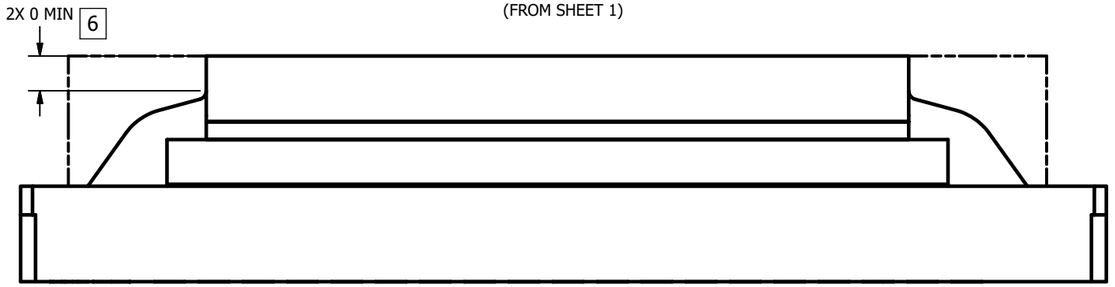
INV11-2006a



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



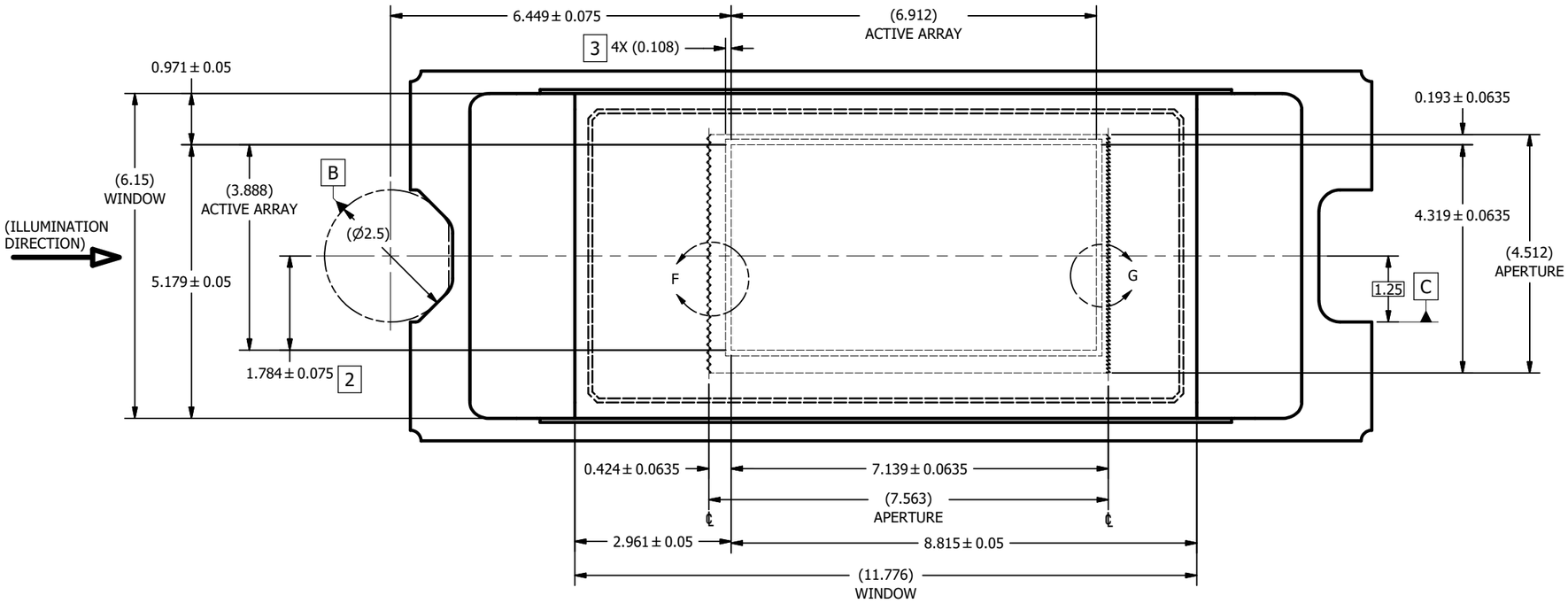
VIEW C 5
ENCAPSULANT MAXIMUM X/Y DIMENSIONS
(FROM SHEET 1)



