

## DLP471TP 0.47 4K 超高清 DMD

### 1 特性

- 0.47 英寸对角线微镜阵列
  - 4K 超高清 (3840 × 2160) 显示分辨率
  - 5.4 μm 微镜间距
  - ±17° 微镜倾斜度 (相对于平坦表面)
  - 底部照明
- 高速串行接口 (HSSI) 输入数据总线
- 支持 4K UHD (60Hz)
- 支持 1080p (高达 240Hz)
- 由 DLPC6540 显示控制器、DLPA3005 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

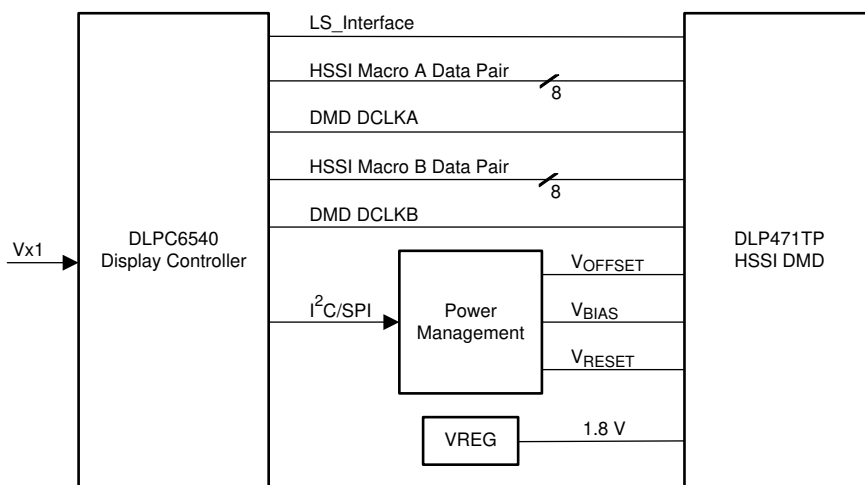
### 3 说明

DLP471TP 数字微镜器件 (DMD) 是一款数控微机电系统 (MEMS) 空间照明调制器 (SLM)，可用于实现高亮的 4K 超高清显示系统。TI DLP® 产品 0.47 英寸 4K UHD 芯片组由 DMD、DLPC6540 显示控制器以及 DLPA3005 PMIC 和 LED 驱动器组成。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<sup>(1)</sup>

器件型号	封装	封装尺寸 (标称值)
DLP471TP	FQQ (270)	25.65mm × 16.9mm

(1) 如需了解所有可用封装，请参阅数据表末尾的可订购产品附录。



简化版应用



## Table of Contents

<b>1 特性</b> .....	<b>1</b>	7.7 Micromirror Power Density Calculation.....	<b>25</b>
<b>2 应用</b> .....	<b>1</b>	7.8 Micromirror Landed-On/Landed-Off Duty Cycle.....	<b>28</b>
<b>3 说明</b> .....	<b>1</b>	<b>8 Application and Implementation</b> .....	<b>31</b>
<b>4 Revision History</b> .....	<b>2</b>	8.1 Application Information.....	<b>31</b>
<b>5 Pin Configuration and Functions</b> .....	<b>3</b>	8.2 Typical Application.....	<b>31</b>
<b>6 Specifications</b> .....	<b>8</b>	8.3 Temperature Sensor Diode.....	<b>32</b>
6.1 Absolute Maximum Ratings.....	<b>8</b>	<b>9 Power Supply Recommendations</b> .....	<b>33</b>
6.2 Storage Conditions.....	<b>9</b>	9.1 DMD Power Supply Power-Up Procedure.....	<b>33</b>
6.3 ESD Ratings.....	<b>9</b>	9.2 DMD Power Supply Power-Down Procedure.....	<b>33</b>
6.4 Recommended Operating Conditions.....	<b>9</b>	<b>10 Layout</b> .....	<b>35</b>
6.5 Thermal Information.....	<b>11</b>	10.1 Layout Guidelines.....	<b>35</b>
6.6 Electrical Characteristics.....	<b>12</b>	10.2 Impedance Requirements.....	<b>35</b>
6.7 Switching Characteristics.....	<b>13</b>	10.3 Layers.....	<b>35</b>
6.8 Timing Requirements.....	<b>14</b>	10.4 Trace Width, Spacing.....	<b>36</b>
6.9 System Mounting Interface Loads.....	<b>17</b>	10.5 Power.....	<b>36</b>
6.10 Micromirror Array Physical Characteristics.....	<b>18</b>	10.6 Trace Length Matching Recommendations.....	<b>37</b>
6.11 Micromirror Array Optical Characteristics.....	<b>19</b>	<b>11 Device and Documentation Support</b> .....	<b>38</b>
6.12 Window Characteristics.....	<b>21</b>	11.1 第三方产品免责声明.....	<b>38</b>
6.13 Chipset Component Usage Specification.....	<b>21</b>	11.2 Device Support.....	<b>38</b>
<b>7 Detailed Description</b> .....	<b>22</b>	11.3 Documentation Support.....	<b>39</b>
7.1 Overview.....	<b>22</b>	11.4 支持资源.....	<b>39</b>
7.2 Functional Block Diagram.....	<b>22</b>	11.5 Trademarks.....	<b>39</b>
7.3 Feature Description.....	<b>23</b>	11.6 静电放电警告.....	<b>39</b>
7.4 Device Functional Modes.....	<b>23</b>	11.7 术语表.....	<b>39</b>
7.5 Optical Interface and System Image Quality Considerations.....	<b>23</b>	<b>12 Mechanical, Packaging, and Orderable Information</b> .....	<b>40</b>
7.6 Micromirror Array Temperature Calculation.....	<b>24</b>		

## 4 Revision History

注：以前版本的页码可能与当前版本的页码不同

Changes from Revision A (June 2022) to Revision B (July 2023)	Page
• Added section "ILLUMINATION" to <i>Recommended Operating Conditions</i> .....	<b>9</b>
• Updated <i>Micromirror Array Temperature Calculation</i> .....	<b>24</b>
• Added <i>Micromirror Power Density Calculation</i> .....	<b>25</b>

Changes from Revision * (August 2020) to Revision A (June 2022)	Page
• 根据最新的德州仪器 (TI) 和行业标准对本文档进行了更新.....	<b>1</b>
• Updated $ T_{\Delta} $ MAX from 14°C to 15°C.....	<b>9</b>
• Updated <i>Micromirror Array Optical Characteristics</i> .....	<b>19</b>
• Updated 图 9-1 .....	<b>33</b>

## 5 Pin Configuration and Functions

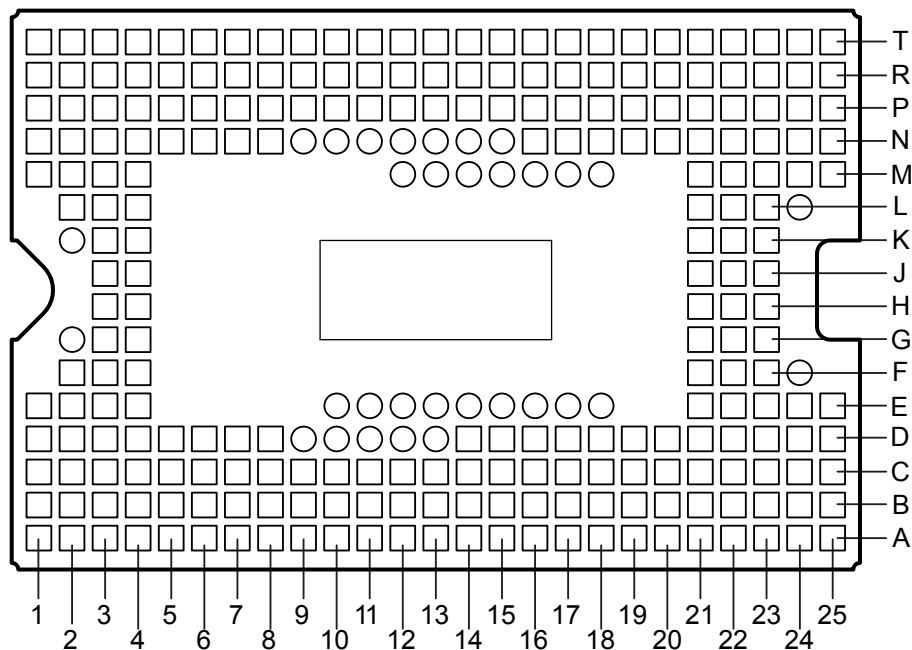


图 5-1. FQQ Package 270-Pin CLGA (Bottom View)

表 5-1. Pin Functions

PIN <sup>(2)</sup>		TYPE <sup>(1)</sup>	DESCRIPTION	TERMINATION	TRACE LENGTH (mm)
NAME	PAD ID				
D_AP(0)	A8	I	High-speed Differential Data Pair lane A0	Differential 100 Ω	2.15873
D_AN(0)	A7	I	High-speed Differential Data Pair lane A0	Differential 100 Ω	2.16135
D_AP(1)	B2	I	High-speed Differential Data Pair lane A1	Differential 100 Ω	8.33946
D_AN(1)	C2	I	High-speed Differential Data Pair lane A1	Differential 100 Ω	8.34121
D_AP(2)	A6	I	High-speed Differential Data Pair lane A2	Differential 100 Ω	6.41271
D_AN(2)	A5	I	High-speed Differential Data Pair lane A2	Differential 100 Ω	6.41305
D_AP(3)	A10	I	High-speed Differential Data Pair lane A3	Differential 100 Ω	1.8959
D_AN(3)	A9	I	High-speed Differential Data Pair lane A3	Differential 100 Ω	1.8959
D_AP(4)	D1	I	High-speed Differential Data Pair lane A4	Differential 100 Ω	12.11543
D_AN(4)	E1	I	High-speed Differential Data Pair lane A4	Differential 100 Ω	12.11539
D_AP(5)	D3	I	High-speed Differential Data Pair lane A5	Differential 100 Ω	12.01561
D_AN(5)	E3	I	High-speed Differential Data Pair lane A5	Differential 100 Ω	12.0164
D_AP(6)	F3	I	High-speed Differential Data Pair lane A6	Differential 100 Ω	12.98403
D_AN(6)	G3	I	High-speed Differential Data Pair lane A6	Differential 100 Ω	12.98177
D_AP(7)	A12	I	High-speed Differential Data Pair lane A7	Differential 100 Ω	2.29773
D_AN(7)	A11	I	High-speed Differential Data Pair lane A7	Differential 100 Ω	2.29773
DCLK_AP	A3	I	High-speed Differential Clock A	Differential 100 Ω	11.75367
DCLK_AN	A4	I	High-speed Differential Clock A	Differential 100 Ω	11.57432
D_BP(0)	A14	I	High-speed Differential Data Pair lane B0	Differential 100 Ω	2.10786
D_BN(0)	A15	I	High-speed Differential Data Pair lane B0	Differential 100 Ω	2.10711

表 5-1. Pin Functions (continued)

PIN <sup>(2)</sup>		TYPE <sup>(1)</sup>	DESCRIPTION	TERMINATION	TRACE LENGTH (mm)
NAME	PAD ID				
D_BP(1)	F23	I	High-speed Differential Data Pair lane B1	Differential 100 $\Omega$	12.79448
D_BN(1)	G23	I	High-speed Differential Data Pair lane B1	Differential 100 $\Omega$	12.79438
D_BP(2)	E24	I	High-speed Differential Data Pair lane B2	Differential 100 $\Omega$	13.00876
D_BN(2)	E23	I	High-speed Differential Data Pair lane B2	Differential 100 $\Omega$	13.00932
D_BP(3)	A22	I	High-speed Differential Data Pair lane B3	Differential 100 $\Omega$	11.21886
D_BN(3)	A23	I	High-speed Differential Data Pair lane B3	Differential 100 $\Omega$	11.21881
D_BP(4)	D25	I	High-speed Differential Data Pair lane B4	Differential 100 $\Omega$	10.79038
D_BN(4)	D24	I	High-speed Differential Data Pair lane B4	Differential 100 $\Omega$	10.78946
D_BP(5)	A20	I	High-speed Differential Data Pair lane B5	Differential 100 $\Omega$	5.75986
D_BN(5)	A21	I	High-speed Differential Data Pair lane B5	Differential 100 $\Omega$	5.75928
D_BP(6)	B24	I	High-speed Differential Data Pair lane B6	Differential 100 $\Omega$	9.01461
D_BN(6)	B25	I	High-speed Differential Data Pair lane B6	Differential 100 $\Omega$	9.01416
D_BP(7)	A18	I	High-speed Differential Data Pair lane B7	Differential 100 $\Omega$	2.08767
D_BN(7)	A19	I	High-speed Differential Data Pair lane B7	Differential 100 $\Omega$	2.08767
DCLK_BP	A17	I	High-speed Differential Clock B	Differential 100 $\Omega$	2.12928
DCLK_BN	A16	I	High-speed Differential Clock B	Differential 100 $\Omega$	2.30933
LS_WDATA_P	T16	I	LVDS Data	Differential 100 $\Omega$	0
LS_WDATA_N	R16	I	LVDS Data	Differential 100 $\Omega$	0.27407
LS_CLK_P	T14	I	LVDS CLK	Differential 100 $\Omega$	2.43086
LS_CLK_N	R14	I	LVDS CLK	Differential 100 $\Omega$	2.40852
LS_RDATA_A_BISTA	R18	O	LVC MOS Output		2.00263
BIST_B	T20	O	LVC MOS Output		4.61261
AMUX_OUT	C21	O	Analog Test Mux		3.03604
DMUX_OUT	R20	O	Digital Test Mux		2.88361
DMD_DEN_ARSTZ	T18	I	ARSTZ	17.5-k $\Omega$ pulldown	1.89945
TEMP_N	R12	I	Temp Diode N		4.02546
TEMP_P	T12	I	Temp Diode P		3.62598

