DLP472TP 0.47 英寸 4K 超高清数字微镜器件

1 特性

- 0.47 英寸对角线微镜阵列
  - 4K UHD (3840 × 2160) 显示分辨率
  - 5.4µm 微镜间距
  - ±17° 微镜倾斜度（相对于平坦表面）
  - 底部照明
- SubLVDS 输入数据总线
- 支持 4K UHD (60Hz)
- 支持 1080p（高达 240Hz）
- 由 DLPC8445 显示控制器、DLPA3085 电源管理 IC (PMIC) 和 LED 驱动器支持 LED 正常运行

2 应用

- 移动智能电视
- 移动投影仪
- 数字标牌

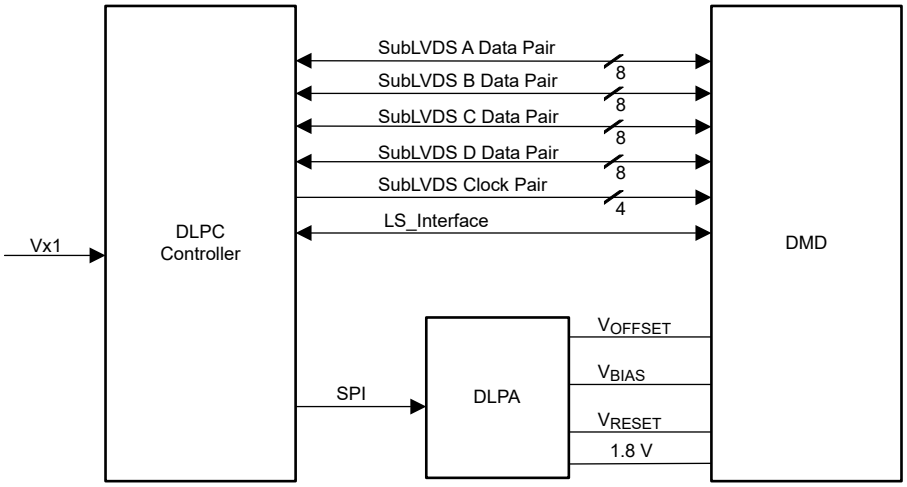
3 说明

DLP472TP 数字微镜器件 (DMD) 是一款数控微机电系统 (MEMS) 空间光调制器 (SLM)，可用于实现高亮的 4K UHD 显示系统。TI DLP® 产品 0.47 英寸 4K UHD 芯片组包括 DLP472TP DMD、DLPC8445 显示控制器、DLPA3085 PMIC 和 LED 驱动器。芯片组的外形紧凑，为体型小巧的 4K 超高清显示器提供完整的系统解决方案。

器件信息

器件型号	封装(1)	封装尺寸
DLP472TP	FQY (166)	24.50mm × 11.00mm

(1) 有关更多信息，请参阅节 12。



简化版应用

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4 Pin Configuration and Functions

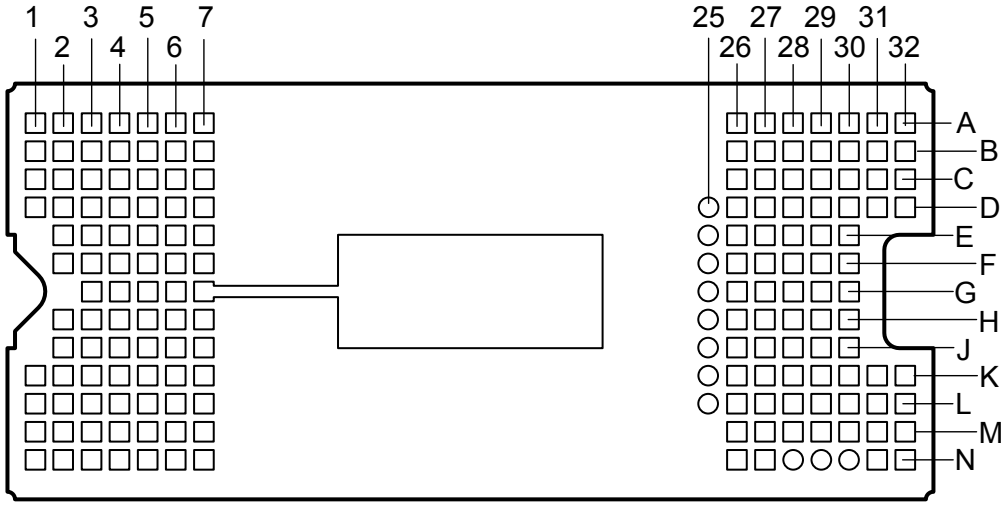


图 4-1. FQY Package 166-Pin LGA (Bottom View)

小心

The layout and operation of signals identified in the Pin Functions table must be properly managed to make sure there is reliable operation of the 0.47” 4K UHD S321 DMD. Refer to the Layout Guidelines for the DMD and Controller before designing the board.

4.1 Pin Functions

PIN(2)		TYPE(1)	DESCRIPTION	TERMINATION	TRACE LENGTH (mm)
NAME	PAD ID				
D_AP(0)	A2	I	High-speed Differential Data Pair lane A0	Differential 100 Ω	3.75497
D_AN(0)	B2	I	High-speed Differential Data Pair lane A0	Differential 100 Ω	3.75482
D_AP(1)	A6	I	High-speed Differential Data Pair lane A1	Differential 100 Ω	4.62509
D_AN(1)	B6	I	High-speed Differential Data Pair lane A1	Differential 100 Ω	4.625
D_AP(2)	C1	I	High-speed Differential Data Pair lane A2	Differential 100 Ω	3.59503
D_AN(2)	C2	I	High-speed Differential Data Pair lane A2	Differential 100 Ω	3.59513
D_AP(3)	C6	I	High-speed Differential Data Pair lane A3	Differential 100 Ω	5.12758
D_AN(3)	C7	I	High-speed Differential Data Pair lane A3	Differential 100 Ω	5.12745
D_AP(4)	G3	I	High-speed Differential Data Pair lane A4	Differential 100 Ω	1.60057
D_AN(4)	G4	I	High-speed Differential Data Pair lane A4	Differential 100 Ω	1.6004
D_AP(5)	F7	I	High-speed Differential Data Pair lane A5	Differential 100 Ω	3.64067
D_AN(5)	F6	I	High-speed Differential Data Pair lane A5	Differential 100 Ω	3.64091
D_AP(6)	F4	I	High-speed Differential Data Pair lane A6	Differential 100 Ω	1.58206
D_AN(6)	F5	I	High-speed Differential Data Pair lane A6	Differential 100 Ω	1.58187
D_AP(7)	H6	I	High-speed Differential Data Pair lane A7	Differential 100 Ω	2.70067
D_AN(7)	G6	I	High-speed Differential Data Pair lane A7	Differential 100 Ω	2.70086
DCLK_AP	E5	I	High-speed Differential Clock A	Differential 100 Ω	2.96493
DCLK_AN	D5	I	High-speed Differential Clock A	Differential 100 Ω	2.9653

PIN[2]		TYPE[1]	DESCRIPTION	TERMINATION	TRACE LENGTH (mm)
NAME	PAD ID				
D_BP(0)	B30	I	High-speed Differential Data Pair lane B0	Differential 100 Ω	3.57087
D_BN(0)	A30	I	High-speed Differential Data Pair lane B0	Differential 100 Ω	3.57064
D_BP(1)	C32	I	High-speed Differential Data Pair lane B1	Differential 100 Ω	4.2546
D_BN(1)	B32	I	High-speed Differential Data Pair lane B1	Differential 100 Ω	4.25425
D_BP(2)	A28	I	High-speed Differential Data Pair lane B2	Differential 100 Ω	4.97968
D_BN(2)	B28	I	High-speed Differential Data Pair lane B2	Differential 100 Ω	4.97953
D_BP(3)	C31	I	High-speed Differential Data Pair lane B3	Differential 100 Ω	3.12736
D_BN(3)	C30	I	High-speed Differential Data Pair lane B3	Differential 100 Ω	3.12743
D_BP(4)	C27	I	High-speed Differential Data Pair lane B4	Differential 100 Ω	5.44353
D_BN(4)	B27	I	High-speed Differential Data Pair lane B4	Differential 100 Ω	5.4433
D_BP(5)	D28	I	High-speed Differential Data Pair lane B5	Differential 100 Ω	3.32124
D_BN(5)	D27	I	High-speed Differential Data Pair lane B5	Differential 100 Ω	3.32115
D_BP(6)	F30	I	High-speed Differential Data Pair lane B6	Differential 100 Ω	2.99334
D_BN(6)	E30	I	High-speed Differential Data Pair lane B6	Differential 100 Ω	2.99374
D_BP(7)	G27	I	High-speed Differential Data Pair lane B7	Differential 100 Ω	3.14865
D_BN(7)	G28	I	High-speed Differential Data Pair lane B7	Differential 100 Ω	3.14902
DCLK_BP	D29	I	High-speed Differential Clock B	Differential 100 Ω	5.03976
DCLK_BN	D30	I	High-speed Differential Clock B	Differential 100 Ω	5.0395
D_CP(0)	J4	I	High-speed Differential Data Pair lane C0	Differential 100 Ω	2.06577
D_CN(0)	H4	I	High-speed Differential Data Pair lane C0	Differential 100 Ω	2.06568
D_CP(1)	J7	I	High-speed Differential Data Pair lane C1	Differential 100 Ω	4.87119
D_CN(1)	J6	I	High-speed Differential Data Pair lane C1	Differential 100 Ω	4.87131
D_CP(2)	K5	I	High-speed Differential Data Pair lane C2	Differential 100 Ω	4.69951
D_CN(2)	J5	I	High-speed Differential Data Pair lane C2	Differential 100 Ω	4.69926
D_CP(3)	L4	I	High-speed Differential Data Pair lane C3	Differential 100 Ω	3.27735
D_CN(3)	L5	I	High-speed Differential Data Pair lane C3	Differential 100 Ω	3.27722
D_CP(4)	L2	I	High-speed Differential Data Pair lane C4	Differential 100 Ω	4.65167
D_CN(4)	M2	I	High-speed Differential Data Pair lane C4	Differential 100 Ω	4.6513
D_CP(5)	M3	I	High-speed Differential Data Pair lane C5	Differential 100 Ω	5.70359
D_CN(5)	N3	I	High-speed Differential Data Pair lane C5	Differential 100 Ω	5.70352
D_CP(6)	M5	I	High-speed Differential Data Pair lane C6	Differential 100 Ω	2.57704
D_CN(6)	M6	I	High-speed Differential Data Pair lane C6	Differential 100 Ω	2.57727
D_CP(7)	N7	I	High-speed Differential Data Pair lane C7	Differential 100 Ω	3.77278
D_CN(7)	M7	I	High-speed Differential Data Pair lane C7	Differential 100 Ω	3.77317
DCLK_CP	K2	I	High-speed Differential Clock C	Differential 100 Ω	2.3747
DCLK_CN	J2	I	High-speed Differential Clock C	Differential 100 Ω	2.37429
D_DP(0)	G29	I	High-speed Differential Data Pair lane D0	Differential 100 Ω	3.67925
D_DN(0)	F29	I	High-speed Differential Data Pair lane D0	Differential 100 Ω	3.6794
D_DP(1)	F27	I	High-speed Differential Data Pair lane D1	Differential 100 Ω	4.73751
D_DN(1)	E27	I	High-speed Differential Data Pair lane D1	Differential 100 Ω	4.73796
D_DP(2)	K30	I	High-speed Differential Data Pair lane D2	Differential 100 Ω	2.76933
D_DN(2)	K29	I	High-speed Differential Data Pair lane D2	Differential 100 Ω	2.76936

PIN[2]		TYPE[1]	DESCRIPTION	TERMINATION	TRACE LENGTH (mm)
NAME	PAD ID				
D_DP(3)	J27	I	High-speed Differential Data Pair lane D3	Differential 100 Ω	3.07794
D_DN(3)	K27	I	High-speed Differential Data Pair lane D3	Differential 100 Ω	3.07804
D_DP(4)	M30	I	High-speed Differential Data Pair lane D4	Differential 100 Ω	3.60026
D_DN(4)	L30	I	High-speed Differential Data Pair lane D4	Differential 100 Ω	3.60028
D_DP(5)	M27	I	High-speed Differential Data Pair lane D5	Differential 100 Ω	3.24012
D_DN(5)	L27	I	High-speed Differential Data Pair lane D5	Differential 100 Ω	3.24002
D_DP(6)	N26	I	High-speed Differential Data Pair lane D6	Differential 100 Ω	4.69564
D_DN(6)	M26	I	High-speed Differential Data Pair lane D6	Differential 100 Ω	4.69594
D_DP(7)	M31	I	High-speed Differential Data Pair lane D7	Differential 100 Ω	3.97347
D_DN(7)	M32	I	High-speed Differential Data Pair lane D7	Differential 100 Ω	3.97352
DCLK_DP	H29	I	High-speed Differential Clock D	Differential 100 Ω	1.7593
DCLK_DN	J29	I	High-speed Differential Clock D	Differential 100 Ω	1.75933
LS_WDATA	D4	I	LVDS Data		2.29224
LS_CLK	C4	I	LVDS CLK		1.73951
LS_RDATA_A	C5	O	LVCMOS Output		2.72344
LS_RDATA_B	D3	O	LVCMOS Output		2.22814
LS_RDATA_C	E3	O	LVCMOS Output		3.22863
LS_RDATA_D	F3	O	LVCMOS Output		4.90151
DMD_DEN_ARSTZ	D2	I	ARSTZ		1.80911
TEMP_N	N1	I	Temp Diode N		1.84006
TEMP_P	M1	I	Temp Diode P		2.62822
VDD	A3, A4, C26, D1, D6, D7, D26, E2, E6, E7, E26, F2, G30, H28, H30, J26, J30, K1, K6, K26, K31, K32, L1, L31, L32, N2	P	Digital Core Supply Voltage		14.26561
VDDI	A5, B5, F26, G26, H26, H27, K7, L7	P	SubLVDS supply voltage		3.72532
VRESET	B3, B26	P	Supply voltage for negative bias of micromirror reset signal		25.57603
VBIAS	A27, B4	P	Supply voltage for positive bias of micromirror reset signal		24.70004
VOFFSET	A26, C3, L6, L26	P	Supply voltage for HVCMOS logic, stepped up logic level		8.73417

PIN[2]		TYPE[1]	DESCRIPTION	TERMINATION	TRACE LENGTH (mm)
NAME	PAD ID				
VSS	A1, A7, A29, A31, A32, B1, B7, B29, B31, C28, C29, D31, D32, E4, E28, E29, F28, G5, G7, H2, H3, H5, H7, J3, J28, K3, K4, K28, L3, L28, L29, M4, M28, M29, N4, N5, N6, N27, N31, N32	G	Ground		24.6246
N/C	N28, N29, N30, L25, K25, J25, H25, G25, F25, E25, D25	NC	No Connect Pin		None

(1) I=Input, O=Output, P=Power, G=Ground, NC=No Connect
(2) Only 163 pins are electrically connected for functional use

5 Specifications

5.1 Absolute Maximum Ratings

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 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.