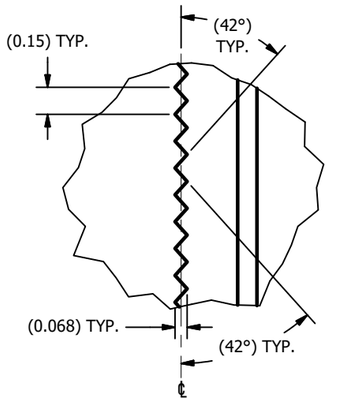
VIEW D
ENCAPSULANT MAXIMUM HEIGHT

Texas Instruments, Dallas Texas	DRAWN B. HASKETT	DATE 6/6/2013	SIZE D		DWG NO 2512014	REV C
			SCALE		SHEET 2 OF 3	

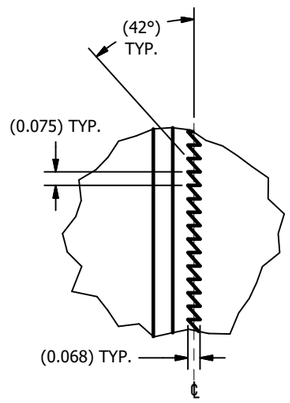
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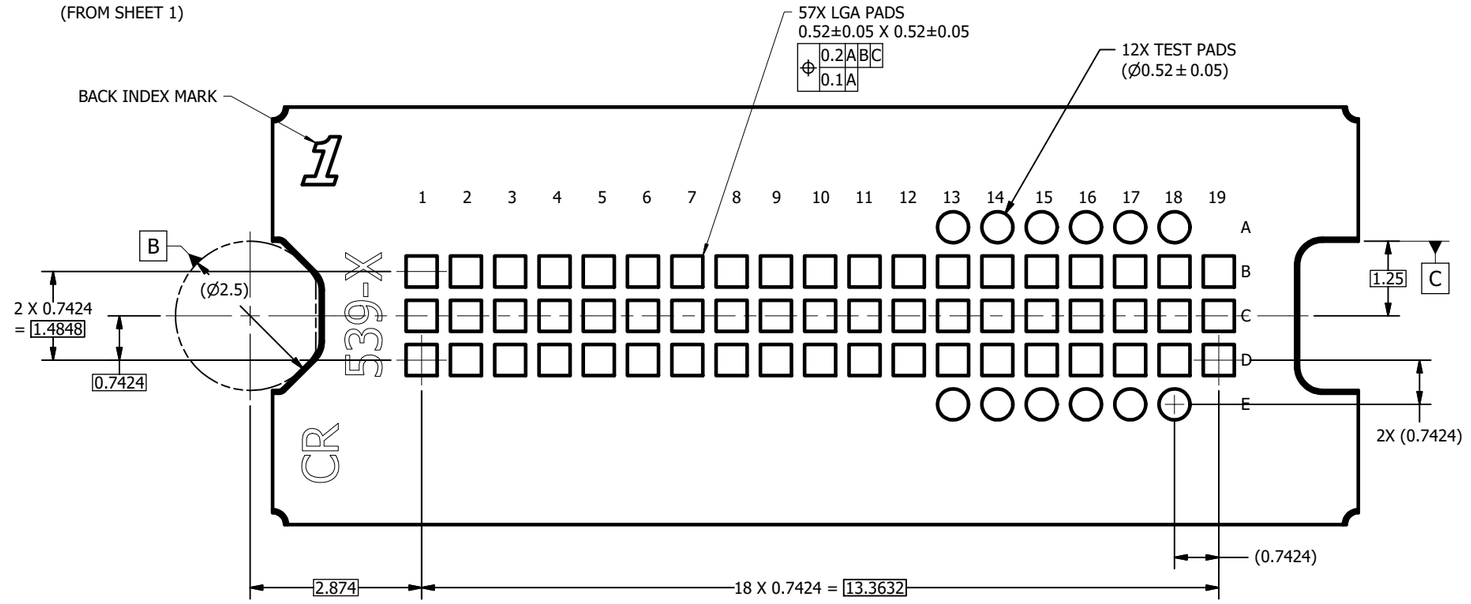
VIEW E
WINDOW AND ACTIVE ARRAY
(FROM SHEET 1)



DETAIL F
APERTURE LEFT EDGE
SCALE 60 : 1



DETAIL G
APERTURE RIGHT EDGE
SCALE 60 : 1



VIEW H-H
BACK SIDE METALLIZATION
(FROM SHEET 1)

Texas Instruments Dallas Texas	DRAWN B. HASKETT	DATE 6/6/2013	SIZE D	DWG NO 2512014	REV C
			SCALE	SHEET 3 OF 3	

INV11-2006a

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