**表 5-1. Pin Functions (continued)**

PIN <sup>(2)</sup>		TYPE <sup>(1)</sup>	DESCRIPTION	TERMINATION	TRACE LENGTH (mm)
NAME	PAD ID				
VDD	B13, C5, C9, C12, C15, C18, C22, D6, D7, D14, D16, D19, D20, E21, G21, J4, J21, J23, K3, K22, L2, L4, L22, M1, M3, M21, M23, M25, N2, N4, N6, N8, N16, N18, N20, N22, N24, P3, P5, P7, P9, P11, P13, P15, P17, P19, P21, P23, P25, R2, R4, R6, R8, R10, T3, T5, T7, T9, T11, T13, T15, T17, T19, T21, T23	P	Digital core supply voltage		Plane
VDDA	A24, B3, B5, B7, B9, B11, B14, B16, B18, B20, B22, C1, C24, D4, D23, E2, F4, F22, H3, H22	P	HSSI supply voltage		Plane
VRESET	A2, R1	P	Supply voltage for negative bias of micromirror reset signal		Plane
VBIAS	B1, P1	P	Supply voltage for positive bias of micromirror reset signal		Plane
VOFFSET	A1, A25, T1, T25	P	Supply voltage for HVCMOS logic, stepped up logic level		Plane

表 5-1. Pin Functions (continued)

PIN <sup>(2)</sup>		TYPE <sup>(1)</sup>	DESCRIPTION	TERMINATION	TRACE LENGTH (mm)
NAME	PAD ID				
VSS	C4, C6, C8, C10, C13, C14, C17, C19, C23, D5, D8, D15, D17, D18, D21, D22, F21, H4, H21, J3, J22, K4, K21, K23, L3, L21, L23, M2, M4, M22, M24, N1, N3, N5, N7, N17, N19, N21, N23, N25, P2, P4, P6, P8, P10, P12, P14, P16, P18, P20, P22, P24, R3, R5, R7, R9, R11, R13, R15, R17, R19, R21, R23, R25, T2, T4, T8, T10	G	Ground		Plane
VSSA	A13, B4, B6, B8, B10, B12, B15, B17, B19, B21, B23, C3, C7, C11, C16, C20, C25, D2, E4, E22, E25, F2, G4, G22, H23	G	Ground		Plane
DMD_Detect	T6	NC	DMD detection		None

**表 5-1. Pin Functions (continued)**

PIN <sup>(2)</sup>		TYPE <sup>(1)</sup>	DESCRIPTION	TERMINATION	TRACE LENGTH (mm)
NAME	PAD ID				
N/C	D9, D10, D11, D12, D13, E10, E11, E12, E13, E14, E15, E16, E17, E18, F24, G2, K2, L24, M12, M13, M14, M15, M16, M17, M18, N9, N10, N11, N12, N13, N14, N15, R22, R24, T22, T24	NC	No connect pin		None

- (1) I=Input, O=Output, P=Power, G=Ground, NC = No Connect  
(2) Only 238 pins are electrically connected for functional use.

## 6 Specifications

### 6.1 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
<b>SUPPLY VOLTAGE</b>				
$V_{DD}$	Supply voltage for LVCMOS core logic and LVCMOS low speed interface (LSIF) <sup>(1)</sup>	- 0.5	2.3	V
$V_{DDA}$	Supply voltage for high speed serial interface (HSSI) receivers <sup>(1)</sup>	- 0.3	2.2	V
$V_{OFFSET}$	Supply voltage for HVCMOS and micromirror electrode <sup>(1) (2)</sup>	- 0.5	11	V
$V_{BIAS}$	Supply voltage for micromirror electrode <sup>(1)</sup>	- 0.5	19	V
$V_{RESET}$	Supply voltage for micromirror electrode <sup>(1)</sup>	- 15	0.5	V
$ V_{DDA} - V_{DD} $	Supply voltage delta (absolute value) <sup>(3)</sup>		0.3	V
$ V_{BIAS} - V_{OFFSET} $	Supply voltage delta (absolute value) <sup>(4)</sup>		11	V
$ V_{BIAS} - V_{RESET} $	Supply voltage delta (absolute value) <sup>(5)</sup>		34	V
<b>INPUT VOLTAGE</b>				
	Input voltage for other inputs – LSIF and LVCMOS <sup>(1)</sup>	- 0.5	2.45	V
	Input voltage for other inputs – HSSI <sup>(1) (6)</sup>	- 0.2	$V_{DDA}$	V
<b>LOW SPEED INTERFACE (LSIF)</b>				
$f_{CLOCK}$	LSIF clock frequency (LS_CLK)		130	MHz
$ V_{ID} $	LSIF differential input voltage magnitude <sup>(6)</sup>		810	mV
$I_{ID}$	LSIF differential input current		10	mA
<b>HIGH SPEED SERIAL INTERFACE (HSSI)</b>				
$f_{CLOCK}$	HSSI clock frequency (DCLK)		1.65	GHz
$ V_{ID} $	HSSI differential input voltage magnitude Data Lane <sup>(6)</sup>		700	mV
$ V_{ID} $	HSSI differential input voltage magnitude Clock Lane <sup>(6)</sup>		700	mV
<b>ENVIRONMENTAL</b>				
$T_{WINDOW}$ and $T_{ARRAY}$	Temperature, operating <sup>(7)</sup>	0	90	°C
	Temperature, non-operating <sup>(7)</sup>	- 40	90	°C
$ T_{DELTA} $	Absolute temperature delta between any point on the window edge and the ceramic test point TP1 <sup>(8)</sup>		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:  $V_{DD}$ ,  $V_{DDA}$ ,  $V_{OFFSET}$ ,  $V_{BIAS}$ , 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  $V_{DDA}$  and  $V_{DD}$  may result in excessive current draw.
- (4) Exceeding the recommended allowable absolute voltage difference between  $V_{BIAS}$  and  $V_{OFFSET}$  may result in excessive current draw.
- (5) Exceeding the recommended allowable absolute voltage difference between  $V_{BIAS}$  and  $V_{RESET}$  may result in excessive current draw.
- (6) This maximum input voltage rating applies when each input of a differential pair is at the same voltage potential. LVDS and HSSI 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 [Micromirror Array Temperature Calculation](#)) or of any point along the window edge as defined in [Figure 7-1](#). The locations of thermal test points TP2, TP3, TP4 and TP5 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.
- (8) 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, TP3, TP4, and TP5 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.



## 6.2 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 <sup>(1)</sup>		24	°C
$T_{DP-ELR}$	Elevated dew point temperature range, non-condensing <sup>(2)</sup>	28	36	°C
$CT_{ELR}$	Cumulative time in elevated dew point 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  $CT_{ELR}$ .

## 6.3 ESD Ratings

		VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>	±2000 V
		Charged device model (CDM), per JEDEC specification ANSI/ESDA/JEDEC JS-002 <sup>(2)</sup>	±500 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.

## 6.4 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 VOLTAGES <sup>(1) (2)</sup>					
V <sub>DD</sub>	Supply voltage for LVCMOS core logic and low speed interface (LSIF)	1.71	1.8	1.95	V
V <sub>DDA</sub>	Supply voltage for high speed serial interface (HSSI) receivers	1.71	1.8	1.95	V
V <sub>OFFSET</sub>	Supply voltage for HVCMOS and micromirror electrode <sup>(3)</sup>	9.5	10	10.5	V
V <sub>BIAS</sub>	Supply voltage for micromirror electrode	17.5	18	18.5	V
V <sub>RESET</sub>	Supply voltage for micromirror electrode	- 14.5	- 14	- 13.5	V
V <sub>DDA</sub> - V <sub>DD</sub>	Supply voltage delta, absolute value <sup>(4)</sup>			0.3	V
V <sub>BIAS</sub> - V <sub>OFFSET</sub>	Supply voltage delta, absolute value <sup>(5)</sup>			10.5	V
V <sub>BIAS</sub> - V <sub>RESET</sub>	Supply voltage delta, absolute value			33	V
LVCMOS INPUT					
V <sub>IH</sub>	High level input voltage <sup>(6)</sup>	0.7 × V <sub>DD</sub>			V
V <sub>IL</sub>	Low level input voltage <sup>(6)</sup>	0.3 × V <sub>DD</sub>			V
LOW SPEED SERIAL INTERFACE (LSIF)					
f <sub>CLOCK</sub>	LSIF clock frequency (LS_CLK) <sup>(7)</sup>	108	120	130	MHz
DCD <sub>IN</sub>	LSIF duty cycle distortion (LS_CLK)	44%		56%	
V <sub>ID</sub>	LSIF differential input voltage magnitude <sup>(7)</sup>	150	350	440	mV
V <sub>LVDS</sub>	LSIF voltage <sup>(7)</sup>	575		1520	mV
V <sub>CM</sub>	Common mode voltage <sup>(7)</sup>	700	900	1300	mV
Z <sub>LINE</sub>	Line differential impedance (PWB/trace)	90	100	110	Ω
Z <sub>IN</sub>	Internal differential termination resistance	80	100	120	Ω

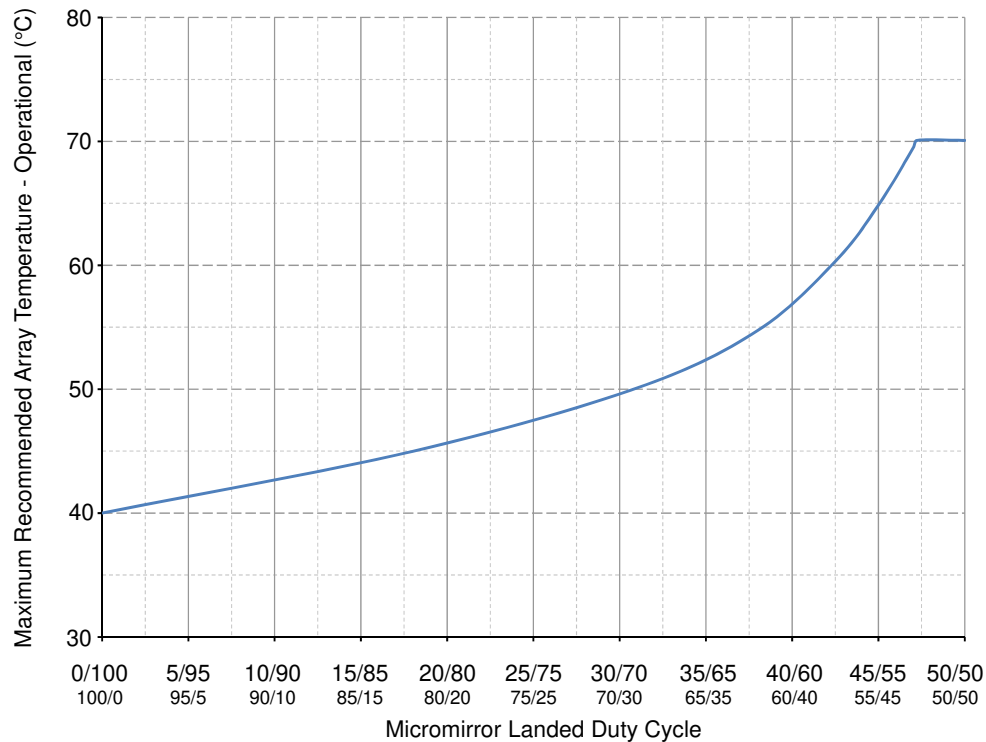
## 6.4 Recommended Operating Conditions (continued)

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
<b>HIGH SPEED SERIAL INTERFACE (HSSI)</b>					
$f_{\text{CLOCK}}$	HSSI clock frequency (DCLK) <sup>(8)</sup>	1.2		1.6	GHz
$\text{DCD}_{\text{IN}}$	HSSI duty cycle distortion (DCLK)	44	50	56	%
$ V_{\text{ID}} _{\text{Data}}$	HSSI differential input voltage magnitude Data Lane <sup>(8)</sup>	100		600	mV
$ V_{\text{ID}} _{\text{CLK}}$	HSSI differential input voltage magnitude Clock Lane <sup>(8)</sup>	295		600	mV
$\text{VCM}_{\text{DC Data}}$	Input common mode voltage (DC) Data Lane <sup>(8)</sup>	200	600	800	mV
$\text{VCM}_{\text{DC CLK}}$	Input common mode voltage (DC) Clk Lane <sup>(8)</sup>	200	600	800	mV
$\text{VCM}_{\text{ACp-p}}$	AC peak to peak (ripple) on common mode voltage of Data Lane and Clock Lane <sup>(8)</sup>			100	mV
$Z_{\text{LINE}}$	Line differential impedance (PWB/trace)		100		$\Omega$
$Z_{\text{IN}}$	Internal differential termination resistance. ( $R_{\text{Xterm}}$ )	80	100	120	$\Omega$
<b>ENVIRONMENTAL</b>					
$T_{\text{ARRAY}}$	Array temperature, long - term operational <sup>(9) (10) (11) (12)</sup>	10		40 to 70 <sup>(11)</sup>	°C
	Array temperature, short-term operational, 500 hr max <sup>(10) (13)</sup>	0		10	°C
$T_{\text{WINDOW}}$	Window temperature, operational <sup>(14)</sup>			85	°C
$ T_{\text{DELTA}} $	Absolute temperature delta between any point on the window edge and the ceramic test point TP1 <sup>(15)</sup>			15	°C
$T_{\text{DP-AVG}}$	Average dew point temperature (non - condensing) <sup>(16)</sup>			24	°C
$T_{\text{DP-ELR}}$	Elevated dew point temperature range (non-condensing) <sup>(17)</sup>	28		36	°C
$\text{CT}_{\text{ELR}}$	Cumulative time in elevated dew point temperature range			6	months
<b>ILLUMINATION</b>					
$\text{ILL}_{\text{UV}}$	Illumination power at wavelengths < 410 nm <sup>(9)</sup>			10	mW/cm <sup>2</sup>
$\text{ILL}_{\text{VIS}}$	Illumination power at wavelengths $\geq 410$ nm and $\leq 800$ nm <sup>(19)</sup>			20.5	W/cm <sup>2</sup>
$\text{ILL}_{\text{IR}}$	Illumination power at wavelengths > 800 nm			10	mW/cm <sup>2</sup>
$\text{ILL}_{\text{BLU}}$	Illumination power at wavelengths $\geq 410$ nm and $\leq 475$ nm <sup>(19)</sup>			6.5	W/cm <sup>2</sup>
$\text{ILL}_{\text{BLU1}}$	Illumination power at wavelengths $\geq 410$ nm and $\leq 445$ nm <sup>(19)</sup>			1.2	W/cm <sup>2</sup>
$\text{ILL}_{\theta}$	Illumination marginal ray angle <sup>(18)</sup>			55	deg

- (1) All power supply connections are required to operate the DMD:  $V_{\text{DD}}$ ,  $V_{\text{DDA}}$ ,  $V_{\text{OFFSET}}$ ,  $V_{\text{BIAS}}$ , and  $V_{\text{RESET}}$ . All  $V_{\text{SS}}$  connections are required to operate the DMD.
- (2) All voltage values are with respect to the  $V_{\text{SS}}$  ground pins.
- (3)  $V_{\text{OFFSET}}$  supply transients must fall within specified max voltages.
- (4) To prevent excess current, the supply voltage delta  $|V_{\text{DDA}} - V_{\text{DD}}|$  must be less than specified limit.
- (5) To prevent excess current, the supply voltage delta  $|V_{\text{BIAS}} - V_{\text{OFFSET}}|$  must be less than specified limit.
- (6) LVCMOS input pin is DMD\_DEN\_ARSTZ.
- (7) See the low speed interface (LSIF) timing requirements in [Timing Requirements](#).
- (8) See the high speed serial interface (HSSI) timing requirements in [Timing Requirements](#).
- (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) shown in [Figure 7-1](#) and the package thermal resistance using the [Micromirror Array Temperature Calculation](#).
- (11) 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 [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) The locations of thermal test points TP2, TP3, TP4, and TP5 shown in 图 7-1 are intended to measure the highest window edge temperature. For most applications, the locations shown are representative of the highest window edge temperature. If a particular application causes additional points on the window edge to be at a higher temperature, test points should be added to those locations.
- (15) Temperature delta is the highest difference between the ceramic test point 1 (TP1) and anywhere on the window edge as shown in 图 7-1. The window test points TP2, TP3, TP4, and TP5 shown in 图 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 in temperature, that point should be used.
- (16) The average over time (including storage and operating) that the device is not in the 'elevated dew point temperature range'.
- (17) Exposure to dew point temperatures in the elevated range during storage and operation should be limited to less than a total cumulative time of  $CT_{ELR}$ .
- (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.
- (19) 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 ( $T_{ARRAY}$ ).