		MIN	MAX	UNIT
SUPPLY VOLTAGE				
V_{DD}	Supply voltage for LVCMOS core logic and LPSDR low speed interface (1)	-0.5	2.3	V
V_{DDI}	Supply voltage for SubLVDS receivers(1)	-0.5	2.3	V
V_{OFFSET}	Supply voltage for HVCMOS and micromirror electrode(1) (2)	-0.5	11	V
V_{BIAS}	Supply voltage for micromirror electrode(1)	-0.5	19	V
V_{RESET}	Supply voltage for micromirror electrode(1)	-15	0.5	V
$\lvert V_{DDI} - V_{DD} \rvert$	Supply voltage delta, absolute value(3)		0.3	V
$\lvert V_{BIAS} - V_{OFFSET} \rvert$	Supply voltage delta, absolute value(4)		11	V
$\lvert V_{BIAS} - V_{RESET} \rvert$	Supply voltage delta, absolute value(5)		34	V
INPUT VOLTAGE				
	Input voltage for other inputs -- LSIF and LVCMOS(1)	-0.5	V_{DD} + 0.5	V
	Input voltage for other inputs -- SubLVDS(1) (6)	-0.5	V_{DDI} + 0.5	V
SUBLVDS INTERFACE				
$\lvert V_{ID} \rvert$	SubLVDS input differential voltage (absolute value)(1) (6)		810	mV
I_{ID}	SubLVDS input differential current		10	mA
CLOCK FREQUENCY				
f_{clock}	Clock frequency for low speed interface LS_CLK	100	130	MHz
TEMPERATURE DIODE				
I_{TEMP_DIODE}	Max current source into temperature diode		120	µA
ENVIRONMENTAL				
T_{WINDOW} and T_{ARRAY}	Temperature, operating(7)	0	90	°C
	Temperature, non-operating(7)	-40	90	°C
$\lvert T_{DELTA} \rvert$	Absolute temperature delta between any point on the window edge and theceramic test point TP1(8)		30	°C
T_{DP}	Dew point temperature, operating and non – operating (noncondensing)		81	°C

(1) All voltage values are with respect to the ground terminals (V_{SS}). The following required power supplies must be connected for proper DMD operation: V_{DD}, V_{DDI}, V_{OFFSET}, V_{BIAS}, and V_{RESET}. All V_{SS} connections are also required.
(2) V_{OFFSET} supply transients must fall within specified voltages.
(3) Exceeding the recommended allowable absolute voltage difference between V_{DDI} and V_{DD} may result in excessive current draw and permanent damage to the device.
(4) Exceeding the recommended allowable absolute voltage difference between V_{BIAS} and V_{OFFSET} may result in excessive current draw and permanent damage to the device.
(5) Exceeding the recommended allowable absolute voltage difference between V_{BIAS} and V_{RESET} may result in excessive current draw and permanent damage to the device.
(6) 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.
(7) The highest temperature of the active array (as calculated using the Micromirror Array Temperature Calculation) or of any point along the window edge. The locations of thermal test points TP2, TP3, TP4, and TP5 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.
(8) Temperature delta is the highest difference between the ceramic test point 1 (TP1) and anywhere on the window edge. The window test points TP2, TP3, TP4, and TP5 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.

5.2 Storage Conditions

Applicable for the DMD as a component or non-operating in a system.

		MIN	MAX	UNIT
T_{DMD}	DMD 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 pointt temperature range		6	months

(1) The average temperature over time (including storage and operating temperatures) 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}.

5.3 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic Discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	±1000	V
		Charged device model (CDM), per JEDEC specification ANSI/ESDA/JEDEC JS-002(2)	±250	V

(1) JEDEC document JEP155 states that 500 V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250 V CDM allows safe manufacturing with a standard ESD control process.

5.4 Recommended Operating Conditions

Over operating free-air temperature range and supply voltages (unless otherwise noted). The functional performance of the device specified in this data sheet 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.

		MIN	TYP	MAX	UNIT
SUPPLY VOLTAGE RANGE					
VDD	Supply voltage for LVCMOS core logic(1) (2) Supply voltage for LPSDR low-speed interface(1) (2)	1.71	1.8	1.95	V
VDDI	Supply voltage for SubLVDS receivers(1) (2)	1.71	1.8	1.95	V
VOFFSET	Supply voltage for HVCMOS and micromirror electrode(1) (2) (3)	9.5	10	10.5	V
VBIAS	Supply voltage for mirror electrode(1) (2)	17.5	18	18.5	V
VRESET	Supply voltage for micromirror electrode(1) (2)	– 14.5	– 14	– 13.5	V
|VDDI- VDD|	Supply voltage delta (absolute value)(1) (2) (4)			0.3	V
|VBIAS-VOFFSET|	Supply voltage delta (absolute value)(1) (2) (5)			10.5	V
|VBIAS- VRESET|	Supply voltage delta (absolute value)(1) (2) (6)			33	V
CLOCK FREQUENCY					
f_{clock}	Clock frequency for low speed interface LS_CLK(7)	108		120	MHz
	Clock frequency for high-speed interface DCLK (8)			720	MHz
DCD_{IN}	Duty cycle distortion	44		56	%
SUBLVDS INTERFACE					
$\|V_{ID}\|$	LVDS differential input voltage magnitude(8)	150	250	350	mV
V_{CM}	Common mode voltage(8)	700	900	1100	mV
$V_{SUBLVDS}$	SubLVDS voltage(8)	525		1275	mV
Z_{LINE}	Line differential impedance (PWB/trace)	90	100	110	Ω
Z_{IN}	Internal differential termination resistance(10)	80	100	120	Ω
	100 Ω differential PCB trace	6.35		152.4	mm
ENVIRONMENTAL					
T_{ARRAY}	Array temperature, long-term operation(9) (10) (11) (12)	10		40 to 70	°C
	Array temperature, short-term operation, 500 hr max(10) (13)	0		10	°C
T_{Window}	Window temperature, operational(14)			85	°C
$\|T_{DELTA}\|$	Absolute Temperature difference between any point on the window edge and the ceramic test point TP1(16)			15	°C
T_{DP-AVG}	Average dew point temperature, (non-condensing)(15)			24	°C
T_{DP-ELR}	Elevated dew point temperature range, (non-condensing)(16)		28	36	°C
CT_{ELR}	Cumulative time in elevated dew point temperature range			6	Months
ILLUMINATION					
ILL_{UV}	Illumination, wavelength < 410nm(9)			10	mW/cm^2
ILL_{VIS}	Illumination power at wavelengths ⩾ 410nm and ⩽ 800nm(17)			20.5	W/cm^2
ILL_{IR}	Illumination, wavelength between > 800nm			10	mW/cm^2
ILL_{BLU}	Illumination power at wavelengths ⩾ 410nm and ⩽ 475nm(17)			6.5	W/cm^2
ILL_{BLU1}	Illumination power at wavelengths ⩾ 410nm and ⩽ 445nm(17)			1.2	W/cm^2
ILL_{θ}	Illumination marginal ray angle(18)			55	deg

(1) The following power supplies are all required to operate the DMD: V_{DD}, V_{DDI}, V_{OFFSET}, V_{BIAS}, and V_{RESET}. All V_{SS} connections are required to operate the DMD.
(2) All voltage values are with respect to the V_{SS} ground pins.
(3) V_{OFFSET} supply transients must fall within specified max voltages.
(4) To prevent excess current, the supply voltage delta $|V_{DDI} - V_{DD}|$ must be less than the specified limit.
(5) To prevent excess current, the supply voltage delta $|V_{BIAS} - V_{OFFSET}|$ must be less than the specified limit.

(6) To prevent excess current, the supply voltage delta $|V_{BIAS} - V_{RESET}|$ must be less than the specified limit.
(7) LS_CLK must run as specified to ensure internal DMD timing for reset waveform commands.
(8) Refer to the SubLVDS timing requirements in 节 5.8.
(9) Simultaneous exposure of the DMD to the maximum Recommended Operating Conditions for temperature and UV illumination will reduce device lifetime.
(10) The array temperature cannot be measured directly and must be computed analytically from the temperature measured at test point (TP1) and the package thermal resistance using the Micromirror Array Temperature Calculation.
(11) Per Maximum Recommended Array Temperature—Derating Curve, 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.
(12) Long-term is defined as the usable life of the device.
(13) Short-term is the total cumulative time over the useful life of the device.
(14) Temperature delta is the highest difference between the ceramic test point 1 (TP1) and anywhere on the window edge. The window test points TP2, TP3, TP4, and TP5 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.
(15) The average over time (including storage and operating) that the device is not in the ‘elevated dew point temperature range'.
(16) 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}.
(17) 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}).
(18) 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.

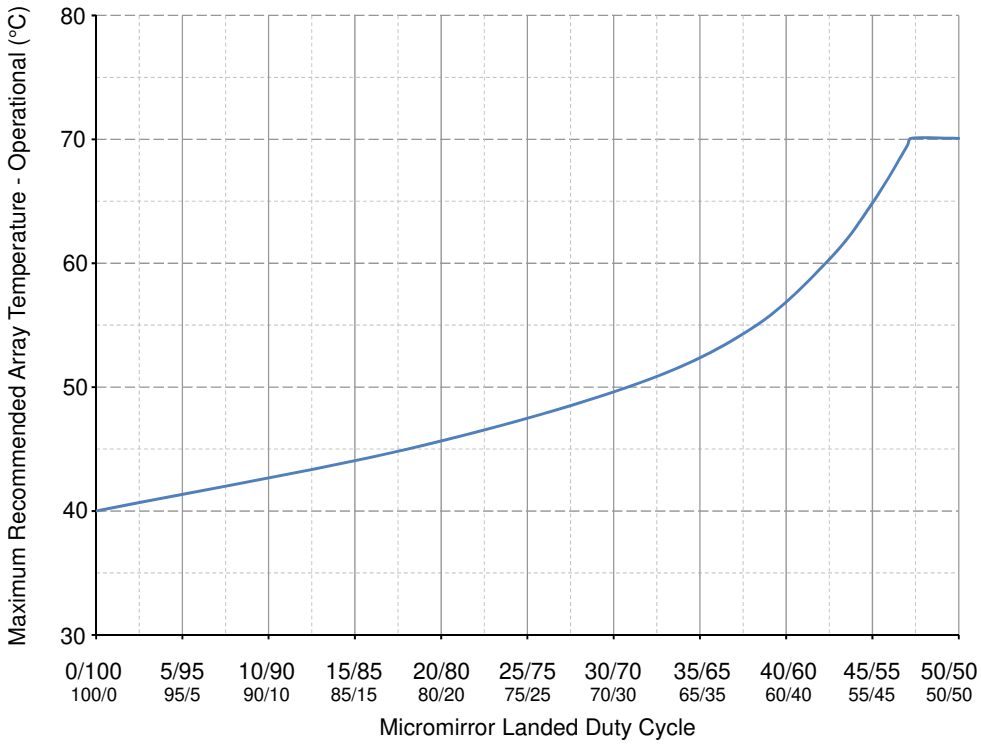


图 5-1. Maximum Recommended Array Temperature—Derating Curve

5.5 Thermal Information

THERMAL METRIC	DLP472TP	UNIT
	FQY	
	163 PIN	
THERMAL INFORMATION		

5.5 Thermal Information（续）

THERMAL METRIC	DLP472TP FQY 163 PIN	UNIT
Thermal Resistance, active area to test point 1 (TP1)(1)	1.2	°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 DMD 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.

5.6 Electrical Characteristics

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

PARAMETER(7)		TEST CONDITIONS (2)	MIN	TYP	MAX	UNIT
CURRENT						
I_{DD}	Supply current: V_{DD} (3) (4)	Typical			140	mA
I_{DDI}	Supply current: V_{DDI} (3) (4)	Typical			45	mA
I_{OFFSET}	Supply current: V_{OFFSET} (5) (6)	Typical			6	mA
I_{BIAS}	Supply current: V_{BIAS} (5) (6)	Typical			.5	mA
I_{RESET}	Supply current: V_{RESET} (6)	Typical	-1.8			mA
POWER						
P_{DD}	Supply power dissipation: V_{DD} (3) (4)	Typical			252	mW
P_{DDI}	Supply power dissipation: V_{DDI} (3) (4)	Typical			81	mW
P_{OFFSET}	Supply power dissipation: V_{OFFSET} (5) (6)	Typical			60	mW
P_{BIAS}	Supply power dissipation: V_{BIAS} (5) (6)	Typical			9	mW
P_{RESET}	Supply power dissipation: V_{RESET} (6)	Typical			25.2	mW
P_{TOTAL}	Supply power dissipation Total	Typical			427.2	mW
LPSDR INPUT						
V_{IH}	High-level input voltage(8) (9)		0.7 x V_{DD}		V_{DD} + 0.3	x VDD
V_{IL}	Low-level input voltage(8) (9)		– 0.3		0.3 x V_{DD}	x VDD
$V_{IH(AC)}$	AC input high voltage(8) (9)		0.8 × V_{DD}		V_{DD} + 0.3	x VDD
$V_{IL(AC)}$	AC input low voltage(8) (9)		– 0.3		0.2 × V_{DD}	x VDD
VHyst	Input Hysteresis (V_{T+} – V_{T-})(11)		0.1 × V_{DD}		0.4 × V_{DD}	V
I_{IL}	Low level input current	V_{DD} = 1.95 V, V_I = 0V	-100			nA
I_{IH}	High level input current	V_{DD} = 1.95 V, V_I = 1.95V			135	uA
LPSDR OUTPUT						
V_{OH}	DC output high voltage(10)	I_{OH} = -2 mA	0.8 x V_{DD}			X VDD
V_{OL}	DC output low voltage(10)	I_{OL} = 2 mA			0.2 x V_{DD}	X VDD
CAPACTIANCE						
C_{IN}	Input capacitance LVCMOS	F = 1 MHz			10	pF
C_{IN}	Input capacitance SubLVDS	F = 1 MHz			20	pF
C_{OUT}	Output capacitance	F = 1 MHz			10	pF

(1) Device electrical characteristics are over 节 5.4 unless otherwise noted.
(2) All voltage values are with respect to the ground pins (V_{SS}).
(3) To prevent excess current, the supply voltage delta | V_{DDI} – V_{DD} | must be less than the specified limit.
(4) Supply power dissipation based on non – compressed commands and data.