**图 6-1. Maximum Recommended Array Temperature—Derating Curve**

## 6.5 Thermal Information

THERMAL METRIC	DLP471TP	Unit
	FQQ PACKAGE	
	270 PIN	
Thermal Resistance, active area to test point 1 (TP1) <sup>(1)</sup>	1.0	°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 节 6.4. 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 and supply voltages (unless otherwise noted)

PARAMETER <sup>(1) (2)</sup>		TEST CONDITIONS <sup>(1)</sup>	MIN	TYP	MAX	UNIT
<b>CURRENT – TYPICAL</b>						
$I_{DD}$	Supply current $V_{DD}$ <sup>(3)</sup>			800	1200	mA
$I_{DDA}$	Supply current $V_{DDA}$ <sup>(3)</sup>			1000	1200	mA
$I_{OFFSET}$	Supply current $V_{OFFSET}$ <sup>(4) (5)</sup>			20	25	mA
$I_{BIAS}$	Supply current $V_{BIAS}$ <sup>(4) (5)</sup>			2.5	4.0	mA
$I_{RESET}$	Supply current $V_{RESET}$ <sup>(5)</sup>		-9.3	-6.9		mA
<b>POWER – TYPICAL</b>						
$P_{DD}$	Supply power dissipation $V_{DD}$ <sup>(3)</sup>			1440	2437.5	mW
$P_{DDA}$	Supply power dissipation $V_{DDA}$ <sup>(3)</sup>			1620	2340	mW
$P_{OFFSET}$	Supply power dissipation $V_{OFFSET}$ <sup>(4) (5)</sup>			230	367.5	mW
$P_{BIAS}$	Supply power dissipation $V_{BIAS}$ <sup>(4) (5)</sup>			43.2	70.3	mW
$P_{RESET}$	Supply power dissipation $V_{RESET}$ <sup>(5)</sup>			107.8	152.25	mW
$P_{TOTAL}$	Supply power dissipation Total			3441	5367.55	mW
<b>LVC MOS INPUT</b>						
$I_{IL}$	Low level input current <sup>(6)</sup>	$V_{DD} = 1.95\text{ V}$ , $V_I = 0\text{ V}$	-100			nA
$I_{IH}$	High level input current <sup>(6)</sup>	$V_{DD} = 1.95\text{ V}$ , $V_I = 1.95\text{ V}$			135	uA
<b>LVC MOS OUTPUT</b>						
$V_{OH}$	DC output high voltage <sup>(7)</sup>	$I_{OH} = -2\text{ mA}$	$0.8 \times V_{DD}$			V
$V_{OL}$	DC output low voltage <sup>(7)</sup>	$I_{OL} = 2\text{ mA}$		$0.2 \times V_{DD}$		V
<b>RECEIVER EYE CHARACTERISTICS</b>						
A1	Minimum data eye opening <sup>(8) (9)</sup>		100	400	600	mV
A2	Maximum data signal swing <sup>(8) (9)</sup>				600	mV
X1	Maximum data eye closure <sup>(8)</sup>				0.275	UI
X2	Maximum data eye closure <sup>(8)</sup>				0.4	UI
$ t_{DRIFT} $	Drift between Clock and Data between Training Patterns				20	ps
<b>CAPACITANCE</b>						
$C_{IN}$	Input capacitance LVC MOS	$f = 1\text{ MHz}$			10	pF
$C_{IN}$	Input capacitance LSIF (low speed interface)	$f = 1\text{ MHz}$			20	pF
$C_{IN}$	Input capacitance HSSI (high speed serial interface)	$f = 1\text{ MHz}$			20	pF
$C_{OUT}$	Output capacitance	$f = 1\text{ MHz}$			10	pF

- (1) All power supply connections are required to operate the DMD:  $V_{DD}$ ,  $V_{DDA}$ ,  $V_{OFFSET}$ ,  $V_{BIAS}$ , and  $V_{RESET}$ . All  $V_{SS}$  connections are required to operate the DMD.
- (2) All voltage values are with respect to the ground pins ( $V_{SS}$ ).
- (3) To prevent excess current, the supply voltage delta  $|V_{DDA} - V_{DD}|$  must be less than specified limit.
- (4) To prevent excess current, the supply voltage delta  $|V_{BIAS} - V_{OFFSET}|$  must be less than specified limit.
- (5) Supply power dissipation based on 3 global resets in 200  $\mu\text{s}$ .
- (6) LVC MOS input specifications are for pin DMD\_DEN\_ARSTZ.
- (7) LVC MOS output specification is for pins LS\_RDATA\_A and LS\_RDATA\_B.
- (8) Refer to [Figure 6-11](#), Receiver Eye Mask (1e-12 BER).
- (9) Defined in [Recommended Operating Conditions](#).

## 6.7 Switching Characteristics

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{pd}$	Output propagation, Clock to Q (C2Q), rising edge of LS_CLK (differential clock signal) input to LS_RDATA output. (1)	$C_L = 5 \text{ pF}$			11.1	ns
		$C_L = 10 \text{ pF}$			11.3	ns
	Slew rate, LS_RDATA	20% - 80%, $C_L < 10 \text{ pF}$	0.5			V/ns
	Output duty cycle distortion, LS_RDATA_A and LS_RDATA_B	50-(C2Q rise - C2Q fall ) $\times 130 \text{ e}6 \times 100$	40%		60%	

(1) See 图 6-2.

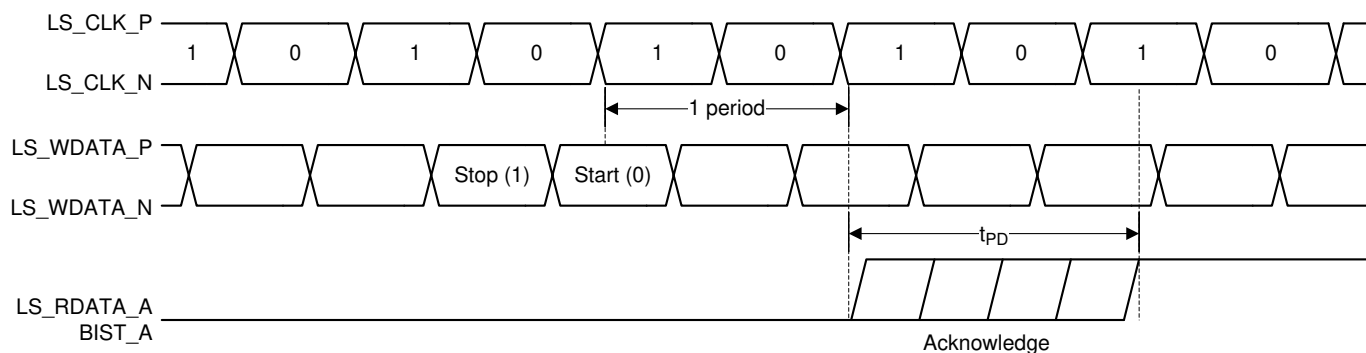


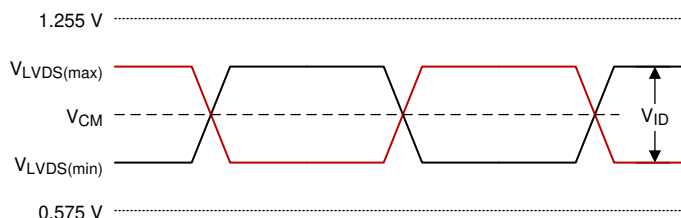
图 6-2. Switching Characteristics

## 6.8 Timing Requirements

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>LVC MOS</b>						
$t_r$	Rise time <sup>(1)</sup>	20% to 80% reference points			25	ns
$t_f$	Fall time <sup>(1)</sup>	80% to 20% reference points			25	ns
<b>LOW SPEED INTERFACE (LSIF)</b>						
$t_r$	Rise time <sup>(2)</sup>	20% to 80% reference points			450	ps
$t_f$	Fall time <sup>(2)</sup>	80% to 20% reference points			450	ps
$t_{W(H)}$	Pulse duration high <sup>(3)</sup>	LS_CLK. 50% to 50% reference points	3.1			ns
$t_{W(L)}$	Pulse duration low <sup>(3)</sup>	LS_CLK. 50% to 50% reference points	3.1			ns
$t_{su}$	Setup time <sup>(4)</sup>	LS_WDATA valid before rising edge of LS_CLK (differential)			1.5	ns
$t_h$	Hold time <sup>(4)</sup>	LS_WDATA valid after rising edge of LS_CLK (differential)			1.5	ns
<b>HIGH SPEED SERIAL INTERFACE (HSSI)</b>						
$t_r$	Rise time - data <sup>(5) (6)</sup>	From - A1 to A1 minimum eye height specification	50		115	ps
	Rise time - clock <sup>(5) (6)</sup>	From - A1 to A1 minimum eye height specification	50		135	ps
$t_f$	Fall time — data <sup>(5) (6)</sup>	From A1 to - A1 minimum eye height specification	50		115	ps
	Fall time — clock <sup>(5) (6)</sup>	From A1 to - A1 minimum eye height specification	50		135	ps
$t_{W(H)}$	Pulse duration high <sup>(7)</sup>	DCLK. 50% to 50% reference points	0.275			ns
$t_{W(L)}$	Pulse duration low <sup>(7)</sup>	DCLK. 50% to 50% reference points	0.275			ns

- (1) See 图 6-9 for rise time and fall time for LVC MOS.  
 (2) See 图 6-4 for rise time and fall time for LSIF.  
 (3) See 图 6-4 for pulse duration high and low time for LSIF.  
 (4) See 图 6-4 for setup and hold time for LSIF.  
 (5) See 图 6-11 for rise time and fall time for HSSI Eye Characteristics.  
 (6) See 图 6-12 for rise time and fall time for HSSI.  
 (7) See 图 6-12 for pulse duration high and low for HSSI.

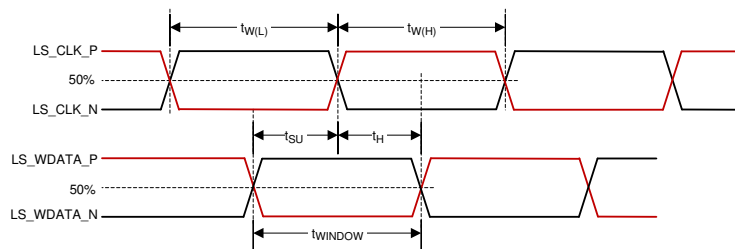


A. See 方程式 1 and 方程式 2

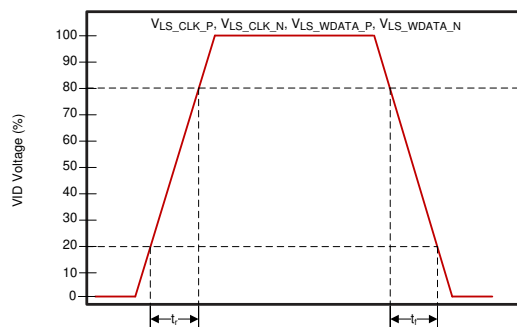
图 6-3. LSIF Waveform Requirements

$$V_{LVDS(max)} = V_{CM(max)} + \left| \frac{1}{2} \times V_{ID(max)} \right| \quad (1)$$

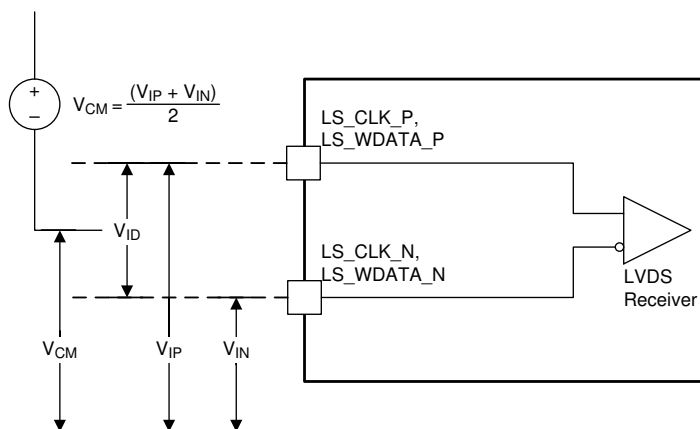
$$V_{LVDS(min)} = V_{CM(min)} - \left| \frac{1}{2} \times V_{ID(max)} \right| \quad (2)$$