(5) To prevent excess current, the supply voltage delta | V_{BIAS} – V_{OFFSET} | must be less than the specified limit.
(6) Supply power dissipation based on 3 global resets in 200 µs.
(7) All power supply connections are required to operate the DMD: V_{DD}, V_{DDI}, V_{OFFSET}, V_{BIAS}, V_{RESET}. All V_{SS} connections are also required.
(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 output specification is for pins LS_RDATA_A, LS_RDATA_B, LS_RDATA_C, LS_RDATA_D.
(11) Refer to Figure 6-10

5.7 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.	C_L = 45 pF			15	ns
	Slew rate, LS_RDATA		0.3			V/ns
	Output duty cycle distortion, LS_RDATA		40		60	%

(1) Device electrical characteristics are over 节 5.4 unless otherwise noted.

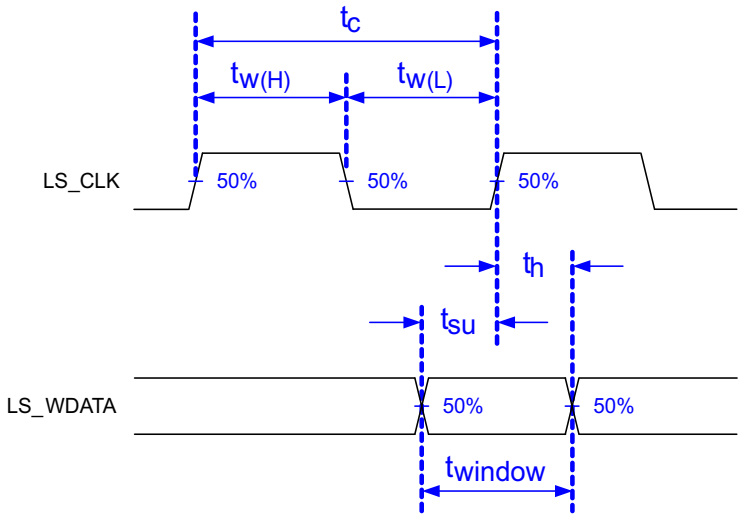
5.8 Timing Requirements

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

			MIN	NOM	MAX	UNIT
LPSDR						
t_f	Fall slew rate (2)	(80% to 20%) × V_{DD} (5)	0.25			V/ns
t_c	Cycle time LS_CLK(5)	50% to 50% reference points(5)	7.7	8.3		ns
t_r	Rise slew rate (1)	(30% to 80%) × V_{DD} (6)	1		3	V/ns
t_f	Fall slew rate (1)	(70% to 20%) x V_{DD} (6)	1		3	V/ns
t_r	Rise slew rate (2)	(20% to 80%) × V_{DD} (6)	0.25			V/ns
$t_{W(H)}$	Pulse duration LS_CLK high	50% to 50% reference points(5)	3.1			ns
$t_{W(L)}$	Pulse duration LS_CLK low	50% to 50% reference points(5)	3.1			ns
t_{WINDOW}	Window time(1) (3)	Setup time + Hold time(5)	3			ns
$t_{DERATING}$	Window time derating(1) (3)	For each 0.25 V/ns reduction in slew rate below 1 V/ns(8)		0.35		ns
t_{su}	Setup time	LS_WDATA valid before LS_CLK(5)			1.5	ns
t_h	Hold time	LS_WDATA valid after LS_CLK(5)			1.5	ns
SubLVDS						
t_r	Rise slew rate	20% to 80% reference points(7)	0.7	1		V/ns
t_f	Fall slew rate	80% to 20% reference points(7)	0.7	1		V/ns
t_c	Cycle time D_CLK(9)	50% to 50% reference points(9)	1.35	1.39		ns
$t_{W(H)}$	Pulse duration DCLK high	50% to 50% reference points(9)	0.7			ns
$t_{W(L)}$	Pulse duration DCLK low	50% to 50% reference points(9)	0.7			ns
t_{su}	Setup time	DATA valid before D_CLK(9)			0.17	ns
t_h	Hold time	DATA valid after D_CLK(9)			0.17	ns
t_{WINDOW}	Window time	Setup time + Hold time(9) (10)			0.25	ns
t_{POWER}	Power-up receiver(4)				200	ns

(1) Specification is for LS_CLK and LS_WDATA pins. Refer to LPSDR input rise 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) 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.
(5) See Figure 6-2 .
(6) See Figure 6-3 .
(7) See Figure 6-4.

(8) See Figure 6-5.
(9) See Figure 6-6.
(10) See Figure 6-7.



The 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.

图 5-2. LPSDR Switching Parameters

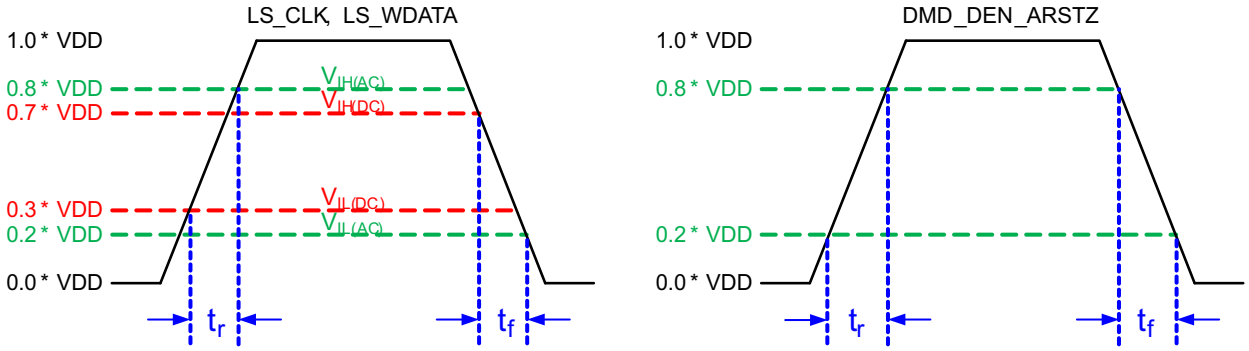


图 5-3. LPSDR Input Rise and Fall Slew Rate

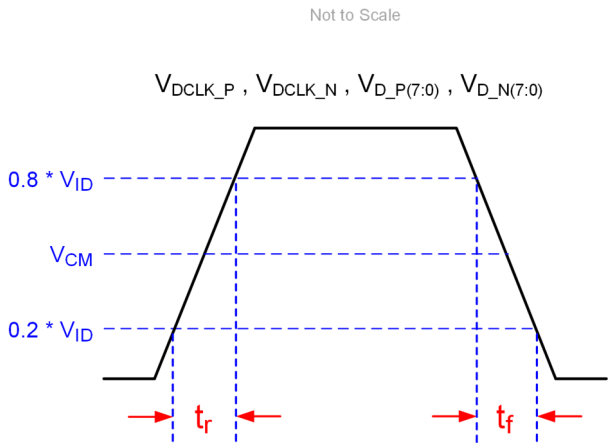


图 5-4. SubLVDS Input Rise and Fall Slew Rate

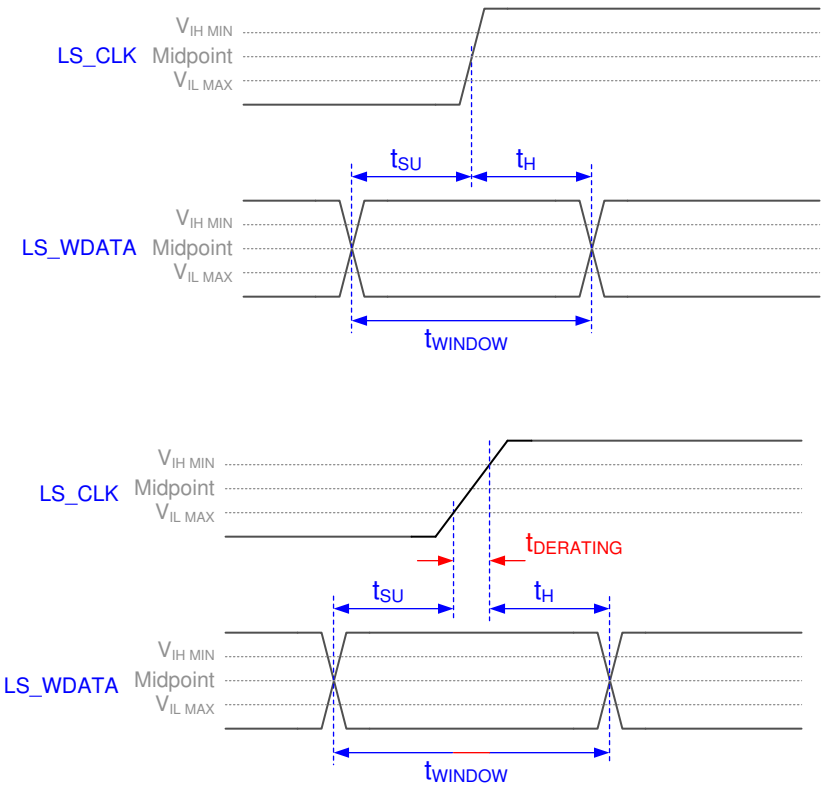


图 5-5. Window Time Derating Concept

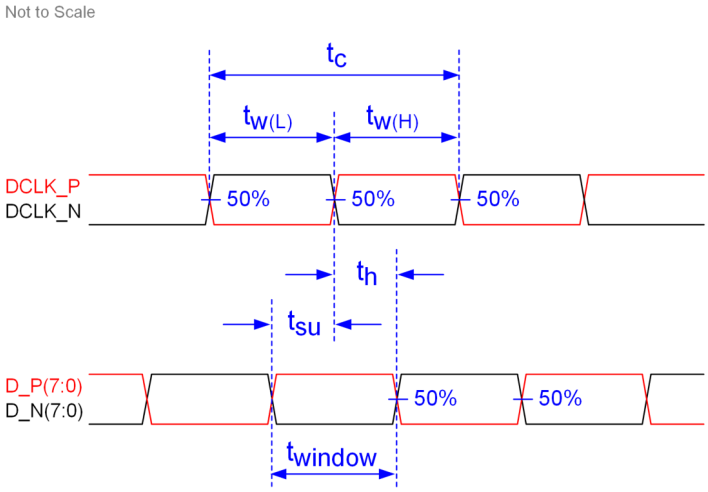
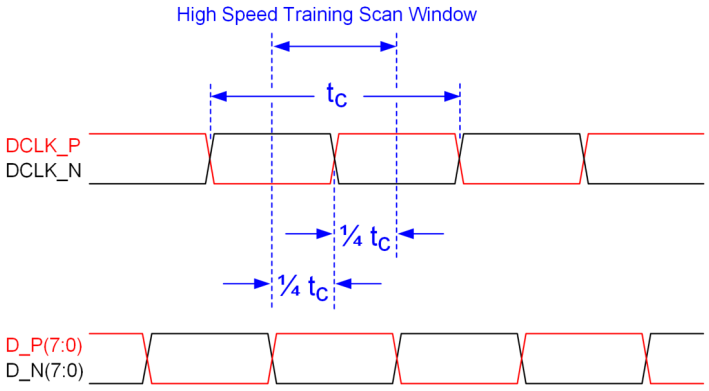


图 5-6. SubLVDS Switching Parameters



Note: Refer to 节 5.8 for details.

图 5-7. High-Speed Training Scan Window

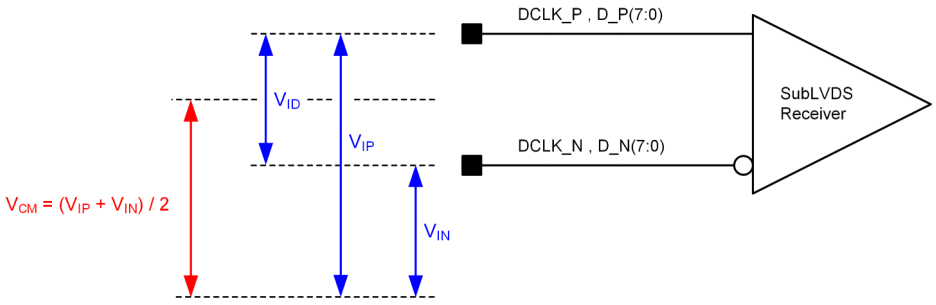


图 5-8. SubLVDS Voltage Parameters

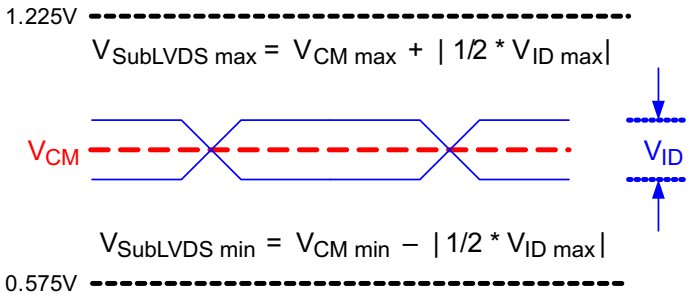


图 5-9. SubLVDS Waveform Parameters

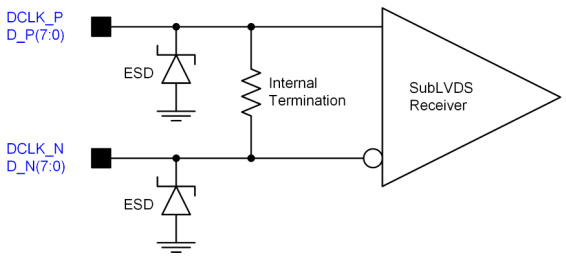


图 5-10. SubLVDS Equivalent Input Circuit

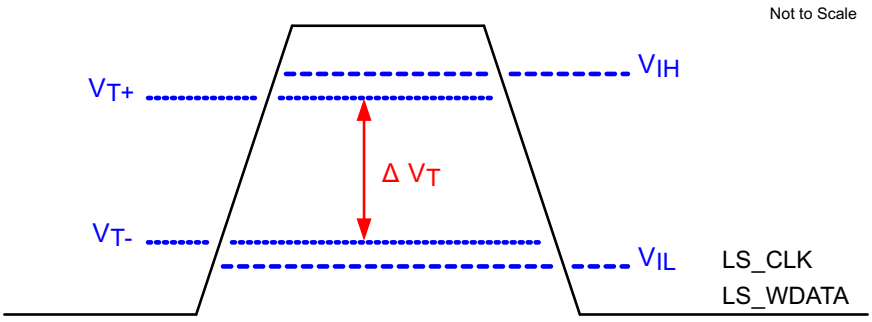


图 5-11. LPSDR Input Hysteresis

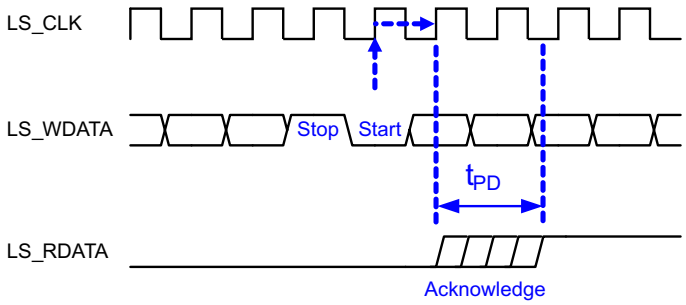
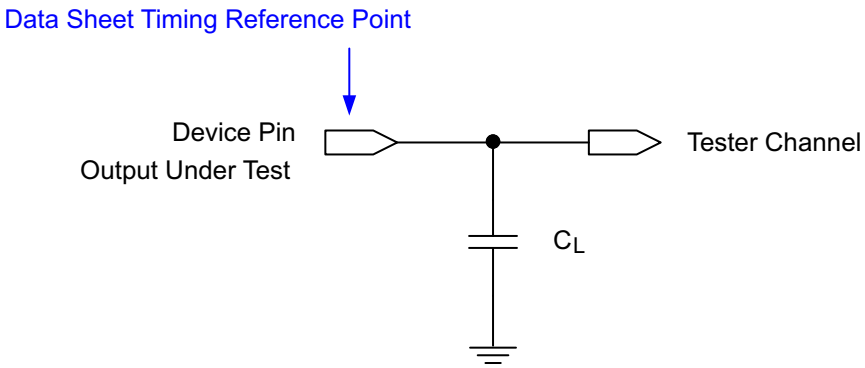


图 5-12. LPSDR Read Out



See 节 5.6 for more information.

图 5-13. Test Load Circuit for Output Propagation Measurement

5.9 System Mounting Interface Loads

PARAMETER	CONDITION	MIN	NOM	MAX	UNIT
Thermal Interface Area	Maximum load evenly distributed within each area (1)			73.5	N
Electrical Interface Area	Maximum load evenly distributed within each area (1)			150	

(1) See Figure 6-14.

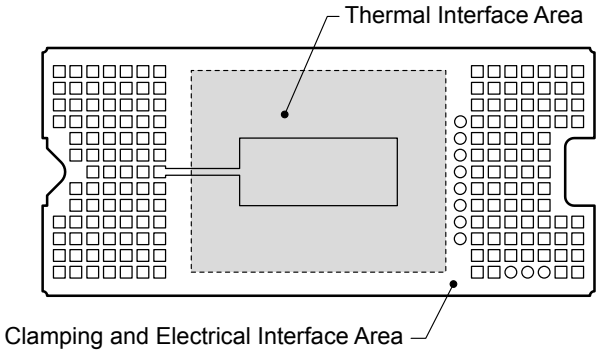


图 5-14. System Mounting Interface Loads

5.10 Micromirror Array Physical Characteristics

PARAMETER DESCRIPTION		VALUE	UNIT
Number of active columns (1) (2)	M	1920	micromirrors
Number of active rows (1) (2)	N	1080	micromirrors
Micromirror (pixel) pitch (1)	P	5.4	µm
Micromirror active array width (1)	Micromirror pitch × number of active columns	10.368	mm
Micromirror active array height (1)	Micromirror pitch × number of active columns	5.832	mm
Micromirror active border (3)	Pond of micromirror (POM)	20	micromirrors/side

(1) See Figure 6-15
(2) The fast switching speed of the DMD micromirrors combined with advanced DLP image processing algorithms enables each micromirror to display four distinct pixels on the screen during every frame, resulting in a full 3840 x 2160 pixel image being displayed.
(3) The structure and qualities of the bordere around the active array includes a band of partially functional micromirrors referred to as the i{Pond of Micromirrors} (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 the OFF state.

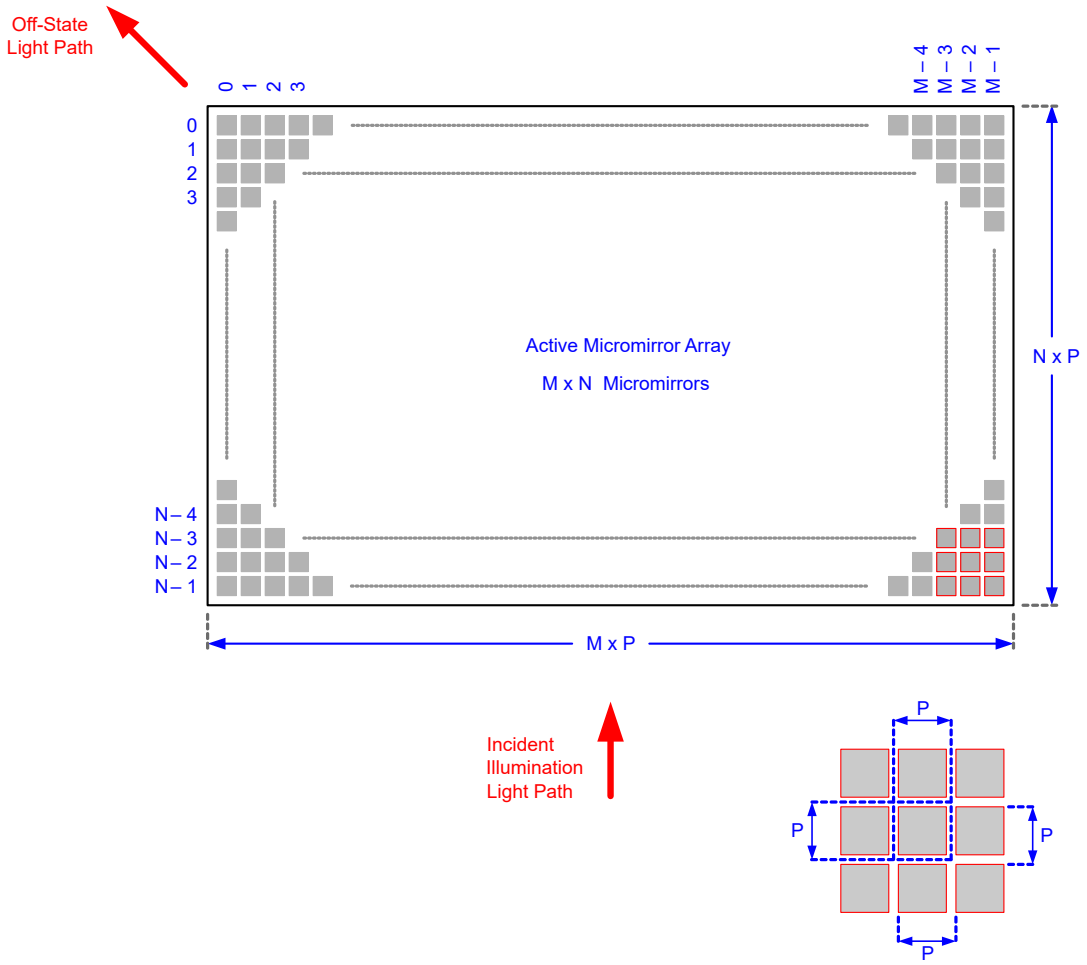


图 5-15. Micromirror Array Physical Characteristics

5.11 Micromirror Array Optical Characteristics

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Micromirror tilt angle		Landed state (1)		17		°
Micromirror tilt angle tolerance (2) (3) (4) (5)			-1.4		1.4	°
Micromirror tilt direction (6) (7)		Landed ON state		270		°
Micromirror tilt direction (6) (7)		Landed OFF state		180		°
Micromirror crossover time (8)		Typical Performance		1	3	µs
Micromirror switching time (9)		Typical Performance	6			
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 the Micromirror Landed Orientation and Tilt Figure 6-16.
(7) Micromirror tilt direction is measured as in a typical polar coordinate system: Measuring counter-clockwise from a 0° degree 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

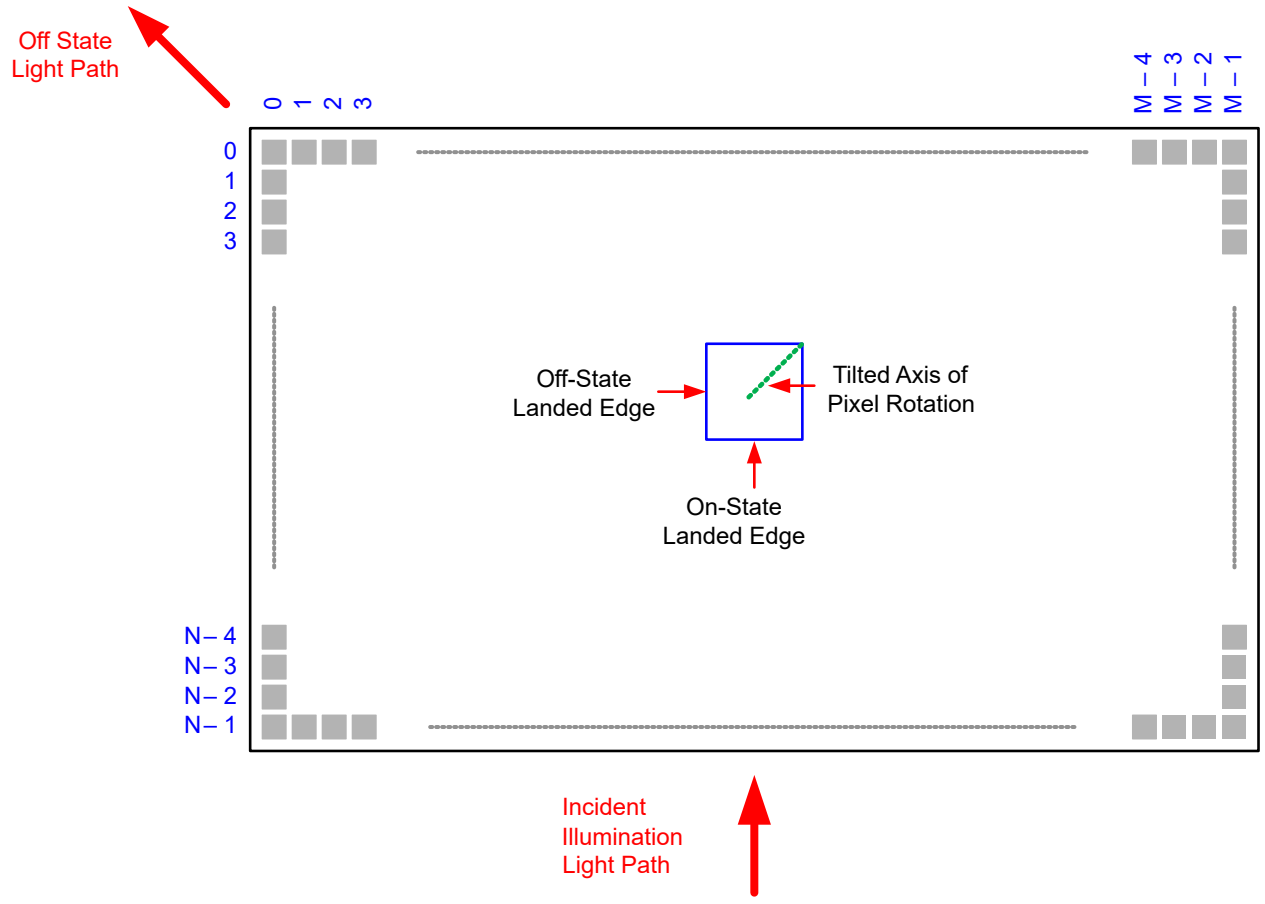


图 5-16. Micromirror Landed Orientation and Tilt

5.12 Window Characteristics

DESCRIPTION(1)		MIN	TYP	MAX
Window material			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 nm to 680 nm. Applies to all angles 0° to 30° AOI. (4)	97%		
	Average over the wavelength range 420 nm to 680 nm. Applies to all angles 30° to 45° AOI. (4)	97%		

(1) See Section 7.5
(2) See the package mechanical characteristics for details regarding the size and location of the window aperture.
(3) The active area of the DMD device is surrounded by an aperture on the inside of the 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.
(4) Angle of incidence (AOI) is the angle between an incident ray and the normal to a reflecting or refracting surface.