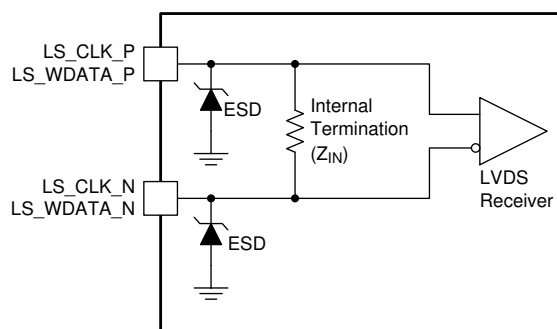
**图 6-4. LSIF Timing Requirements**



**图 6-5. LSIF Rise, Fall Time Slew**



**图 6-6. LSIF Voltage Requirements**



**图 6-7. LSIF Equivalent Input**

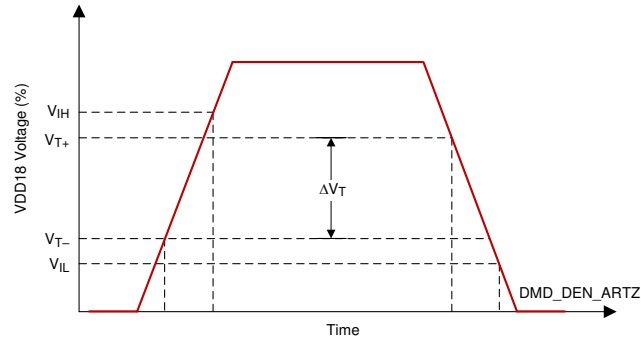


图 6-8. LVCMOS Input Hysteresis

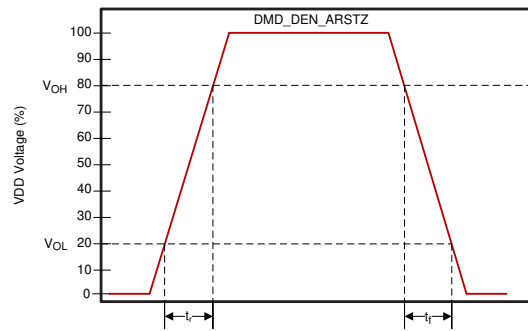
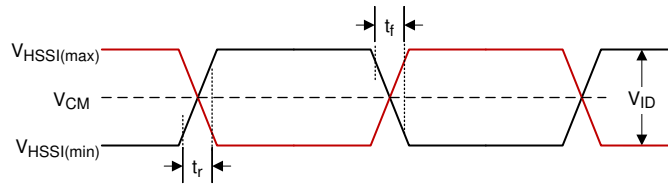


图 6-9. LVCMOS Rise, Fall Time Slew Rate



A. See 方程式 3 and 方程式 4

图 6-10. HSSI Waveform Requirements

$$V_{HSSI(max)} = V_{CM(max)} + \left| \frac{1}{2} \times V_{ID(max)} \right| \quad (3)$$

$$V_{HSSI(min)} = V_{CM(min)} - \left| \frac{1}{2} \times V_{ID(max)} \right| \quad (4)$$



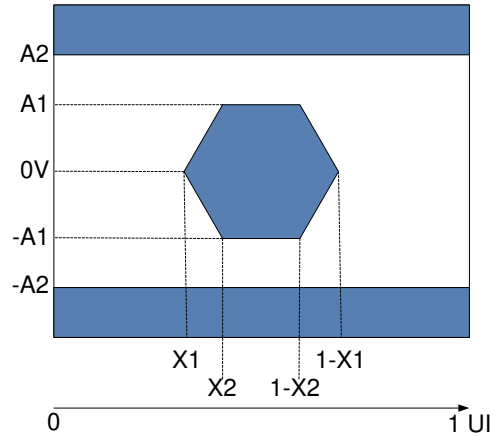


图 6-11. HSSI Eye Characteristics

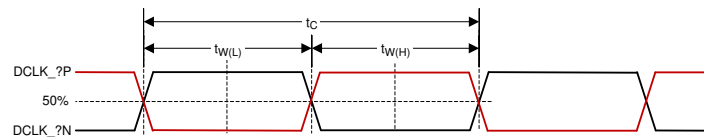


图 6-12. HSSI CLK Characteristics

## 6.9 System Mounting Interface Loads

PARAMETER	MIN	TYP	MAX	UNIT
Thermal interface area <sup>(1)</sup>			100	N
Electrical interface area <sup>(1)</sup>			245	N

(1) The load should be uniformly applied within the area shown in 图 6-13.

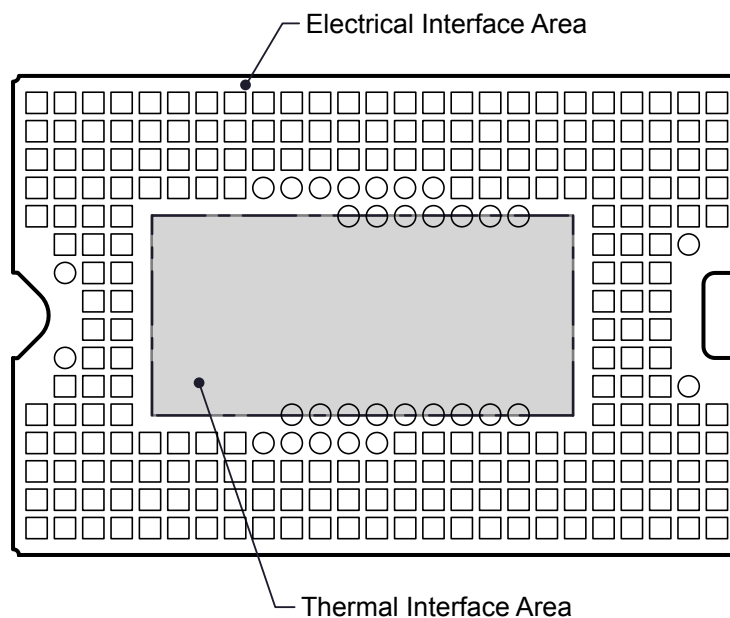
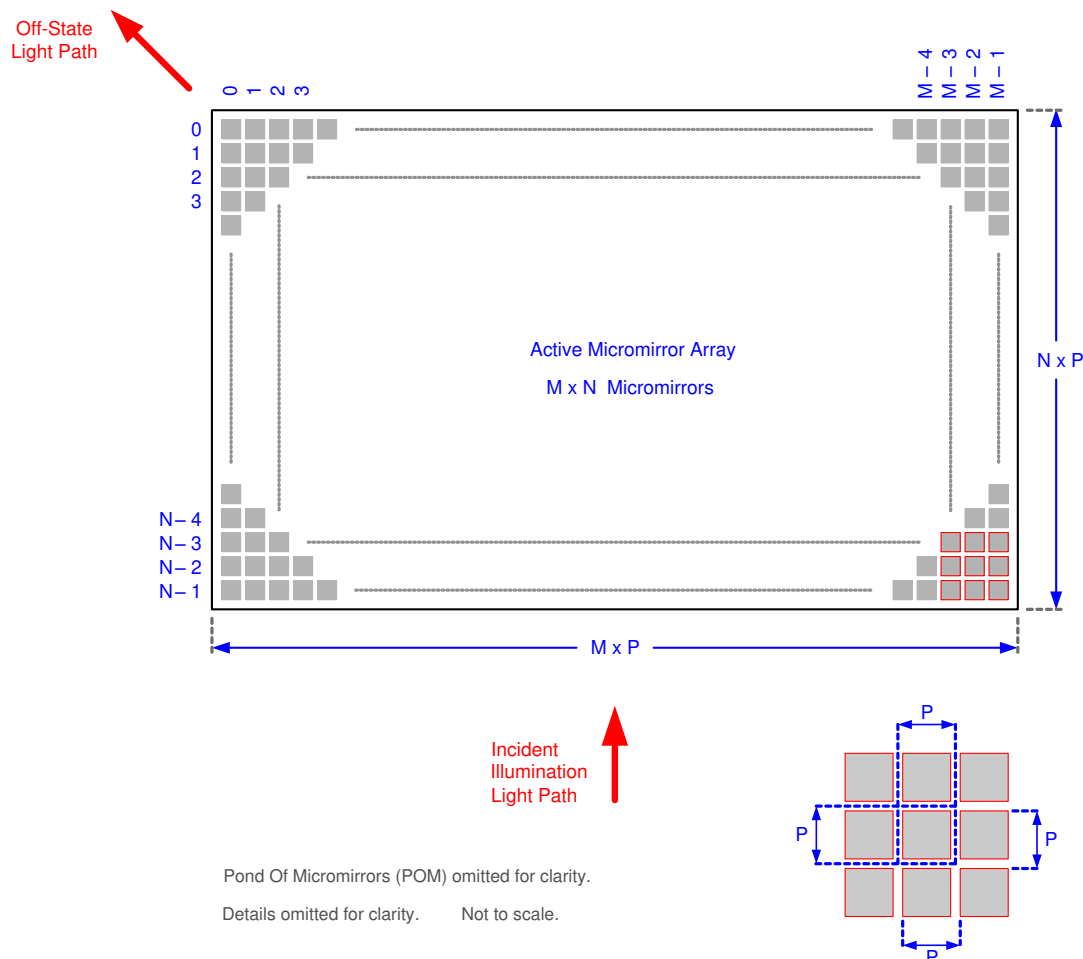


图 6-13. System Mounting Interface Loads

## 6.10 Micromirror Array Physical Characteristics

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

- (1) See [图 6-14](#).
- (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 × 2160 pixel image being displayed.
- (3) The structure and qualities of the border around the active array includes a band of partially functional micromirrors referred to as the *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 6-14. Micromirror Array Physical Characteristics**

## 6.11 Micromirror Array Optical Characteristics

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

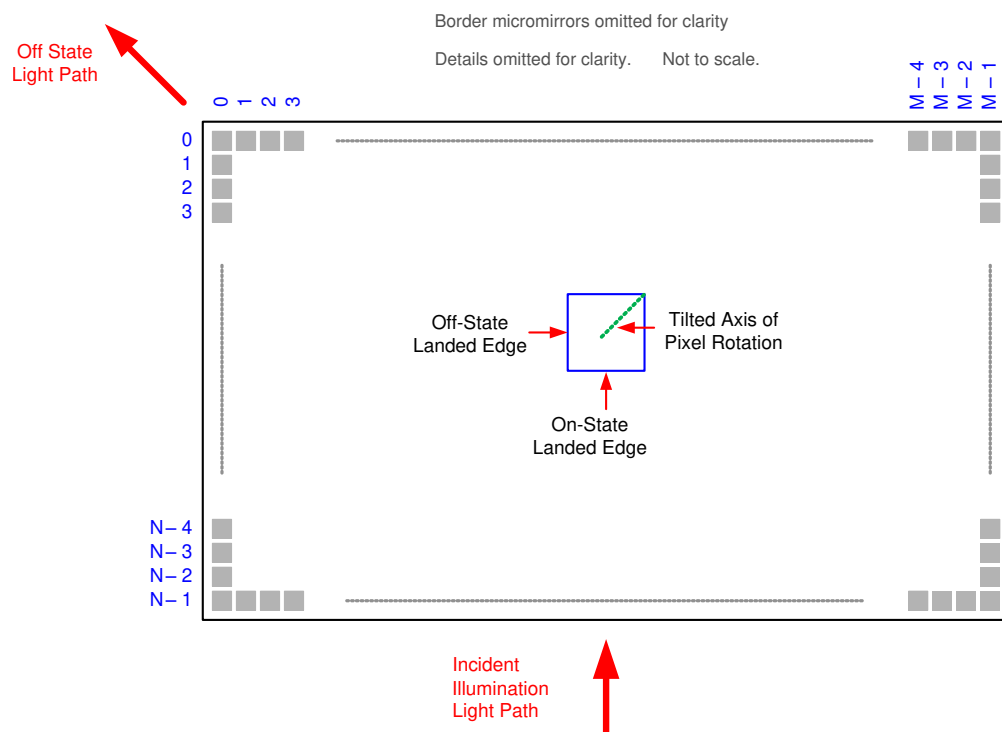


图 6-15. Micromirror Landed Orientation and Tilt

## 6.12 Window Characteristics

DESCRIPTION <sup>(1)</sup>		MIN	TYP	MAX
Window material		Corning Eagle XG		
Window refractive index	At wavelength 546.1 nm	1.5119		
Window aperture <sup>(2)</sup>		See <sup>(2)</sup> .		
Illumination overfill <sup>(3)</sup>		See <sup>(3)</sup> .		
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 <sup>(4)</sup>	97%		
	Average over the wavelength range 420 nm to 680 nm. Applies to all angles 30° to 45° AOI <sup>(4)</sup>	97%		

- (1) See 节 7.5 for more information.
- (2) See the package mechanical characteristics for details regarding the size and location of the window aperture.
- (3) The active area of the DLP471TP 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.
- (4) Angle of incidence (AOI) is the angle between an incident ray and the normal to a reflecting or refracting surface.

## 6.13 Chipset Component Usage Specification

Reliable function and operation of the DLP471TP 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.