5.13 Chipset Component Usage Specification

Reliable function and operation of the DLP472TP DMD 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 consists of the TI technology and devices used for operating or controlling a DLP DMD.

备注

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

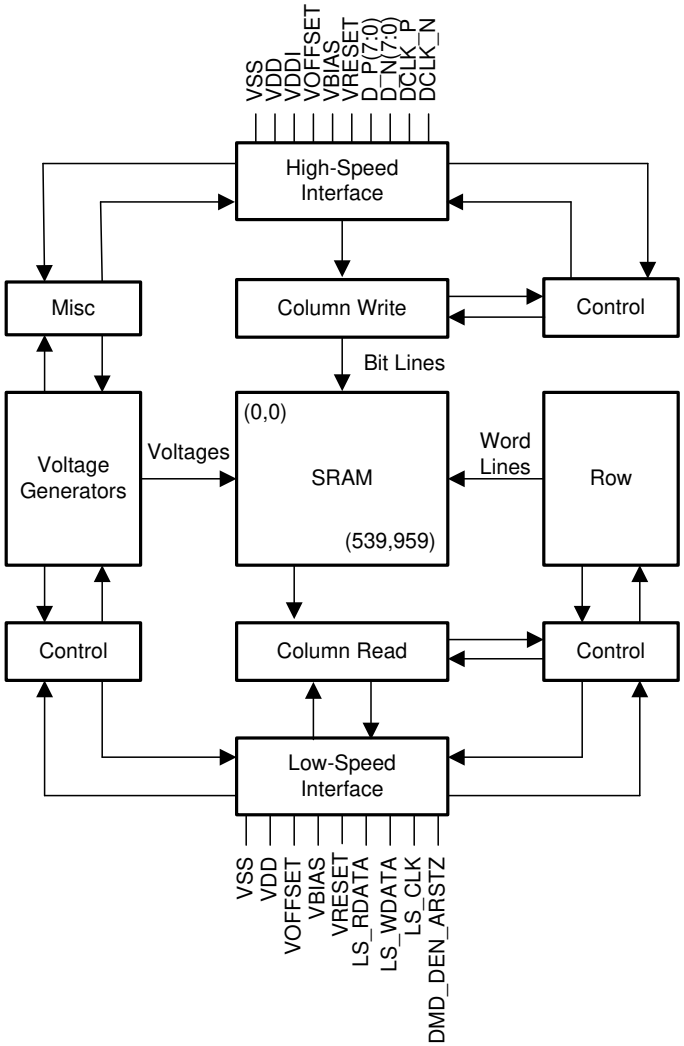
6 Detailed Description

6.1 Overview

The DLP472TP DMD is a 0.47-inch diagonal spatial light modulator which consists of an array of highly reflective aluminum micromirrors. The DMD is an electrical input, optical output micro-optical-electrical-mechanical system (MOEMS). The fast switching speed of the DMD micromirrors combined with advanced DLP image processing algorithms enables each micromirror to display four distinct pixels on the screen during every frame, resulting in a full 3840 × 2160 pixel image being displayed. The electrical interface is low voltage differential signaling (LVDS). The DMD consists of a two-dimensional array of 1-bit CMOS memory cells. The array is organized in a grid of M memory cell columns by N memory cell rows. Refer to the Functional Block Diagram. The positive or negative deflection angle of the micromirrors can be individually controlled by changing the address voltage of underlying CMOS addressing circuitry and micromirror reset signals (MBRST).

The DLP 0.47” 4K UHD chipset is comprised of the DLP472TP DMD, DLPC8445 display controller, and the DLPA3085 PMIC driver. To ensure reliable operation, the DLP472TP DMD must always be used with the DLP display controller and the PMIC specified in the chipset.

6.2 Functional Block Diagram



6.3 Feature Description

6.3.1 Power Interface

The DMD requires 4 DC voltages: 1.8V source, V_{OFFSET}, V_{RESET}, and V_{BIAS}. In a typical LED-based system, 1.8V, V_{OFFSET}, V_{RESET}, and V_{BIAS} is managed by the DLPA3085 PMIC and LED driver.

6.3.2 LPSDR 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.

6.3.3 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.

6.3.4 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 considered. 图 5-13 shows an equivalent test load circuit for the output under test. Timing reference loads are not intended to be precise representations 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.

6.4 Device Functional Modes

DMD functional modes are controlled by the DLPC8445 display controller. See the DLPC8445 display controller data sheet or contact a TI applications engineer.

6.5 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.

6.5.1 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 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 active area could occur.

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

6.5.3 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 optical architecture, overfill light may have to be further reduced below the suggested 10% level in order to be acceptable.

6.6 Micromirror Array Temperature Calculation

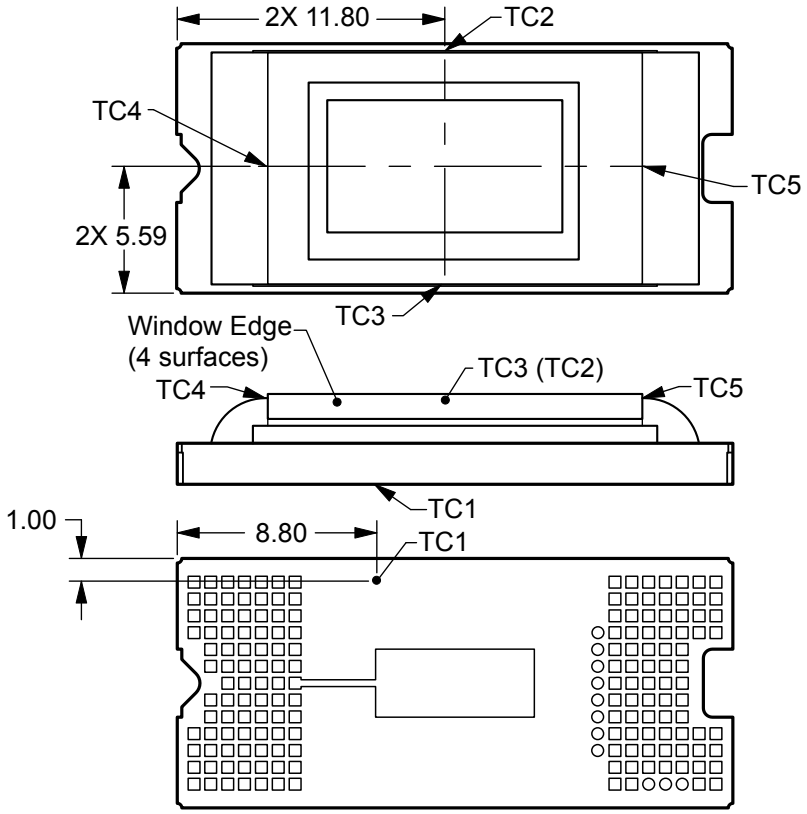


图 6-1. DMD Thermal Test Points

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 TC1/TP1 in 图 6-1) 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 图 6-1 from array to ceramic TP1 (°C/Watt)
- 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 1.0 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:

$Q_{INCIDENT}$ = 9.4W (measured)

$T_{CERAMIC}$ = 55.0°C (measured)

$Q_{ELECTRICAL}$ = 1.0W

Q_{ARRAY} = 1.0W + (0.40 × 9.4W) = 4.76W

T_{ARRAY} = 55.0°C + (4.76 W × 1.2°C/W) = 60.7°C

6.7 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)
- $OP_{UV\text{-}RATIO}$ = ratio of the optical power for wavelengths <410nm to the total optical power in the illumination spectrum (spectral measurement)
- $OP_{VIS\text{-}RATIO}$ = ratio of the optical power for wavelengths ⩾410nm and ⩽800nm to the total optical power in the illumination spectrum (spectral measurement)
- $OP_{IR\text{-}RATIO}$ = ratio of the optical power for wavelengths >800nm to the total optical power in the illumination spectrum (spectral measurement)
- $OP_{BLU\text{-}RATIO}$ = ratio of the optical power for wavelengths ⩾410nm and ⩽475nm to the total optical power in the illumination spectrum (spectral measurement)
- $OP_{BLU1\text{-}RATIO}$ = ratio of the optical power for wavelengths ⩾410nm and ⩽445nm 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 the 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:

$Q_{INCIDENT}$ = 9.40W (measured)

A_{ARRAY} = ((10.368mm × 5.832mm) ÷ 100) = 0.6047cm^2 (data sheet)

OV_{ILL} = 16.3% (optical model)

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

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

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

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

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

A_{ILL} = 0.6047cm^2 ÷ (1 - 0.163) = 0.7224cm^2

ILL_{UV} = [0.00021 × 9.40W] × 1000 ÷ 0.7224cm^2 = 2.732mW/cm^2

ILL_{VIS} = [0.99977 × 9.40W] ÷ 0.7224cm^2 = 13.01mW/cm^2

ILL_{IR} = [0.00002 × 9.40W] × 1000 ÷ 0.7224cm^2 = 0.260mW/cm^2

ILL_{BLU} = [0.28100 × 9.40W] ÷ 0.7224cm^2 = 3.66mW/cm^2

ILL_{BLU1} = [0.03200 × 9.40W] ÷ 0.7224cm^2 = 0.42mW/cm^2

6.8 Micromirror Landed-On/Landed-Off Duty Cycle

6.8.1 Definition of Micromirror Landed-On/Landed-Off Duty Cycle

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

For 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 for 50% of the time (and OFF for 50% of the time).

Note that when assessing the 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.

6.8.2 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 micromirror array (also called the active array) to an asymmetric landed duty cycle for a prolonged period of time can reduce the DMD useful 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.

6.8.3 Landed Duty Cycle and Operational DMD Temperature

Operational DMD temperature and landed duty cycle interact to affect DMD useful life, and this interaction can be exploited to reduce the impact that an asymmetrical landed duty cycle has on the DMD useful life. This is quantified in the derating curve shown in 图 5-1. The importance of this curve is that:

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

This curve specifies the maximum operating DMD temperature that the DMD should be operated at for a given long-term average landed duty cycle.

6.8.4 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 operates under a 100/0 landed duty cycle during that time period. Likewise, when displaying pure-black, the pixel operates under 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 表 6-1.

表 6-1. 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
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.

Use 方程式 1 to calculate the landed duty cycle of a given pixel during a given time period.

$$\text{Landed Duty Cycle} = (\text{Red\_Cycle\_\%} \times \text{Red\_Scale\_Value}) + (\text{Green\_Cycle\_\%} \times \text{Green\_Scale\_Value}) + (\text{Blue\_Cycle\_\%} \times \text{Blue\_Scale\_Value}) \quad (1)$$

where

- Red_Cycle_%, represents the percentage of the frame time that red is displayed to achieve the desired white point
- Green_Cycle_% represents the percentage of the frame time that green is displayed to achieve the desired white point
- Blue_Cycle_%, represents the percentage of the frame time that blue is displayed to achieve the desired white point

For example, assume that the red, green, and blue color cycle times are 30%, 50%, and 20% 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 表 6-2 and 表 6-3.

表 6-2. Example Landed Duty Cycle for Full-Color, Color Percentage

CYCLE PERCENTAGE		
RED	GREEN	BLUE
30%	50%	20%

表 6-3. Example Landed Duty Cycle for Full-Color

SCALE VALUE			LANDED DUTY CYCLE
RED	GREEN	BLUE	
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 controller, the gamma function affects the landed duty cycle.

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 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 图 6-2.

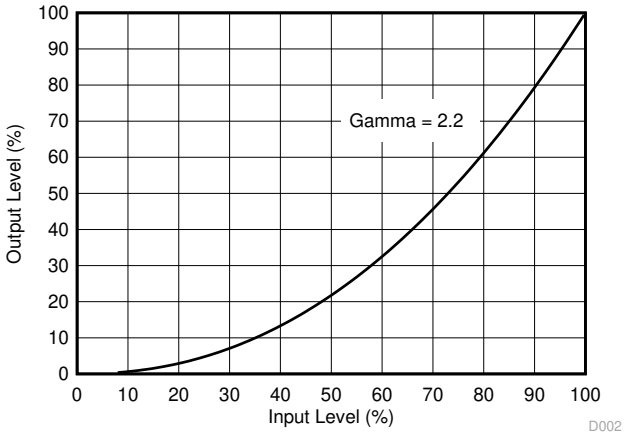


图 6-2. Example of Gamma = 2.2

From 图 6-2, if the gray scale value of a given input pixel is 40% (before gamma is applied), then gray scale value will be 13% after gamma is applied. Therefore, it can be seen that since gamma has a direct impact displayed gray scale level of a pixel, it also has a direct impact on the landed duty cycle of a pixel.

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

7 Application and Implementation

备注

以下应用部分中的信息不属于 TI 元件规格，TI 不担保其准确性和完整性。TI 的客户负责确定元件是否适合其用途，以及验证和测试其设计实现以确认系统功能。

7.1 Application Information

DMDs are spatial light modulators that 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 DLPC8445 controller. The high tilt pixel in the bottom-illuminated DMD increases brightness performance and enables a smaller system footprint for thickness-constrained applications. Typical applications using the DLP472TP include mobile smart TVs and digital signage.

DMD power-up and power-down sequencing is strictly controlled by the DLPA3085 . Refer to 节 8 for power-up and power-down specifications. To ensure reliable operation, the DLP472TP DMD must always be used with the DLPC8445 controller and a DLPA3085 PMIC.

7.2 Typical Application

The DLP472TP DMD, combined with DLPC8445 digital controller and a power management device, provides full 4K UHD resolution for bright, colorful display applications. See 图 7-1, which shows the system components needed along with the LED configuration of the DLP 0.47” 4K UHD chipset. The components include the DLP472TP DMD, the DLPC8445 display controller, and the DLPA3085 PMIC and LED driver.

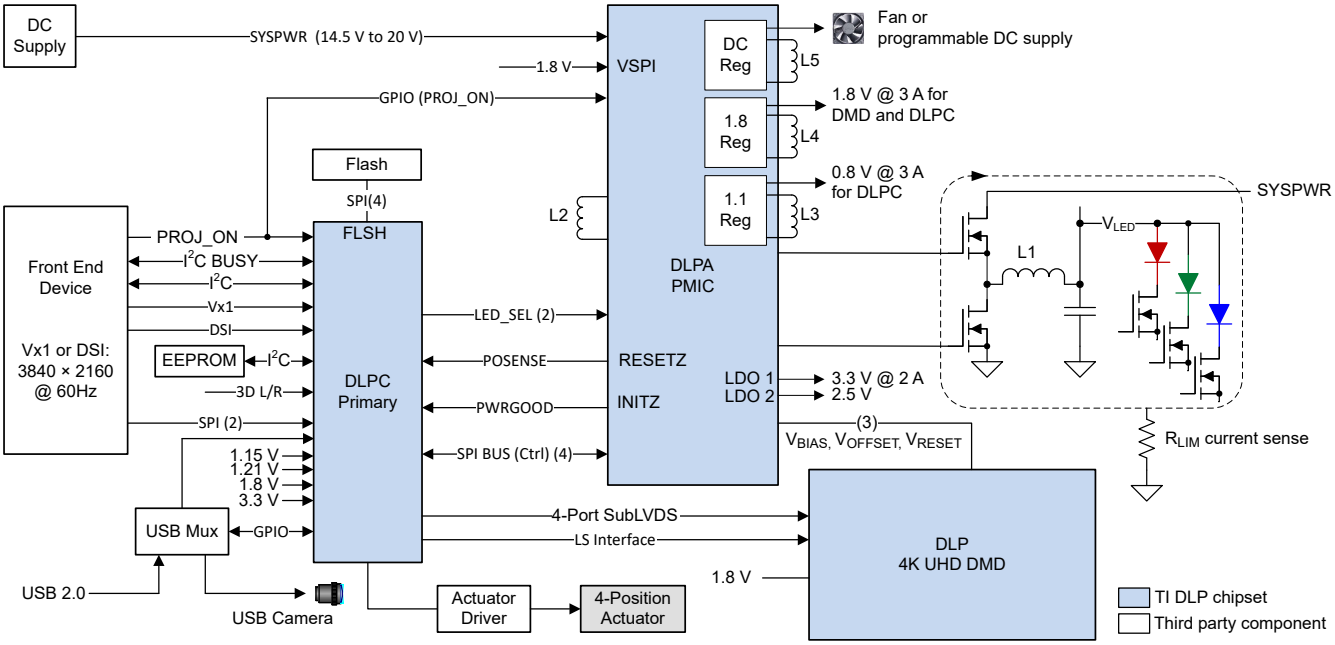


图 7-1. Typical 4K UHD LED Application Diagram

7.2.1 Design Requirements

Other core components of the display system include an illumination source, an optical engine for the illumination and projection optics, other electrical and mechanical components, and software. The type of illumination used and the desired brightness have a major effect on the overall system design and size.

The display system uses the DLP472TP as the core imaging device and contains a 0.47-inch array of micromirrors. The DLPC8445 controller is the digital interface between the DMD and the rest of the system, taking digital input from the front-end receiver and driving the DMD over a high-speed interface. The DLPA3085 PMIC serves as a voltage regulator for the DMD, controller, and LED illumination functionality.

7.2.2 Detailed Design Procedure

For a complete DLP system, an optical module or light engine is required that contains the DLP472TP DMD, associated illumination sources, optical elements, and necessary mechanical components.

To ensure reliable operation, the DMD must always be used with the DLPC8445 display controller and the DLPA3085 PMIC driver.

7.2.3 Application Curve

The typical LED-current-to-luminance relationship when LED illumination is used is shown in 图 7-2.

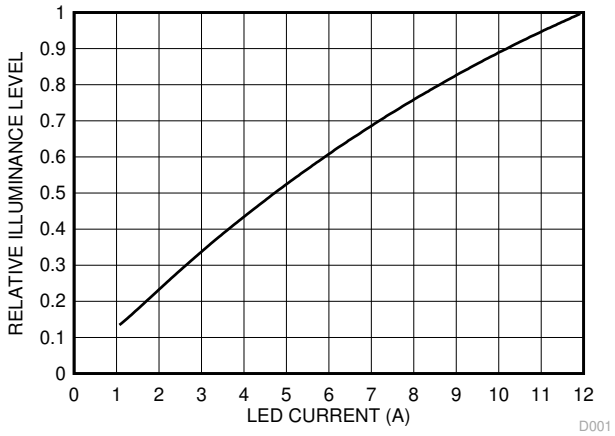


图 7-2. Luminance vs. Current

7.3 Temperature Sensor Diode

The software application provides functions to configure the TMP411 to read the DLP472TP DMD temperature sensor diode. Use this data to incorporate additional functionality in the overall system design, such as adjusting illumination, fan speeds, and so on. All communication between the TMP411 and the DLPC8445 controller is completed using the I^2C interface. The TMP411 connects to the DMD through the pins outlined in 节 4.

8 Power Supply Recommendations

The following power supplies are all required to operate the DMD:

- V_{SS}
- V_{BIAS}
- V_{DD}
- V_{DDI}
- V_{OFFSET}
- V_{RESET}

DMD power-up and power-down sequencing is strictly controlled by the DLP display controller.

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For reliable operation of the DMD, the following power supply sequencing requirements must be followed. Failure to adhere to any of the prescribed power-up and power-down requirements may affect device reliability. See the DMD power supply sequencing requirements in 图 8-1.

V_{BIAS}, V_{DD}, V_{DDI}, V_{OFFSET}, and V_{RESET} power supplies must be coordinated during power-up and power-down operations. Failure to meet any of the below requirements result in a significant reduction in the DMD reliability and lifetime. Common ground V_{SS} must also be connected.

表 8-1. Power Supply Sequence Requirements

SYMBOL	PARAMETER	DESCRIPTION	MIN	TYP	MAX	UNIT
t_{DELAY}	Delay requirement	from V_{OFFSET} power up to V_{BIAS} power up	2			ms
V_{OFFSET}	Supply voltage level	at beginning of power-up sequence delay(1)			6	V
V_{BIAS}	Supply voltage level	at end of power-up sequence delay(1)			6	V

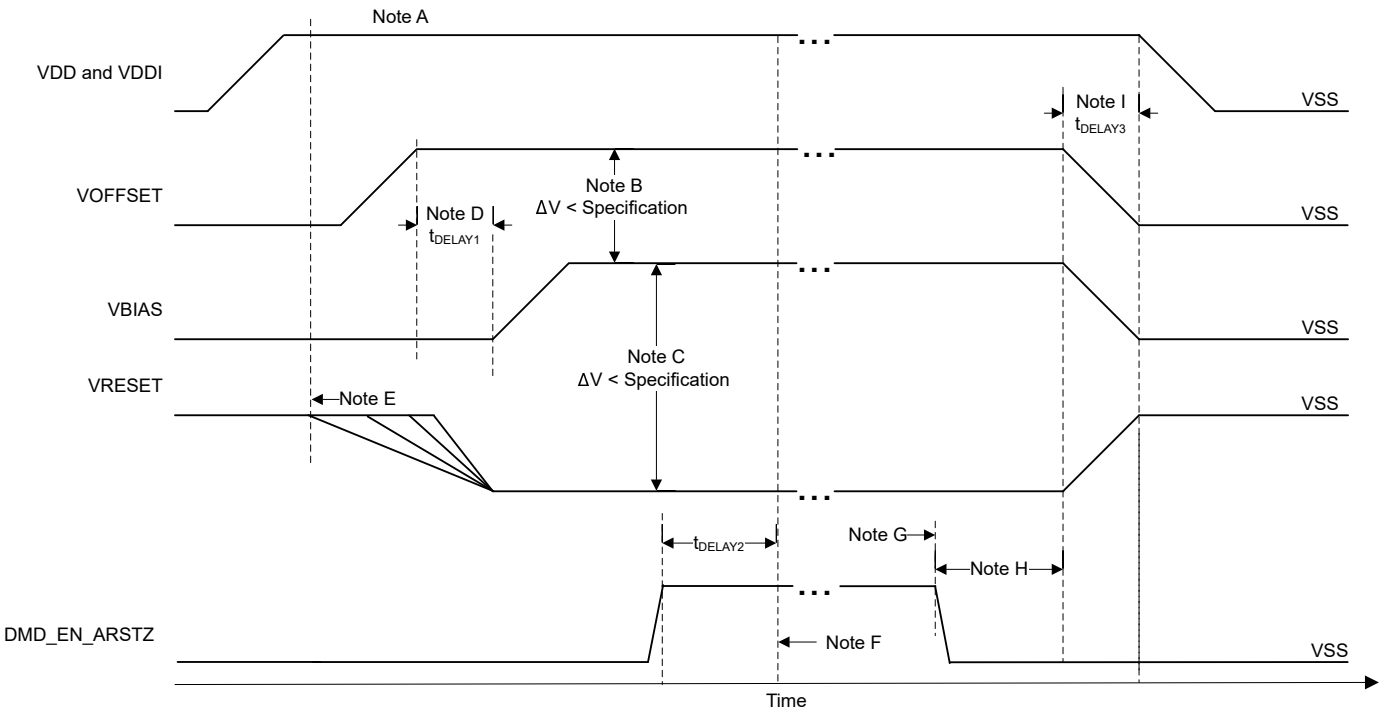
(1) See 图 8-1, Power-Up Sequence Delay Requirement.

8.1 DMD Power Supply Power-Up Procedure

- During power-up, V_{DD} and V_{DDI} must always start and settle before V_{OFFSET} plus Delay1 specified in 表 8-2, V_{BIAS}, and V_{RESET} voltages are applied to the DMD.
- During power-up, it is a strict requirement that the voltage difference between V_{BIAS} and V_{OFFSET} must be within the specified limit shown in 节 5.4.
- During power-up, there is no requirement for the relative timing of V_{RESET} with respect to V_{BIAS}.
- Power supply slew rates during power-up are flexible, provided that the transient voltage levels follow the requirements specified in 节 5.1, in 节 5.4, and in 图 8-1.
- During power-up, LVCMOS input pins must not be driven high until after V_{DD} have settled at operating voltages listed in 节 5.4.

8.2 DMD Power Supply Power-Down Procedure

- During power-down, V_{DD} and V_{DDI} must be supplied until after V_{BIAS}, V_{RESET}, and V_{OFFSET} are discharged to within the specified limit of ground. See 表 8-2.
- During power-down, it is a strict requirement that the voltage difference between V_{BIAS} and V_{OFFSET} must be within the specified limit shown in 节 5.4.
- During power-down, there is no requirement for the relative timing of V_{RESET} with respect to V_{BIAS}.
- Power supply slew rates during power-down are flexible, provided that the transient voltage levels follow the requirements specified in 节 5.1, in 节 5.4, and in 图 8-1.
- During power-down, LVCMOS input pins must be less than specified in 节 5.4.



A. See 节 4 for the *Pin Functions Table*.
B. To prevent excess current, the supply voltage difference $|V_{OFFSET} - V_{BIAS}|$ must be less than the specified limit in 节 5.4.
C. To prevent excess current, the supply difference $|V_{BIAS} - V_{RESET}|$ must be less than the specified limit in 节 5.4.
D. V_{BIAS} should power up after V_{OFFSET} has powered up, per the Delay1 specification in 表 8-2.
E. DLP controller software initiates the global V_{BIAS} command.
F. After the DMD micromirror park sequence is complete, the DLP controller software initiates a hardware power-down that activates DMD_EN_ARSTZ and disables V_{BIAS}, V_{RESET}, and V_{OFFSET}.
G. Under power-loss conditions where emergency DMD micromirror park procedures are being enacted by the DLP controller hardware DMD_EN_ARSTZ will go low.
H. V_{DD} must remain high until after V_{OFFSET}, V_{BIAS}, and V_{RESET} go low, per Delay2 specification in 表 8-2.
I. To prevent excess current, the supply voltage delta $|V_{DDI} - V_{DD}|$ must be less than the specified limit in 节 5.4.

图 8-1. DMD Power Supply Requirements

表 8-2. DMD Power-Supply Requirements

PARAMETER	DESCRIPTION	MIN	NOM	MAX	UNIT
Delay1(1)	Delay from V_{OFFSET} settled at recommended operating voltage to V_{BIAS} and V_{RESET} power up	1	2		ms
Delay2(1)	Delay V_{DD} must be held high from V_{OFFSET}, V_{BIAS}, and V_{RESET} powering down.	50			µs

(1) See 图 8-1.