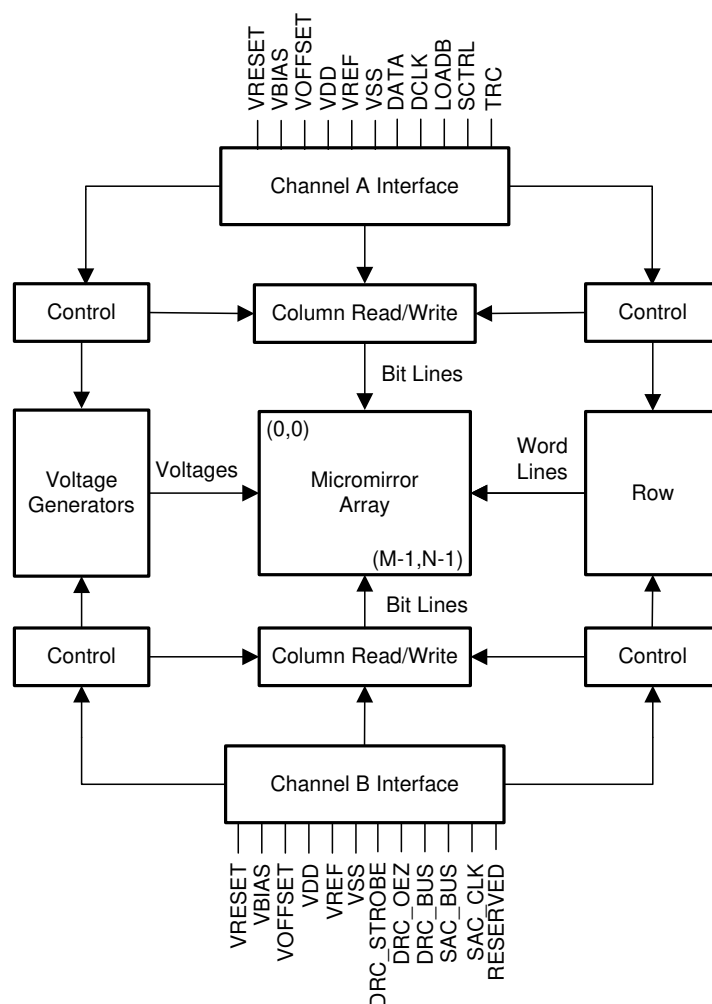
## 7 Detailed Description

### 7.1 Overview

The 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 DLP471TP DMD, DLPC6540 display controller, and the [DLPA3005](#) PMIC and the LED driver. To ensure reliable operation, the DLP471TP DMD must always be used with the DLP display controller and the PMIC specified in the chipset.

### 7.2 Functional Block Diagram



## 7.3 Feature Description

### 7.3.1 Power Interface

The DMD requires 4 DC voltages: 1.8 V source,  $V_{\text{OFFSET}}$ ,  $V_{\text{RESET}}$ , and  $V_{\text{BIAS}}$ . In a typical LED-based system, 1.8 V is provided by a [TPS54320](#) and the  $V_{\text{OFFSET}}$ ,  $V_{\text{RESET}}$ , and  $V_{\text{BIAS}}$  is managed by the [DLPA3005](#) PMIC and LED driver.

### 7.3.2 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. 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.

## 7.4 Device Functional Modes

DMD functional modes are controlled by the DLPC6540 display controller. See the DLPC6540 display 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 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.

### 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 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

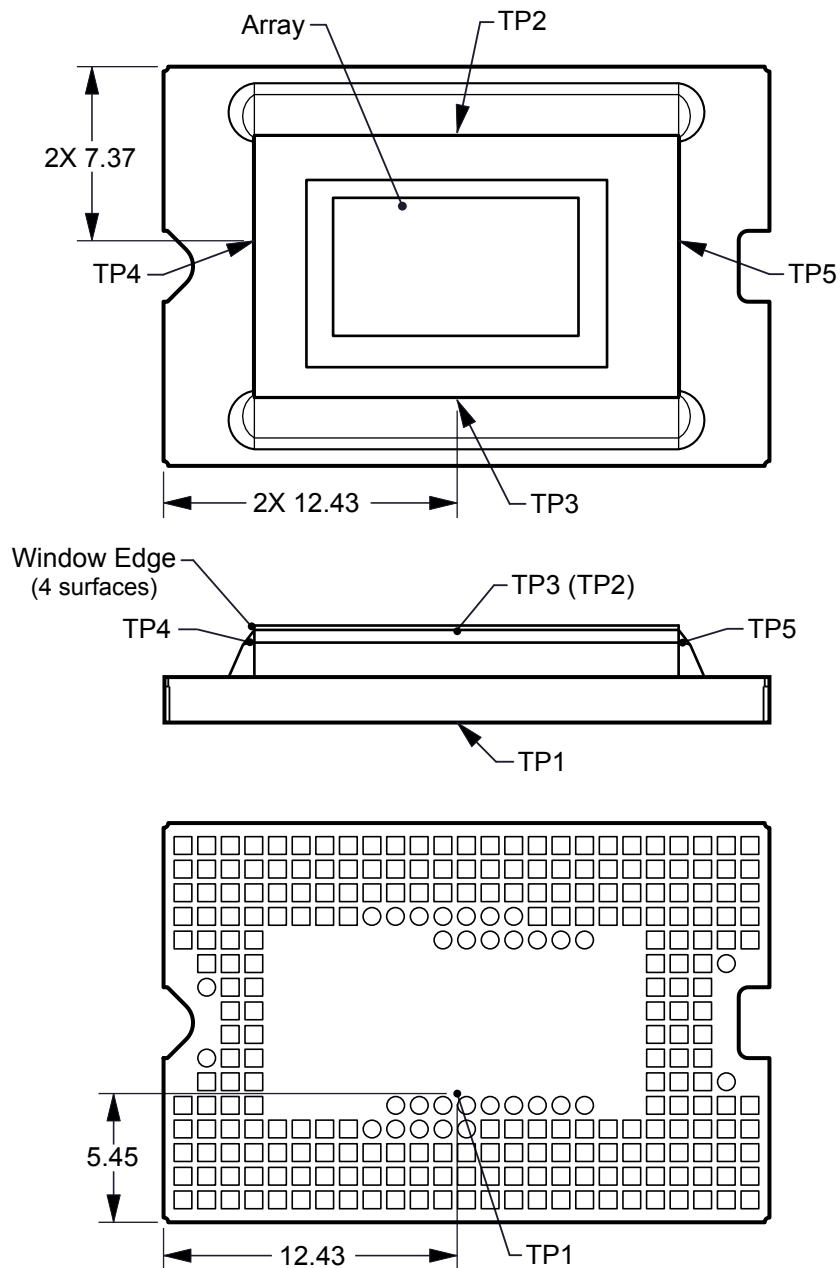


图 7-1. DMD Thermal Test Points



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:

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

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

where

- $T_{\text{ARRAY}}$  = Computed array temperature (°C)
- $T_{\text{CERAMIC}}$  = Measured ceramic temperature (°C) (TP1 location)
- $R_{\text{ARRAY-TO-CERAMIC}}$  = Thermal resistance of package specified in [Section 6.5](#) from array to ceramic TP1 (°C/Watt)
- $Q_{\text{ARRAY}}$  = Total DMD power on the array (W) (electrical + absorbed)
- $Q_{\text{ELECTRICAL}}$  = Nominal electrical power (W)
- $Q_{\text{INCIDENT}}$  = Incident illumination optical power (W)
- $Q_{\text{ILLUMINATION}}$  = (DMD average thermal absorptivity  $\times$   $Q_{\text{INCIDENT}}$ ) (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 2.5 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:

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

$$T_{\text{CERAMIC}} = 55.0^\circ\text{C (measured)}$$

$$Q_{\text{ELECTRICAL}} = 2.5 \text{ W}$$

$$Q_{\text{ARRAY}} = 2.5 \text{ W} + (0.40 \times 9.4 \text{ W}) = 6.26 \text{ W}$$

$$T_{\text{ARRAY}} = 55.0^\circ\text{C} + (6.26 \text{ W} \times 1.0^\circ\text{C/W}) = 61.3^\circ\text{C}$$

## 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.

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

$$A_{ILL} = A_{ARRAY} \div (1 - OV_{ILL}) \text{ (cm}^2\text{)}$$

where:

- $ILL_{UV}$  = UV illumination power density on the DMD (mW/cm<sup>2</sup>)
- $ILL_{VIS}$  = VIS illumination power density on the DMD (W/cm<sup>2</sup>)
- $ILL_{IR}$  = IR illumination power density on the DMD (mW/cm<sup>2</sup>)
- $ILL_{BLU}$  = BLU illumination power density on the DMD (W/cm<sup>2</sup>)
- $ILL_{BLU1}$  = BLU1 illumination power density on the DMD (W/cm<sup>2</sup>)
- $A_{ILL}$  = illumination area on the DMD (cm<sup>2</sup>)
- $Q_{INCIDENT}$  = total incident optical power on DMD (W) (measured)
- $A_{ARRAY}$  = area of the array (cm<sup>2</sup>) (data sheet)
- $OV_{ILL}$  = percent of total illumination on the DMD outside the array (%) (optical model)
- $OP_{UV-RATIO}$  = 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  $\geq 410$  and  $\leq 800$  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  $\geq 410$  and  $\leq 475$  nm to the total optical power in the illumination spectrum (spectral measurement)
- $OP_{BLU1-RATIO}$  = ratio of the optical power for wavelengths  $\geq 410$  and  $\leq 445$  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:

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

$$A_{ARRAY} = (1.0368 \times 0.5832) = 0.6047 \text{ cm}^2 \text{ (data sheet)}$$

$$OV_{ILL} = 16.3\% \text{ (optical model)}$$

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

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

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

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

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

$$A_{\text{ILL}} = 0.6047 \div (1 - 0.163) = 0.7224 \text{ cm}^2$$

$$\text{ILL}_{\text{UV}} = [0.00021 \times 9.40\text{W}] \times 1000 \div 0.7224 \text{ cm}^2 = 2.732 \text{ mW/cm}^2$$

$$\text{ILL}_{\text{VIS}} = [0.99977 \times 9.40\text{W}] \div 0.7224 \text{ cm}^2 = 13.01 \text{ W/cm}^2$$

$$\text{ILL}_{\text{IR}} = [0.00002 \times 9.40\text{W}] \times 1000 \div 0.7224 \text{ cm}^2 = 0.260 \text{ mW/cm}^2$$

$$\text{ILL}_{\text{BLU}} = [0.28100 \times 9.40\text{W}] \div 0.7224 \text{ cm}^2 = 3.66 \text{ W/cm}^2$$

$$\text{ILL}_{\text{BLU}1} = [0.03200 \times 9.40\text{W}] \div 0.7224 \text{ cm}^2 = 0.42 \text{ W/cm}^2$$

## 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 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 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 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.

### 7.8.3 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 de-rating curve shown in [Figure 6-1](#). 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).

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 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 [Table 7-1](#).

**表 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
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 5](#) to calculate the landed duty cycle of a given pixel during a given time period

$$\text{Landed Duty Cycle} = (\text{Red\_Cycle\_}\% \times \text{Red\_Scale\_Value}) + (\text{Green\_Cycle\_}\% \times \text{Green\_Scale\_Value}) + (\text{Blue\_Cycle\_}\% \times \text{Blue\_Scale\_Value}) \quad (5)$$

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 7-2](#) and [表 7-3](#).

**表 7-2. Example Landed Duty Cycle for Full-Color, Color Percentage**

CYCLE PERCENTAGE		
RED	GREEN	BLUE
30%	50%	20%

表 7-3. 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 DLPC6540 controller, the gamma function affects the landed duty cycle.

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

In the DLPC6540 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 7-2.

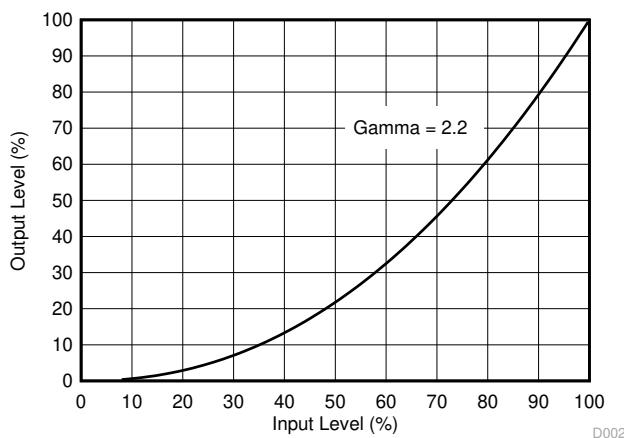


图 7-2. Example of Gamma = 2.2

From 图 7-2, 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 DLPC6540 controller.

## 8 Application and Implementation

### 备注

以下应用部分中的信息不属于 TI 器件规格的范围，TI 不担保其准确性和完整性。TI 的客户应负责确定器件是否适用于其应用。客户应验证并测试其设计，以确保系统功能。

### 8.1 Application Information

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 DLPC6540 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 DLP471TP include mobile smart TV and digital signage.

DMD power-up and power-down sequencing is strictly controlled by the DLPA3005. Refer to 节 9 for power-up and power-down specifications. To ensure reliable operation, the DLP471TP DMD must always be used with DLPC6540 controller and a DLPA3005 PMIC/LED driver.

### 8.2 Typical Application

The DLP471TP DMD combined with DLPC6540 digital controller and a power management device provides full 4K UHD resolution for bright, colorful display applications. See [Typical 4K UHD LED Application Diagram](#), which shows the system components needed along with the LED configuration of the DLP 0.47" 4K UHD chipset. The components include the DLP471TP DMD, DLPC6540 display controller and the [DLPA3005](#) PMIC and LED driver.

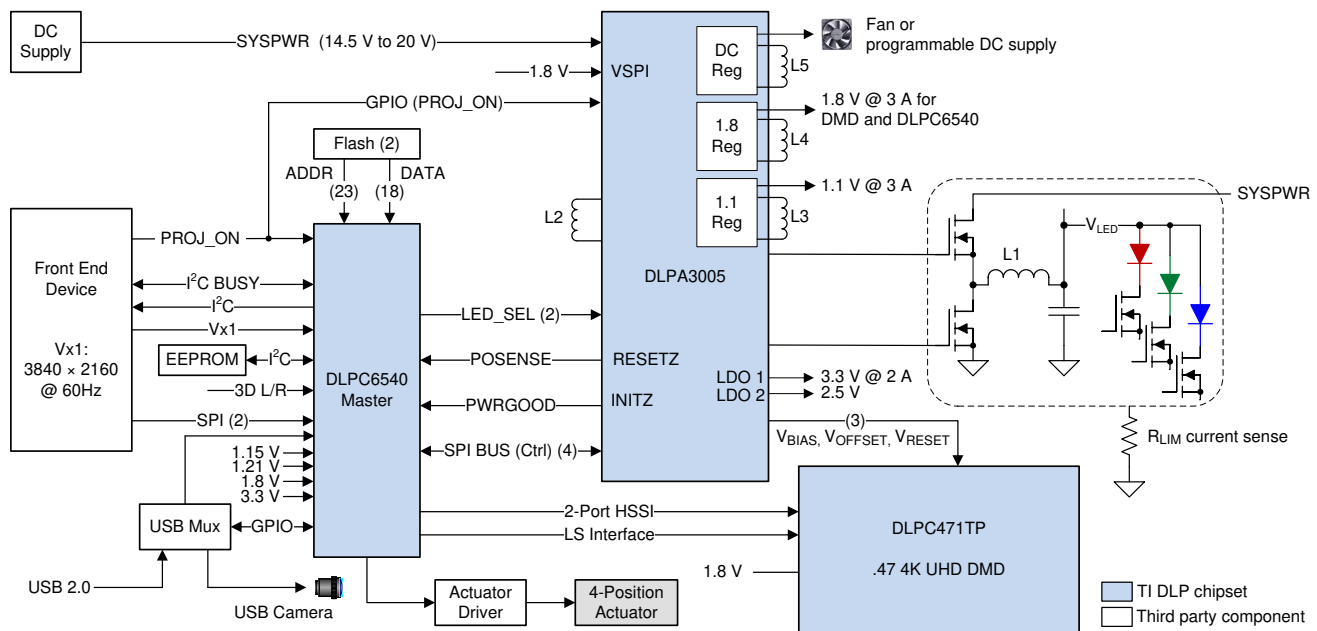


图 8-1. Typical 4K UHD LED Application Diagram

#### 8.2.1 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 desired brightness will have a major effect on the overall system design and size.