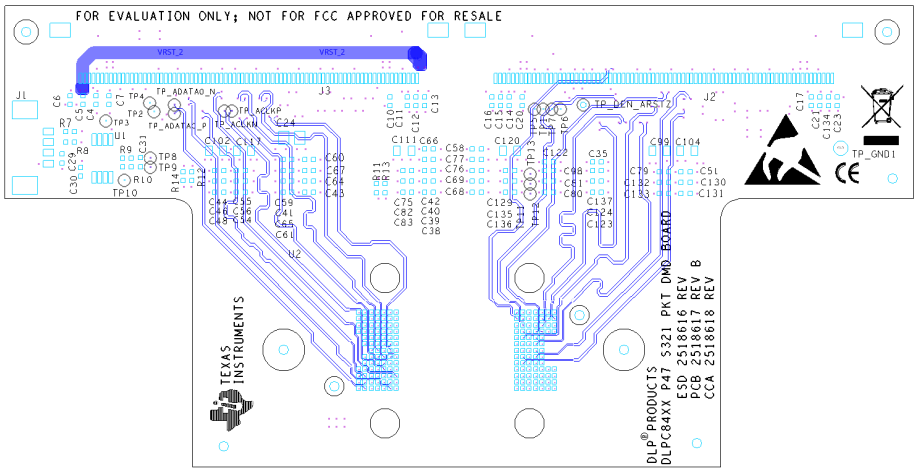
9 Layout

9.1 Layout Guidelines

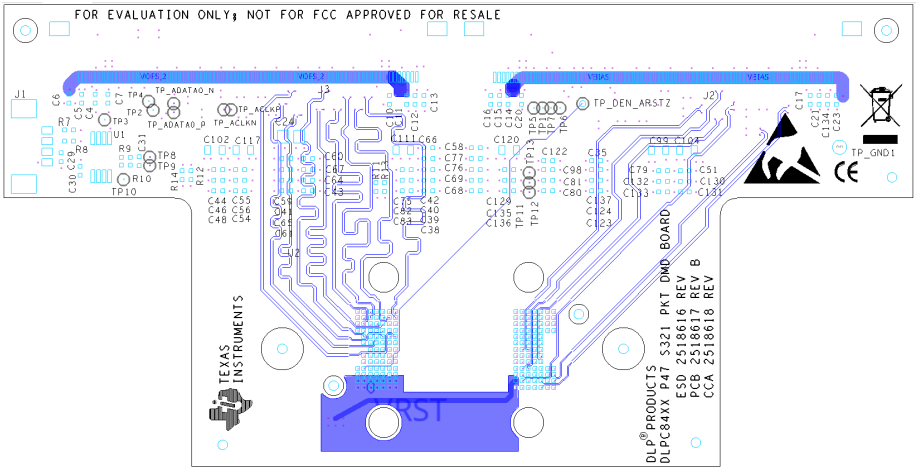
The DLP472TP DMD connects to a PCB or a flex circuit using an interposer. For additional layout guidelines regarding length matching and impedance, see the DLPC8445 controller data sheet. For a detailed layout example, refer to the layout design files. Some layout guidelines for routing to the DLP472TP DMD are:

- Match lengths for the LS_WDATA and LS_CLK signals, as specified in the DLPC8445 controller data sheet.
- Match lengths for the HS_bus differential signals as specified in the DLPC8445 controller data sheet.
- Minimize vias, layer changes, and turns for the HS bus signals. Refer to 图 9-1.
- Supply capacitance needs can vary per design. Refer to the layout design file for a general guideline. Supplies need to be verified on the design to ensure all supplies are operating in the recommended operating range at the DMD.

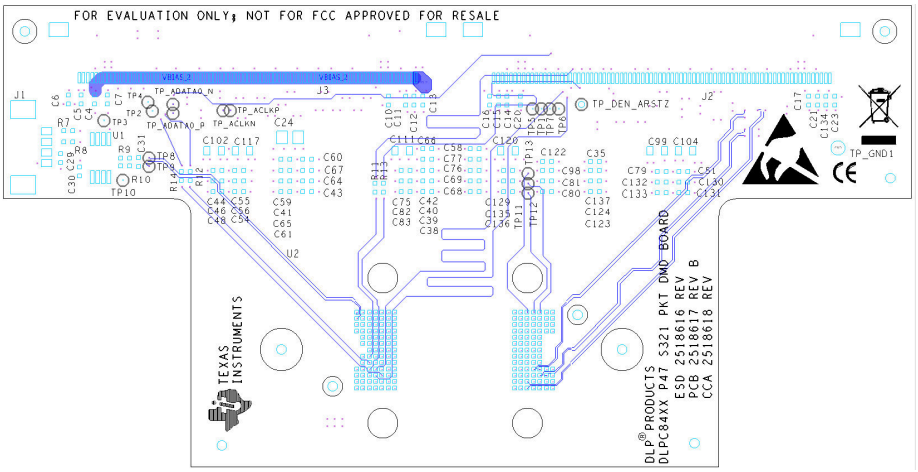
9.2 Layout Example



Layer 4



Layer 7



Layer 9

图 9-1. Routing Example

10 器件和文档支持

10.1 第三方产品免责声明

TI 发布的与第三方产品或服务有关的信息，不能构成与此类产品或服务或保修的适用性有关的认可，不能构成此类产品或服务单独或与任何 TI 产品或服务一起的表示或认可。

10.2 器件支持

10.2.1 器件命名规则

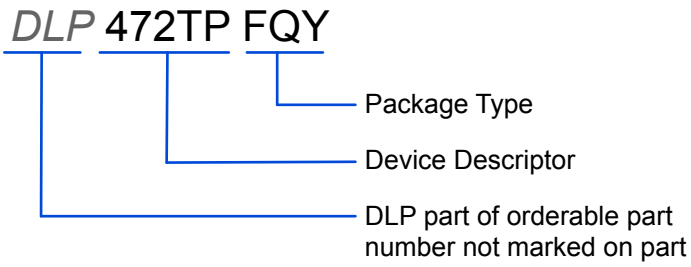


图 10-1. 器件型号说明

10.2.2 器件标识

器件标识包括人类可读的信息和二维矩阵码。图 10-2 说明了可供人类读取的信息，其中包括 GHJJJJK 472TPFQY 这一清晰可辨的字符串。GHJJJJK 是批次追踪代码，472TPFQY 则是器件标识。

示例： GHJJJJK DLP472TPFQY

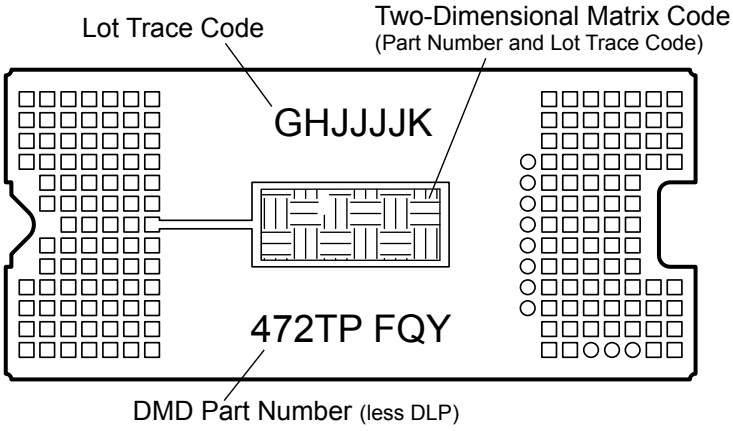


图 10-2. DMD 标识位置

10.3 文档支持

10.3.1 相关文档

以下文档包含与该 DMD 一起使用的芯片组元件相关的更多信息。

- *DLPC8445 高分辨率控制器数据表*
- *DLPA3085 PMIC 和高电流 LED 驱动器 IC 数据表*

10.4 接收文档更新通知

要接收文档更新通知，请导航至 ti.com 上的器件产品文件夹。点击*通知* 进行注册，即可每周接收产品信息更改摘要。有关更改的详细信息，请查看任何已修订文档中包含的修订历史记录。

10.5 商标

DLP® is a registered trademark of Texas Instruments.
所有商标均为其各自所有者的财产。

10.6 静电放电警告

静电放电 (ESD) 会损坏这个集成电路。德州仪器 (TI) 建议通过适当的预防措施处理所有集成电路。如果不遵守正确的处理和安装程序，可能会损坏集成电路。

ESD 的损坏小至导致微小的性能降级，大至整个器件故障。精密的集成电路可能更容易受到损坏，这是因为非常细微的参数更改都可能会导致器件与其发布的规格不相符。

10.7 术语表

TI 术语表　　本术语表列出并解释了术语、首字母缩略词和定义。

11 Revision History

注：以前版本的页码可能与当前版本的页码不同

DATE	REVISION	NOTES
August 2024	*	Initial Release

12 机械、封装和可订购信息

以下页面包含机械、封装和可订购信息。这些信息是指定器件的最新可用数据。数据如有变更，恕不另行通知，且不会对此文档进行修订。有关此数据表的浏览器版本，请查阅左侧的导航栏。

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)
DLP472TPFQY	Active	Production	CLGA (FQY) | 174	80 | JEDEC TRAY (5+1)	In-Work	NI/AU	N/A for Pkg Type	0 to 70	
DLP472TPFQY.B	Active	Production	CLGA (FQY) | 174	80 | JEDEC TRAY (5+1)	In-Work	NI/AU	N/A for Pkg Type	0 to 70	
XDLP472TPFQY.B	Active	Preproduction	CLGA (FQY) | 174	80 | JEDEC TRAY (5+1)	Yes	NI/AU	N/A for Pkg Type	0 to 70	

(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.

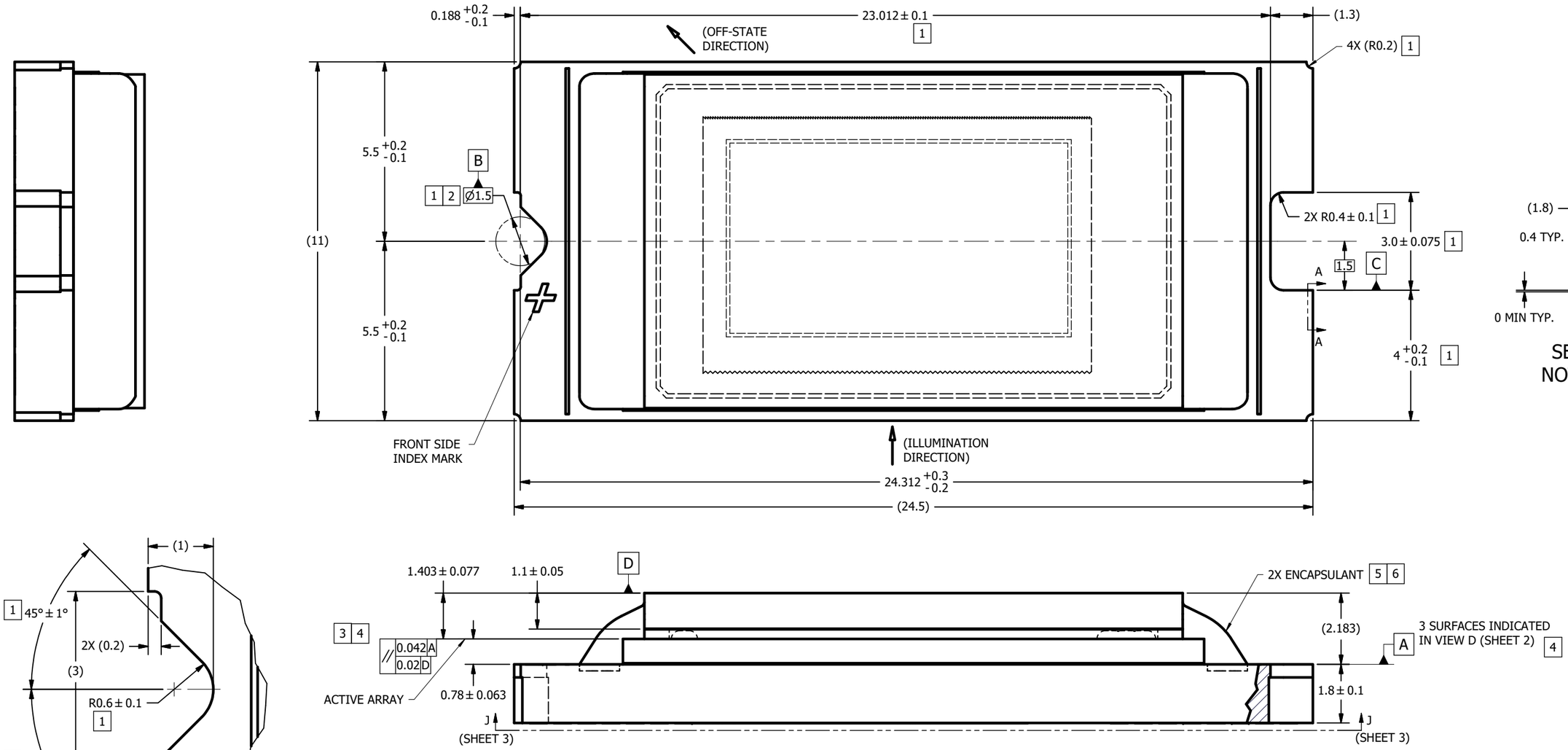
Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

REVISIONS

REV	DESCRIPTION	DATE	BY
A	ECO 2202674: INITIAL RELEASE	12/22/22	HG

NOTES UNLESS OTHERWISE SPECIFIED:

1. NOTCH DIMENSIONS ARE DEFINED BY UPPERMOST LAYERS OF CERAMIC, AS SHOWN IN SECTION A-A.
2. SEE DETAIL B FOR "V-NOTCH" DIMENSIONS.
3. DIE PARALLELISM TOLERANCE APPLIES TO DMD ACTIVE ARRAY ONLY.
4. 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.
5. ENCAPSULANT TO BE CONTAINED WITHIN DIMENSIONS SHOWN IN VIEW D (SHEET 2). NO ENCAPSULANT IS ALLOWED ON TOP OF THE WINDOW.
6. ENCAPSULANT NOT TO EXCEED THE HEIGHT OF THE WINDOW.
7. ROTATION ANGLE OF DMD ACTIVE ARRAY IS A REFINEMENT OF THE LOCATION TOLERANCE AND HAS A MAXIMUM ALLOWED VALUE OF 0.6 DEGREES.
8. BOUNDARY MIRRORS SURROUNDING THE DMD ACTIVE ARRAY.