The display system uses the DLP471TP as the core imaging device and contains a 0.47-inch array of micromirrors. The DLPC6540 controller is the digital interface between the DMD and the rest of the system, taking digital input from front end receiver and driving the DMD over a high-speed interface. The [DLPA3005](#) PMIC serves as a voltage regulator for the DMD, controller, and LED illumination functionality.

### 8.2.2 Detailed Design Procedure

For a complete DLP system, an optical module or light engine is required that contains the DLP471TP DMD, associated illumination sources, optical elements, and necessary mechanical components.

To ensure reliable operation, the DMD must always be used with DLPC6540 display controller and the [DLPA3005](#) PMIC and LED driver. Refer to [PCB Design Requirements for TI DLP Pico TRP Digital Micromirror Devices](#) for the DMD board design and manufacturing handling of the DMD sub assemblies.

### 8.2.3 Application Curves

The typical LED-current-to-luminance relationship when LED illumination is utilized is shown in [图 8-2](#).

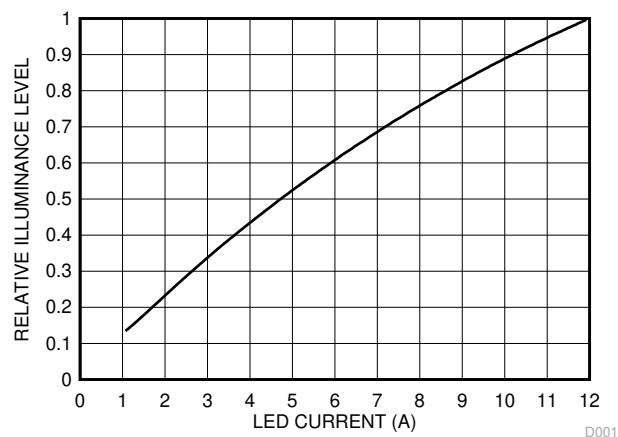


图 8-2. Luminance vs. Current

### 8.3 Temperature Sensor Diode

The software application provides functions to configure the [TMP411](#) to read the DLP471TP DMD temperature sensor diode. Customers can 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 DLPC6540 controller is completed using the I<sup>2</sup>C interface. The [TMP411](#) connects to the DMD through the pins outlined in [节 5](#).



## 9 Power Supply Recommendations

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

- $V_{SS}$
- $V_{BIAS}$
- $V_{DD}$
- $V_{DDA}$
- $V_{OFFSET}$
- $V_{RESET}$

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

### CAUTION

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 9-1](#).

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

**表 9-1. 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 <sup>(1)</sup>			6	V
$V_{BIAS}$	Supply voltage level	at end of power-up sequence delay <sup>(1)</sup>			6	V

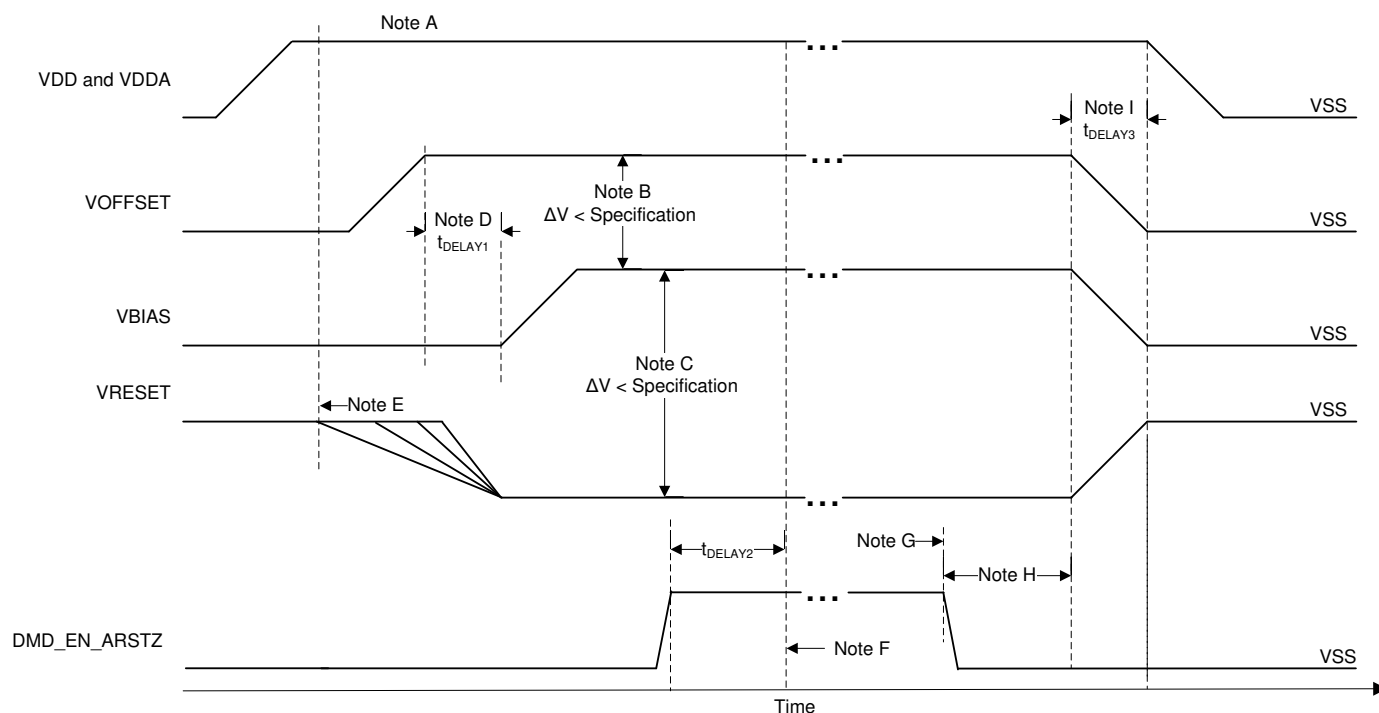
(1) See [图 9-1](#), Power-Up Sequence Delay Requirement.

### 9.1 DMD Power Supply Power-Up Procedure

- During power-up,  $V_{DD}$  and  $V_{DDA}$  must always start and settle before  $V_{OFFSET}$  plus Delay1 specified in [表 9-2](#),  $V_{BIAS}$ , 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 6.4](#).
- 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 6.1](#), in [节 6.4](#), and in [图 9-1](#).
- During power-up, LVCMOS input pins must not be driven high until after  $V_{DD}$  have settled at operating voltages listed in [节 6.4](#).

### 9.2 DMD Power Supply Power-Down Procedure

- During power-down,  $V_{DD}$  and  $V_{DDA}$  must be supplied until after  $V_{BIAS}$ ,  $V_{RESET}$ , and  $V_{OFFSET}$  are discharged to within the specified limit of ground. See [表 9-2](#).
- 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 6.4](#).
- 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 6.1](#), in [节 6.4](#), and in [图 9-1](#).
- During power-down, LVCMOS input pins must be less than specified in [节 6.4](#).



- A. See [节 5](#) for the *Pin Functions Table*.
- B. To prevent excess current, the supply voltage difference  $|V_{\text{OFFSET}} - V_{\text{BIAS}}|$  must be less than the specified limit in [节 6.4](#).
- C. To prevent excess current, the supply difference  $|V_{\text{BIAS}} - V_{\text{RESET}}|$  must be less than the specified limit in [节 6.4](#).
- D.  $V_{\text{BIAS}}$  should power up after  $V_{\text{OFFSET}}$  has powered up, per the Delay1 specification in [表 9-2](#).
- E. DLP controller software initiates the global  $V_{\text{BIAS}}$  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  $V_{\text{BIAS}}$ ,  $V_{\text{RESET}}$ , and  $V_{\text{OFFSET}}$ .
- 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.  $V_{\text{DD}}$  must remain high until after  $V_{\text{OFFSET}}$ ,  $V_{\text{BIAS}}$ ,  $V_{\text{RESET}}$  go low, per Delay2 specification in [表 9-2](#).
- I. To prevent excess current, the supply voltage delta  $|V_{\text{DDA}} - V_{\text{DD}}|$  must be less than specified limit in [节 6.4](#).

图 9-1. DMD Power Supply Requirements

表 9-2. DMD Power-Supply Requirements

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

(1) See [图 9-1](#).

## 10 Layout

### 10.1 Layout Guidelines

The DLP471TP DMD is part of a chipset that is controlled by DLPC6540 display controller in conjunction with the [DLP471TP](#) PMIC and LED driver. These guidelines are targeted at designing a PCB board with the DLP471TP DMD. The DMD board is a high-speed multi-layer PCB, with primarily high-speed digital logic including double data rate 3.2 Gbps and 250 Mbps differential data buses run to the DMD. TI recommends that full or mini power planes are used for  $V_{\text{OFFSET}}$ ,  $V_{\text{RESET}}$ , and  $V_{\text{BIAS}}$ . Solid planes are required for ground ( $V_{\text{SS}}$ ). The target impedance for the PCB is  $50\ \Omega \pm 10\%$  with exceptions listed in [Table 10-1](#). TI recommends a 10 layer stack-up as described in [Table 10-2](#). TI recommends manufacturing the PCB with a high quality FR-4 material.

### 10.2 Impedance Requirements

TI recommends a target impedance for the PCB of  $50\ \Omega \pm 10\%$  for all signals. The exceptions are listed in [Table 10-1](#).

**Table 10-1. Special Impedance Requirements**

Signal Type	Signal Name	Impedance (ohms)
DMD High Speed Data Signals	DMD_HSSI0_N_(0...7), DMD_HSSI0_P_(0...7), DMD_HSSI1_N_(0...7), DMD_HSSI1_P_(0...7), DMD_HSSI0_CLK_N, DMD_HSSI0_CLK_P, DMD_HSSI1_CLK_N, DMD_HSSI1_CLK_P	100- $\Omega$ differential (50- $\Omega$ single ended)
DMD Low Speed Interface Signals	DMD_LS0_WDATA_N, DMD_LS0_WDATA_P, DMD_LS0_CLK_N, DMD_LS0_CLK_P	100- $\Omega$ differential (50- $\Omega$ single ended)

### 10.3 Layers

The layer stack-up and copper weight for each layer is shown in [Table 10-2](#).

**Table 10-2. Layer Stack-Up**

LAYER NO.	LAYER NAME	COPPER WT. (oz.)	COMMENTS
1	Side A - DMD, primary components, power mini-planes	0.5 oz. (before plating)	DMD and escapes. Two data input connectors. Top components including power generation and two-data input connectors. Low frequency signals routing. Should have copper fill (GND) plated up to 1 oz.
2	Ground	0.5	Solid ground plane (net GND) reference for signal layers #1, 3
3	Signal (high frequency)	0.5	High-speed signal layer. High-speed differential data buses from input connector to DMD.
4	Ground	0.5	Solid ground plane (net GND) reference for signal layers #3, #5
5	Power	0.5	Primary split power planes for 1.8 V, 10 V, - 14 V, 18 V
6	Power	0.5	Primary split power planes for 1.8 V, 10 V, - 14 V, 18 V
7	Ground	0.5	Solid ground plane (net GND) reference for signal layer #8
8	Signal (high frequency)	0.5	High-speed signal layer. High-speed differential data buses from input connector to DMD
9	Ground	0.5	Solid ground plane (net GND) reference for signal layers #8, 10
10	Side B - secondary components, power mini-planes	0.5 oz. (before plating)	Discrete components if necessary. Low-frequency signals routing. Should have copper fill plated up to 1 oz.

## 10.4 Trace Width, Spacing

Unless otherwise specified, TI recommends that all signals follow the 0.005" / 0.015" (Trace-Width/Spacing) design rule. Actual trace widths and clearances should be determined and calculated based on an analysis of impedance and stack-up requirements.

The width of all voltage signals shall be maximized as space permits. In particular, the following width and spacing requirements shall be observed for the specific signals listed in 表 10-3.

**表 10-3. Special Trace Widths, Spacing Requirements**

SIGNAL NAME	MINIMUM TRACE WIDTH (MIL)	MINIMUM TRACE SPACING (MIL)	LAYOUT REQUIREMENT
GND	MAXIMIZE	5	Maximize trace width to connecting pin as a minimum.
P1P8V	100	15	Create mini planes on layers 1 and 10 as needed. Connect to devices on layers 1 and 10 as necessary with multiple vias.
V <sub>OFFSET</sub>	40	15	Create mini planes on layers 1 and 10 as needed. Connect to devices on layers 1 and 10 as necessary.
V <sub>RESET</sub>	40	15	Create mini planes on layers 1 and 10 as needed. Connect to devices on layers 1 and 10 as necessary.
V <sub>BIAS</sub>	40	15	Create mini planes on layers 1 and 10 as needed. Connect to devices on layers 1 and 10 as necessary.

## 10.5 Power

TI strongly discourages signal routing on power planes or on planes adjacent to power planes. If signals must be routed on layers adjacent to power planes, they must not cross splits in power planes to prevent EMI and preserve signal integrity.

Have all internal digital ground (GND) planes connected together in as many places as possible. If possible, all internal ground planes should be connected together with a minimum distance between connections of 0.5" . Extra vias may not be required if there are sufficient ground vias due to normal ground connections of devices.