DETAIL B
V-NOTCH
SCALE 30 : 1

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	H. GAGLIARDI	1/22/2023
ENGINEER	H. GAGLIARDI	12/22/2022
QA/CE	P. KONRAD	12/27/2022
CM	B. HASKETT	12/22/2022
	J. McKINLEY	12/22/2022
APPROVED	M. GARCIA	1/3/2023

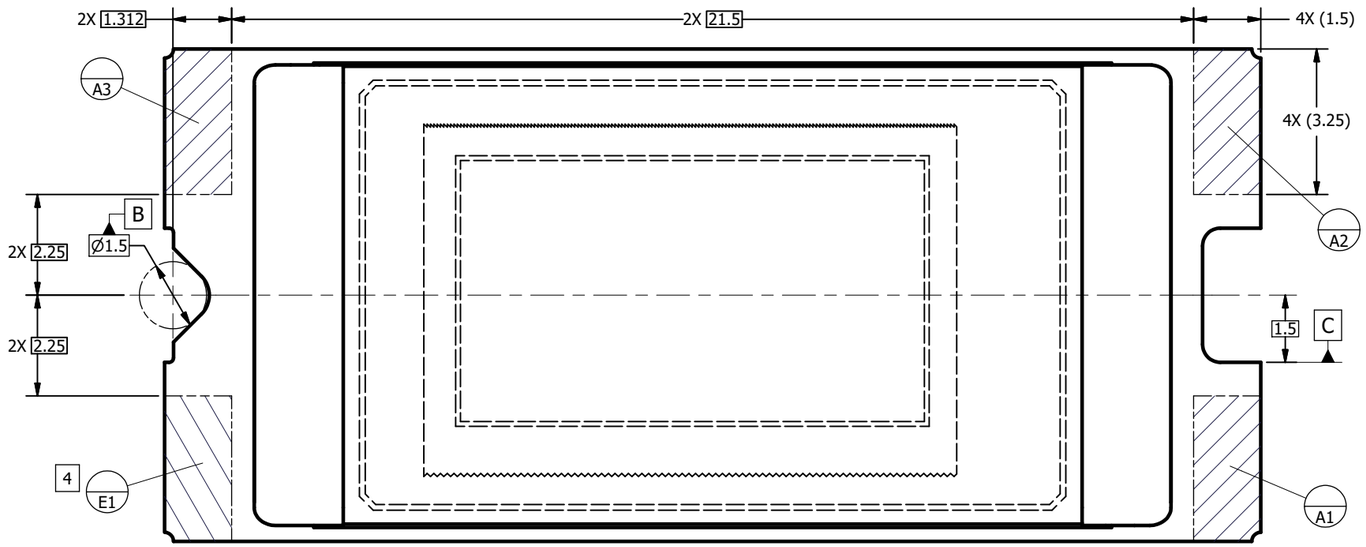
TEXAS INSTRUMENTS
Dallas Texas

TITLE
ICD, MECHANICAL, DMD,
.47 4K PKT-LVDS3 SERIES 321,
(FQY PACKAGE)

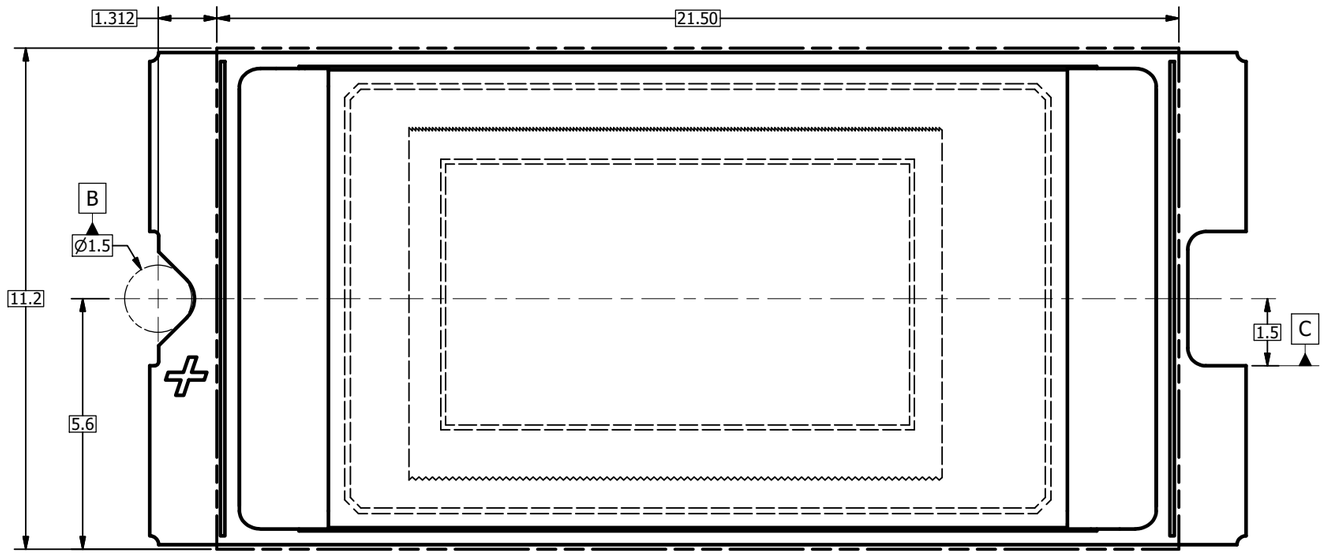
SIZE	DWG NO	REV
D	2518523	A

SCALE 15:1 SHEET 1 OF 3

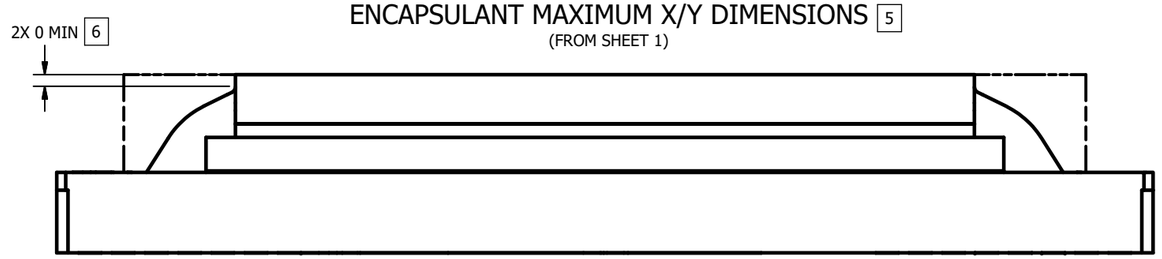
INV11-2006a



VIEW C
DATUMS A AND E
(SUBSTRATE METALLIZATION OMITTED FOR CLARITY)
(FROM SHEET 1)



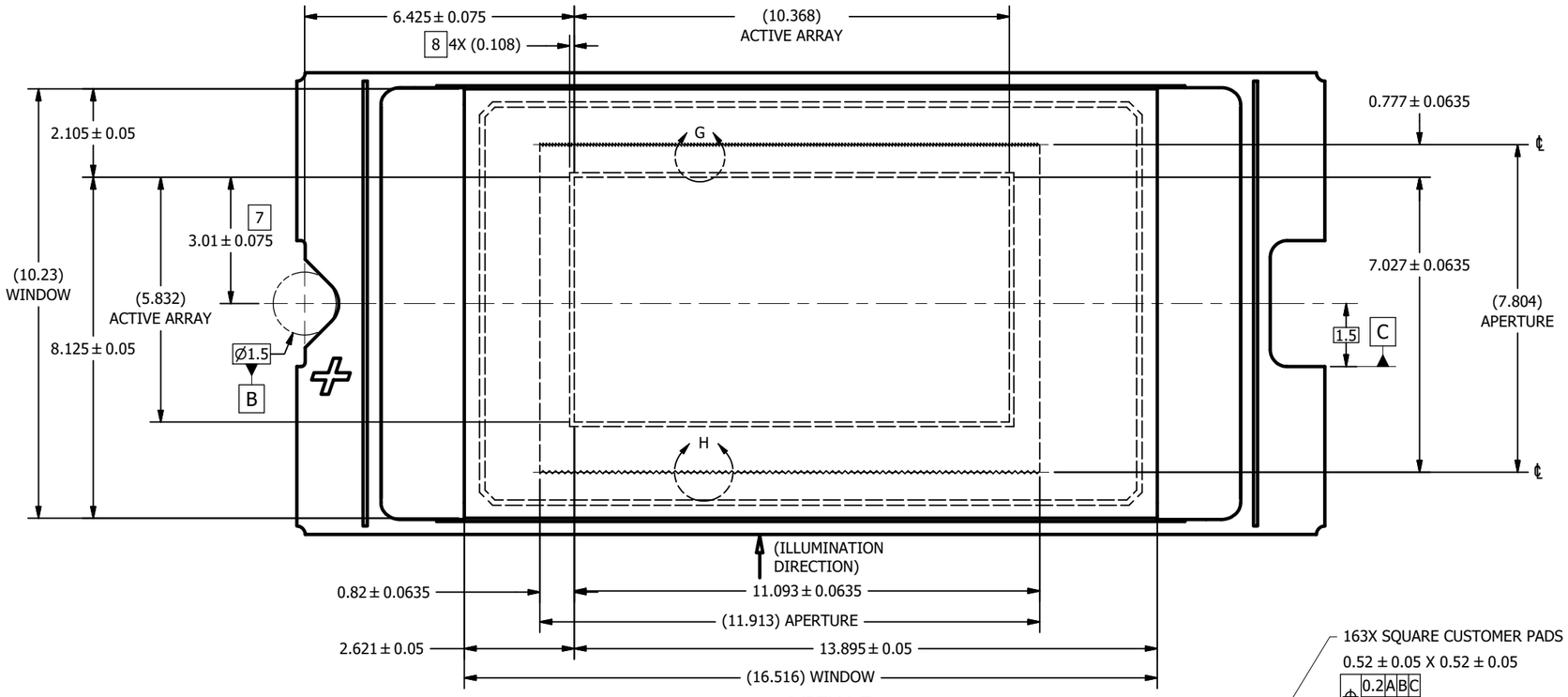
VIEW D
ENCAPSULANT MAXIMUM X/Y DIMENSIONS 5
(FROM SHEET 1)



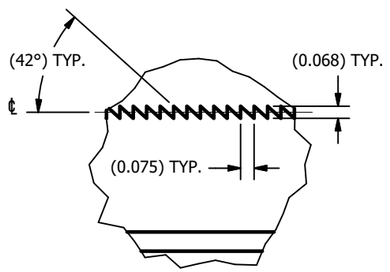
VIEW E
ENCAPSULANT MAXIMUM HEIGHT

TEXAS INSTRUMENTS Dallas Texas	DRAWN H. GAGLIARDI	DATE 1/22/2023	SIZE D	DWG NO 2518523	REV A
			SCALE	SHEET 2 OF 3	

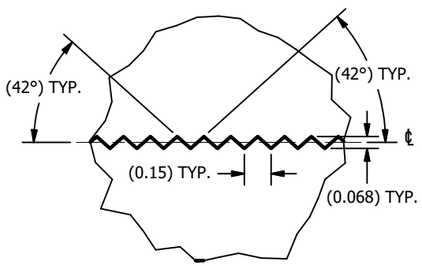
INV11-2006a



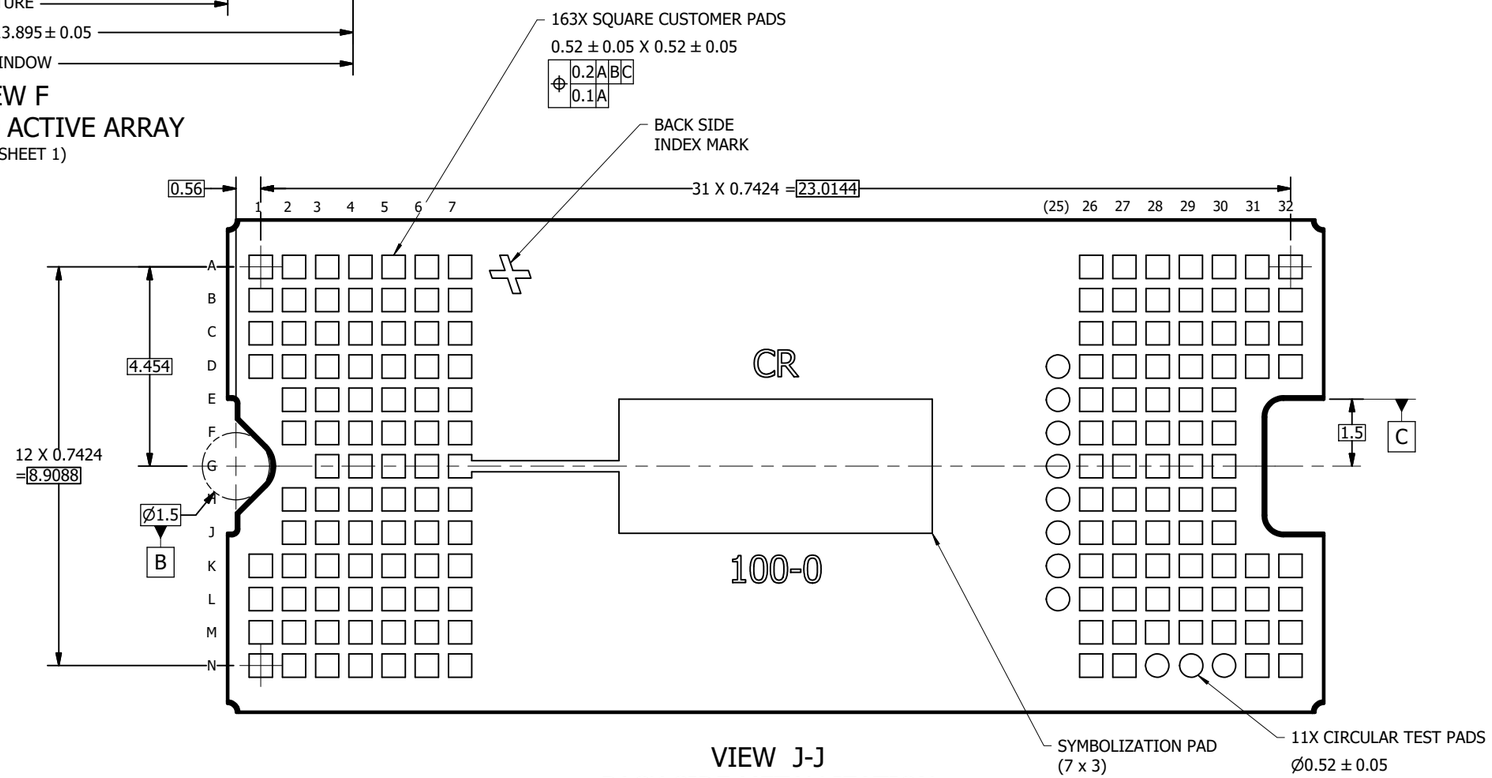
VIEW F
WINDOW AND ACTIVE ARRAY
(FROM SHEET 1)



DETAIL G
APERTURE TOP EDGE
SCALE 60 : 1



DETAIL H
APERTURE BOTTOM EDGE
SCALE 60 : 1



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

TEXAS INSTRUMENTS Dallas Texas	DRAWN H. GAGLIARDI	DATE 1/22/2023	SIZE D	DWG NO 2518523	REV A
			SCALE	SHEET 3 OF 3	

INV11-2006a

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