The power and ground pins of each component should be connected to the power and ground planes with at least one via for each pin. Trace lengths for component power and ground pins should be minimized (ideally, less than 0.100" ).

Ground plane slots are strongly discouraged.

## 10.6 Trace Length Matching Recommendations

Recommended signal trace length matching requirements can be found in 表 10-4 and 表 10-5. When length matching traces, the longer signals should be routed in a serpentine fashion, keeping the number of turns to a minimum and the turn angles no sharper than 45 degrees as opposed to running long traces over large areas of the PCB.

Signals in 表 10-4 should be routed for data rate operation at up to 3.2 Gbps. Layer changes for these signals should be minimized, the number of vias should be minimized. Avoid sharp turns and layer switching while keeping lengths to a minimum. When layer changes are necessary, GND vias should be placed around the signal vias to provide a signal return path. The distance from one pair of differential signals to another shall be at least 2 times the distance within the pair.

**表 10-4. HSSI High Speed DMD Data Signals**

SIGNAL NAME	REFERENCE SIGNAL	Routing Spec	Unit
DMD_HSSI0_N(0...7), DMD_HSSI0_P(0...7)	DMD_HSSI0_CLK_N, DMD_HSSI_CLK_P	+/- 0.25	inch
DMD_HSSI1_N(0...7), DMD_HSSI1_P(0...7)	DMD_HSSI0_CLK_N, DMD_HSSI_CLK_P	+/- 0.25	inch
DMD_HSSI0_CLK_P	DMD_HSSI1_CLK_P	+/- 0.05	inch
Intra-pair P	Intra-pair N	+/- 0.01	inch

**表 10-5. Other Timing Critical Signals**

SIGNAL NAME	Constraints	Routing Layers
LS_CLK_P, LS_CLK_N LS_WDATA_P, LS_WDATA_N LS_RDATA_A	Intra-pair (P to N) Matched to 0.01 inches Signal-to-signal Matched to +/- 0.25 inches	Layers 3, 8

## 11 Device and Documentation Support

### 11.1 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。

### 11.2 Device Support

#### 11.2.1 Device Nomenclature

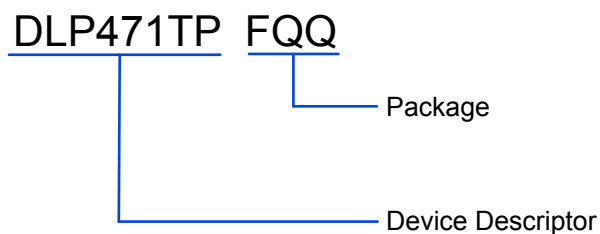


图 11-1. Part Number Description

#### 11.2.2 Device Markings

The device marking includes both human-readable information and a 2-dimensional matrix code. The human-readable information is described in 图 11-2 and includes the legible character string GHJJJK DLP471TPFQQ. GHJJJK is the lot trace code and DLP471TPFQQ is the device marking.

Example: GHJJJK DLP471TPFQQ

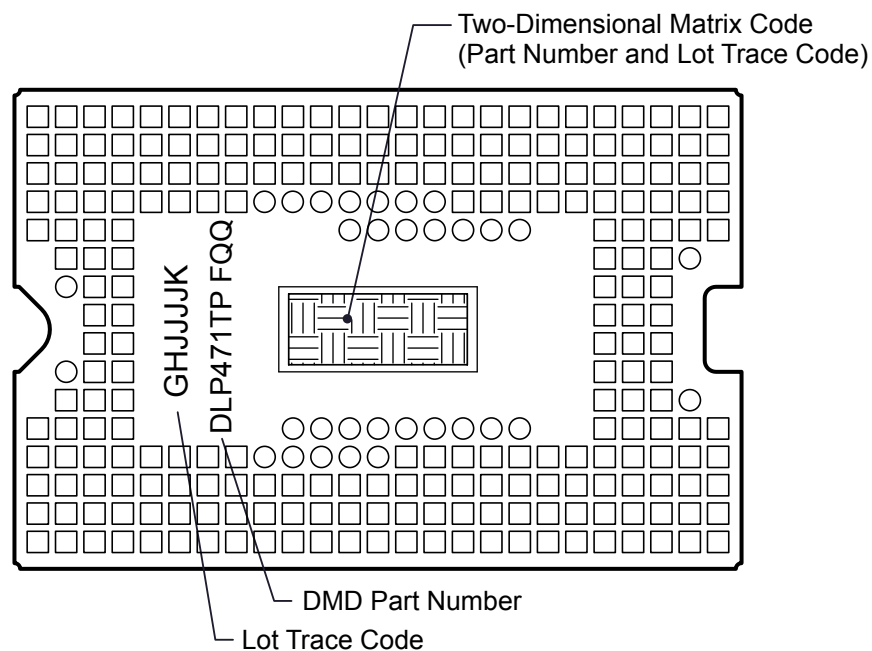


图 11-2. DMD Marking Locations

## 11.3 Documentation Support

### 11.3.1 Related Documentation

The following documents contain additional information related to the chipset components used with the DMD.

- [DLPC6540 Display Controller Data Sheet](#)
- [DLPA3005 PMIC/LED Driver Data Sheet](#)

### 11.4 支持资源

**TI E2E™ 支持论坛**是工程师的重要参考资料，可直接从专家获得快速、经过验证的解答和设计帮助。搜索现有解答或提出自己的问题可获得所需的快速设计帮助。

链接的内容由各个贡献者“按原样”提供。这些内容并不构成 TI 技术规范，并且不一定反映 TI 的观点；请参阅 TI 的《使用条款》。

### 11.5 Trademarks

TI E2E™ is a trademark of Texas Instruments.

DLP® is a registered trademark of Texas Instruments.

所有商标均为其各自所有者的财产。

### 11.6 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。

### 11.7 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。

## 12 Mechanical, Packaging, and Orderable Information

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



## PACKAGING INFORMATION

Orderable 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)
<a href="#">DLP471TPFQQ</a>	Active	Production	CLGA (FQQ)   270	54   JEDEC TRAY (5+1)	Yes	NIAU	N/A for Pkg Type	0 to 70	
DLP471TPFQQ.B	Active	Production	CLGA (FQQ)   270	54   JEDEC TRAY (5+1)	Yes	NIAU	N/A for Pkg Type	0 to 70	

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

<sup>(2)</sup> **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.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

<sup>(4)</sup> **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.

<sup>(5)</sup> **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.

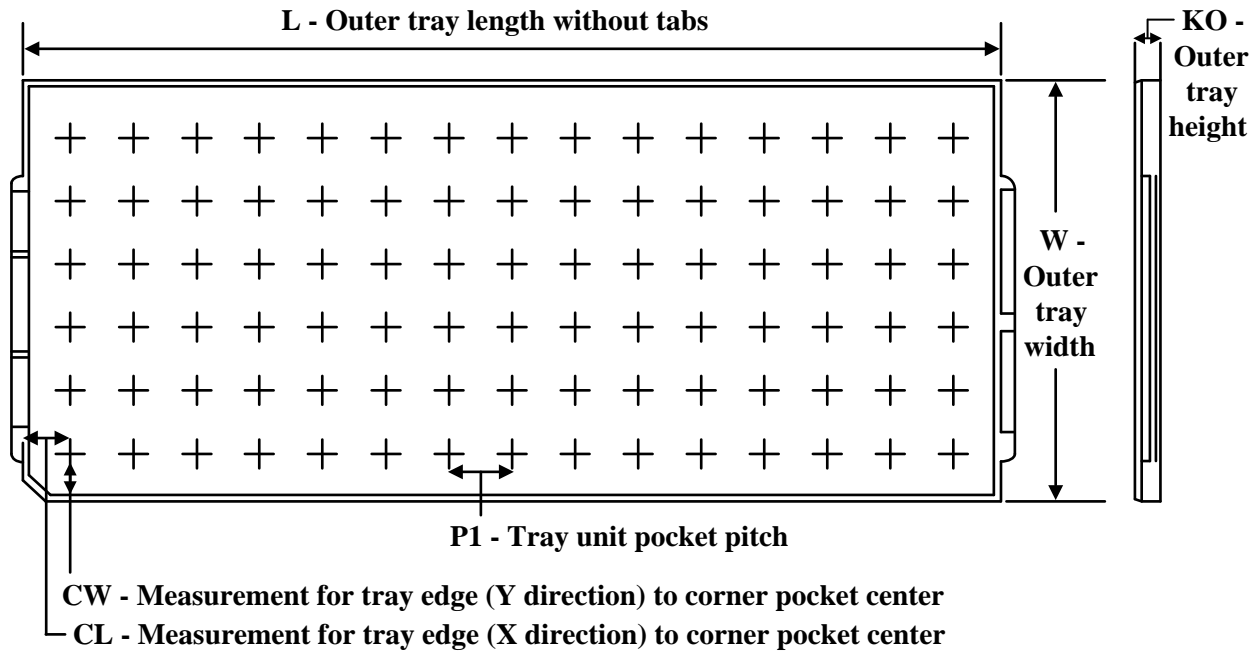
<sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

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.

**Important Information and Disclaimer:** The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

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.

## TRAY



Chamfer on Tray corner indicates Pin 1 orientation of packed units.

\*All dimensions are nominal

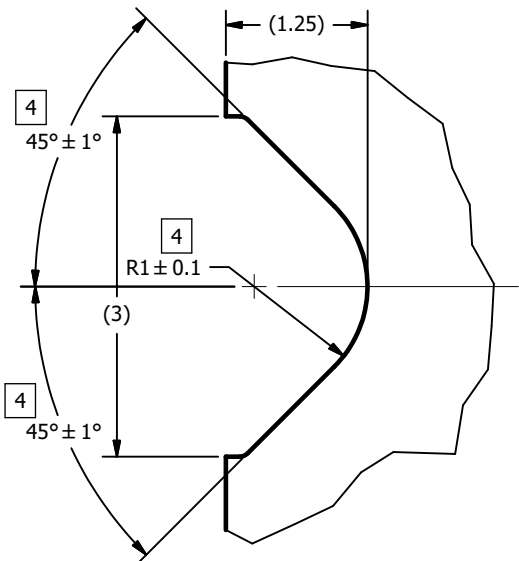
Device	Package Name	Package Type	Pins	SPQ	Unit array matrix	Max temperature (°C)	L (mm)	W (mm)	K0 (μm)	P1 (mm)	CL (mm)	CW (mm)
DLP471TPFQQ	FQQ	CLGA	270	54	6 x 9	150	315	135.9	12190	31.5	31.5	16.2
DLP471TPFQQ.B	FQQ	CLGA	270	54	6 x 9	150	315	135.9	12190	31.5	31.5	16.2

NOTES UNLESS OTHERWISE SPECIFIED:

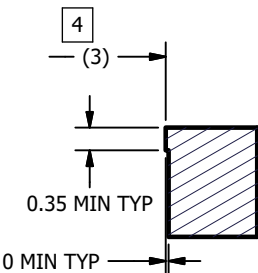
- 1 DIE PARALLELISM TOLERANCES APPLY TO DMD ACTIVE ARRAY ONLY.
- 2 ROTATION ANGLE OF DMD ACTIVE ARRAY IS A REFINEMENT OF THE LOCATION TOLERANCE AND HAS A MAXIMUM ALLOWED VALUE OF 0.6 DEGREES.
- 3 BOUNDARY MIRRORS SURROUNDING THE DMD ACTIVE ARRAY.
- 4 NOTCH DIMENSIONS ARE DEFINED BY UPPERMOST LAYERS OF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

© COPYRIGHT 2018 TEXAS INSTRUMENTS  
UN-PUBLISHED. ALL RIGHTS RESERVED.

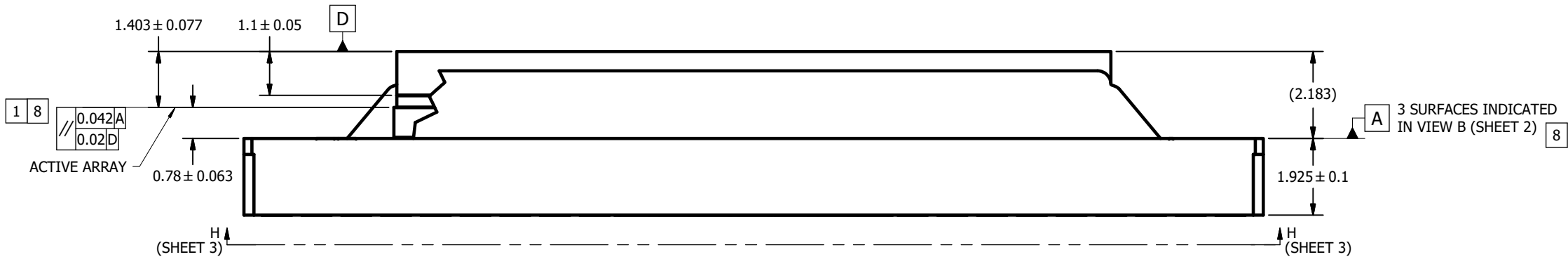
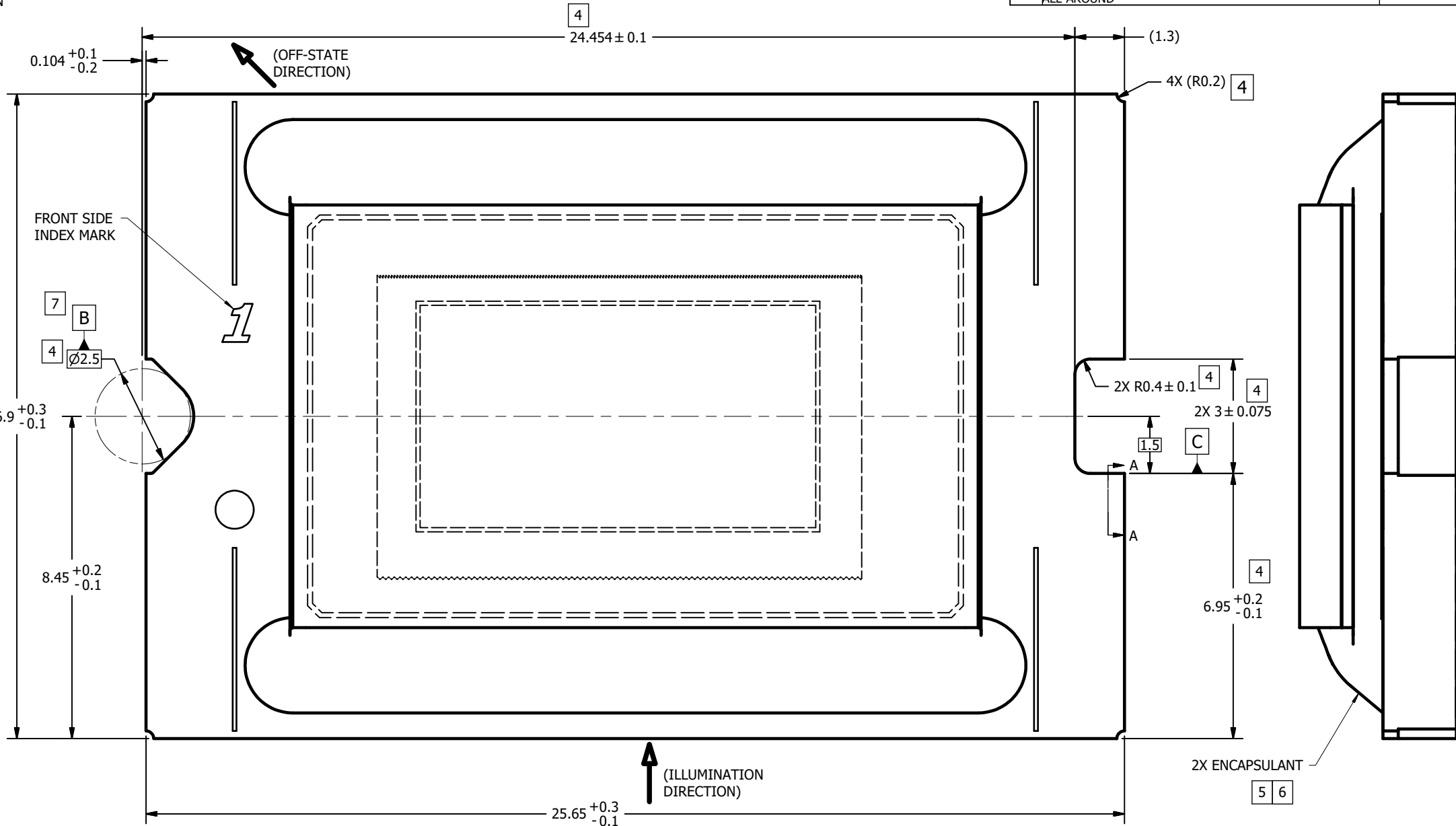
REVISIONS			
REV	DESCRIPTION	DATE	BY
A	ECO 2178176: INITIAL RELEASE	12/11/2018	BMH
B	ECO: 2187413: CHANGE SHORT APERTURE SLOTS TO ALL-AROUND	4/29/2020	PPC



DETAIL B  
V-NOTCH  
SCALE 30 : 1



SECTION A-A  
(ROTATED 90°)

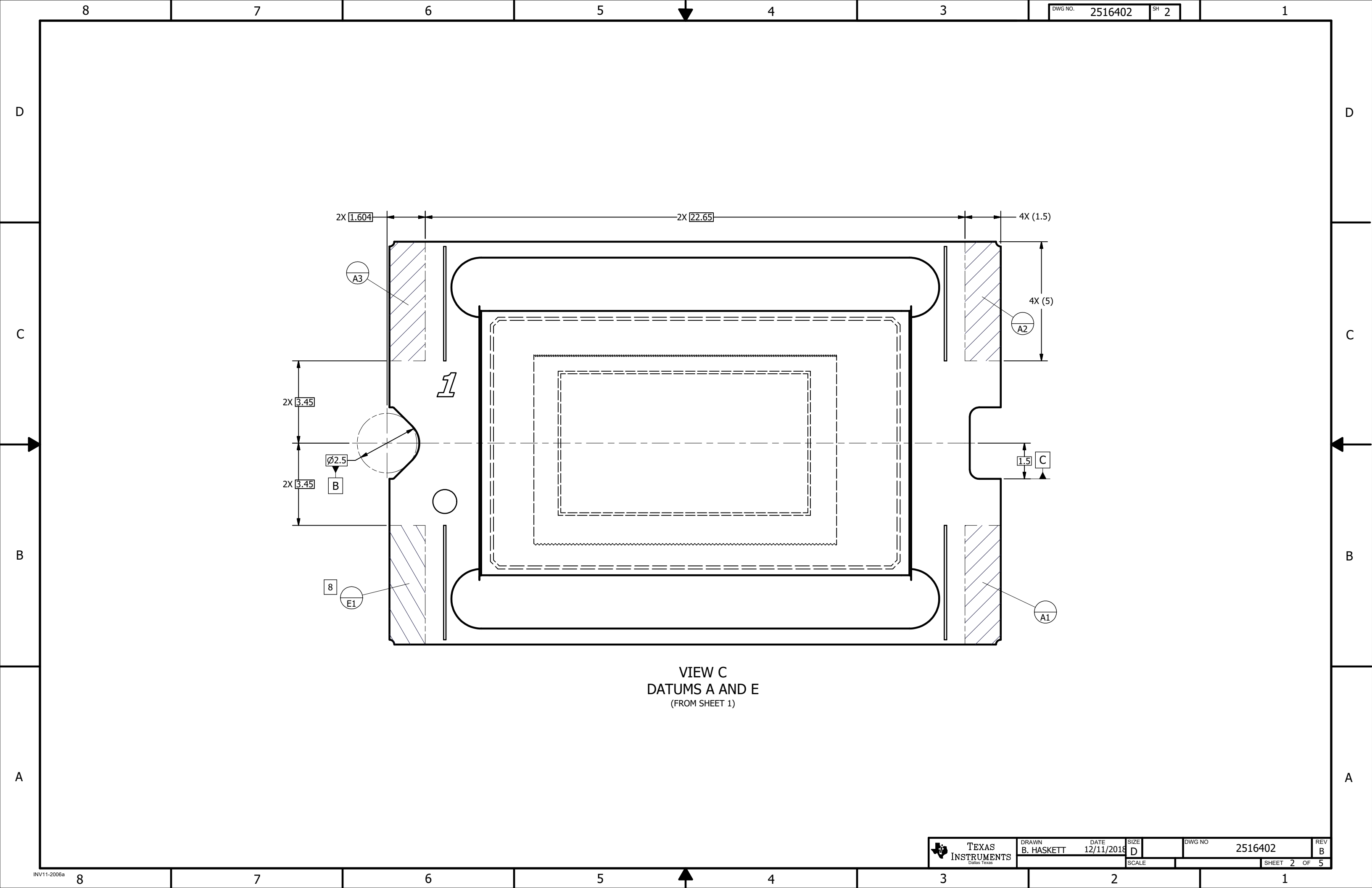


0314DA	USED ON
NEXT ASSY	APPLICATION

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

DRAWN	B. HASKETT	DATE	12/11/2018
ENGINEER	B. HASKETT	DATE	12/11/2018
QA/CE	K. DICKERSON	DATE	12/12/2018
CM	B. HASKETT	DATE	12/19/2018
APPROVED	J. MCKINLEY	DATE	12/18/2018
HERMOSILLO	DATE	12/18/2018	

TEXAS INSTRUMENTS Dallas, Texas		TITLE ICD, MECHANICAL, DMD, .47 4K HSSI SERIES 317 (FQQ PACKAGE)	
SIZE D	DWG NO 2516402	REV B	SHEET 1 OF 5



8

7

6

5

4

3

DWG NO. 2516402

SH 3

1

D

D

C

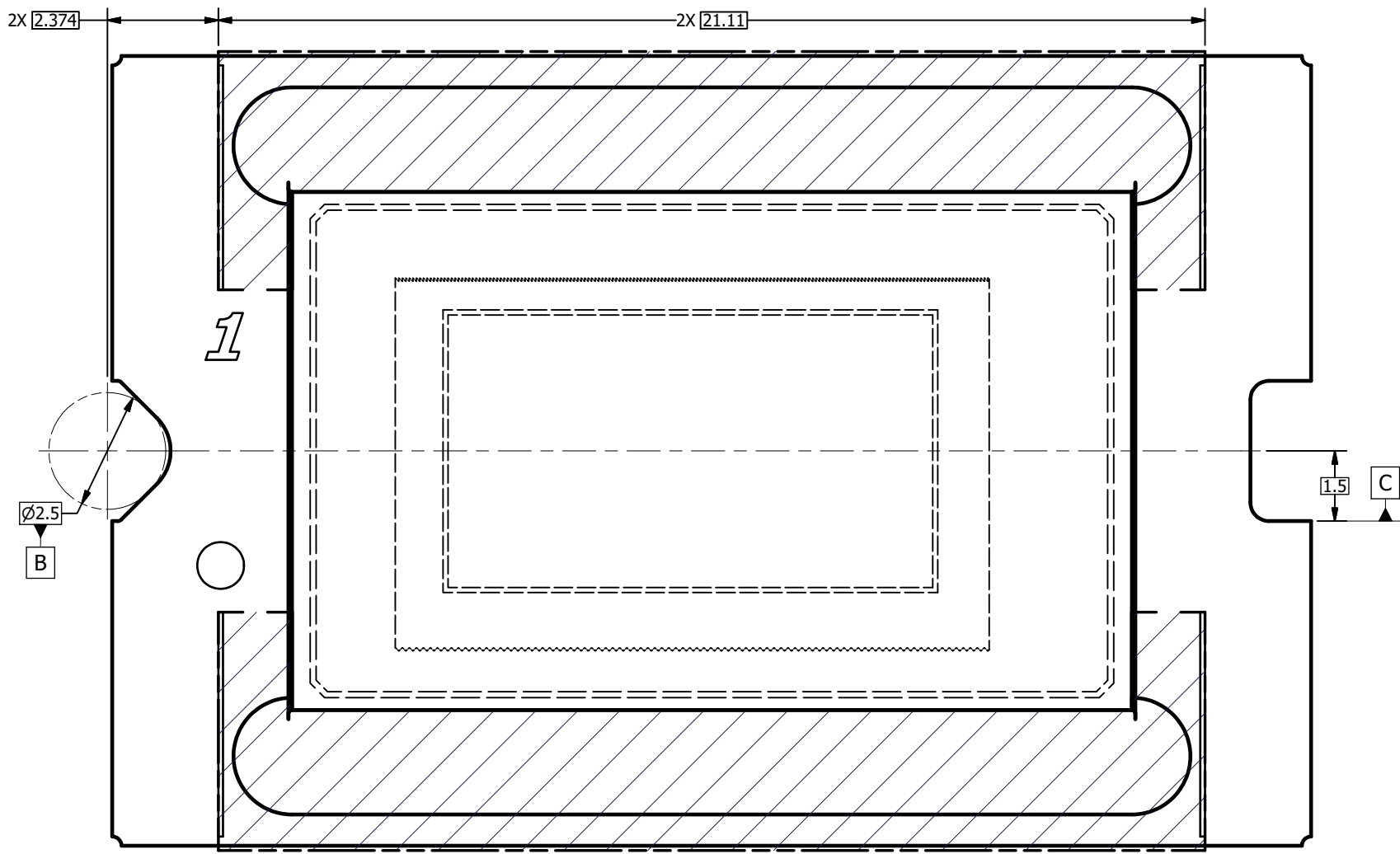
C

B

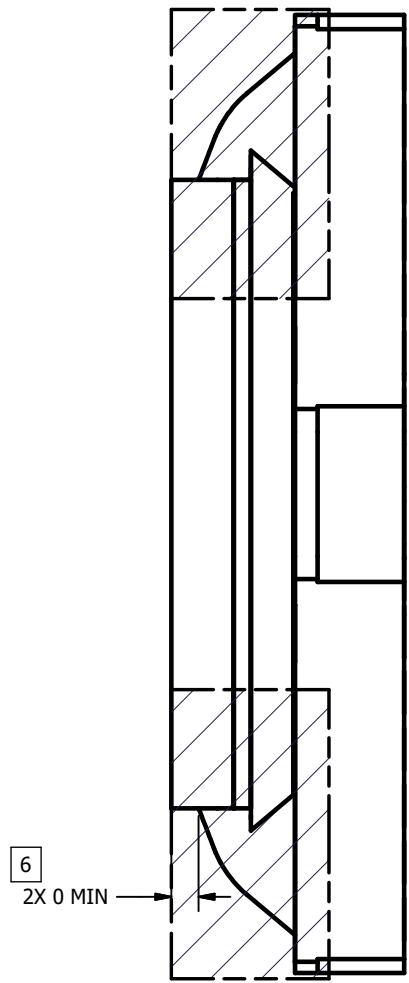
B

A

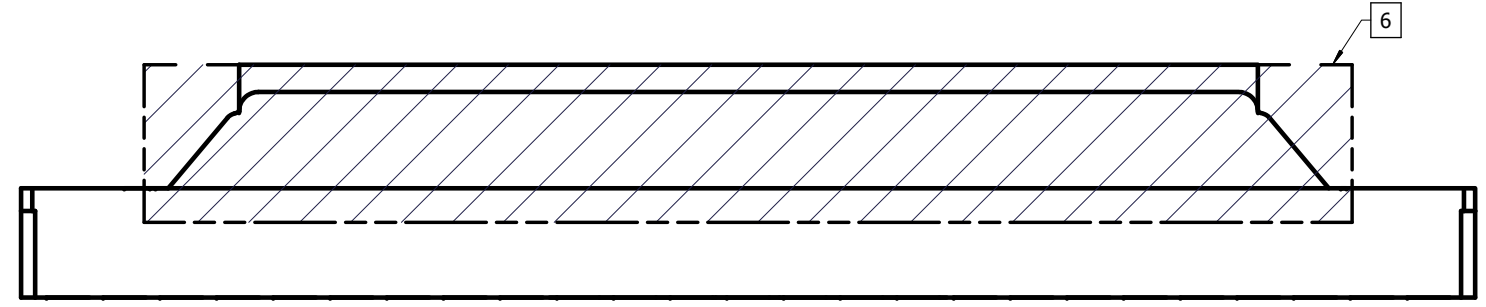
A



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



VIEW E  
MAXIMUM ENCAPSULANT HEIGHT



8

7

6

5

4

3

2

1

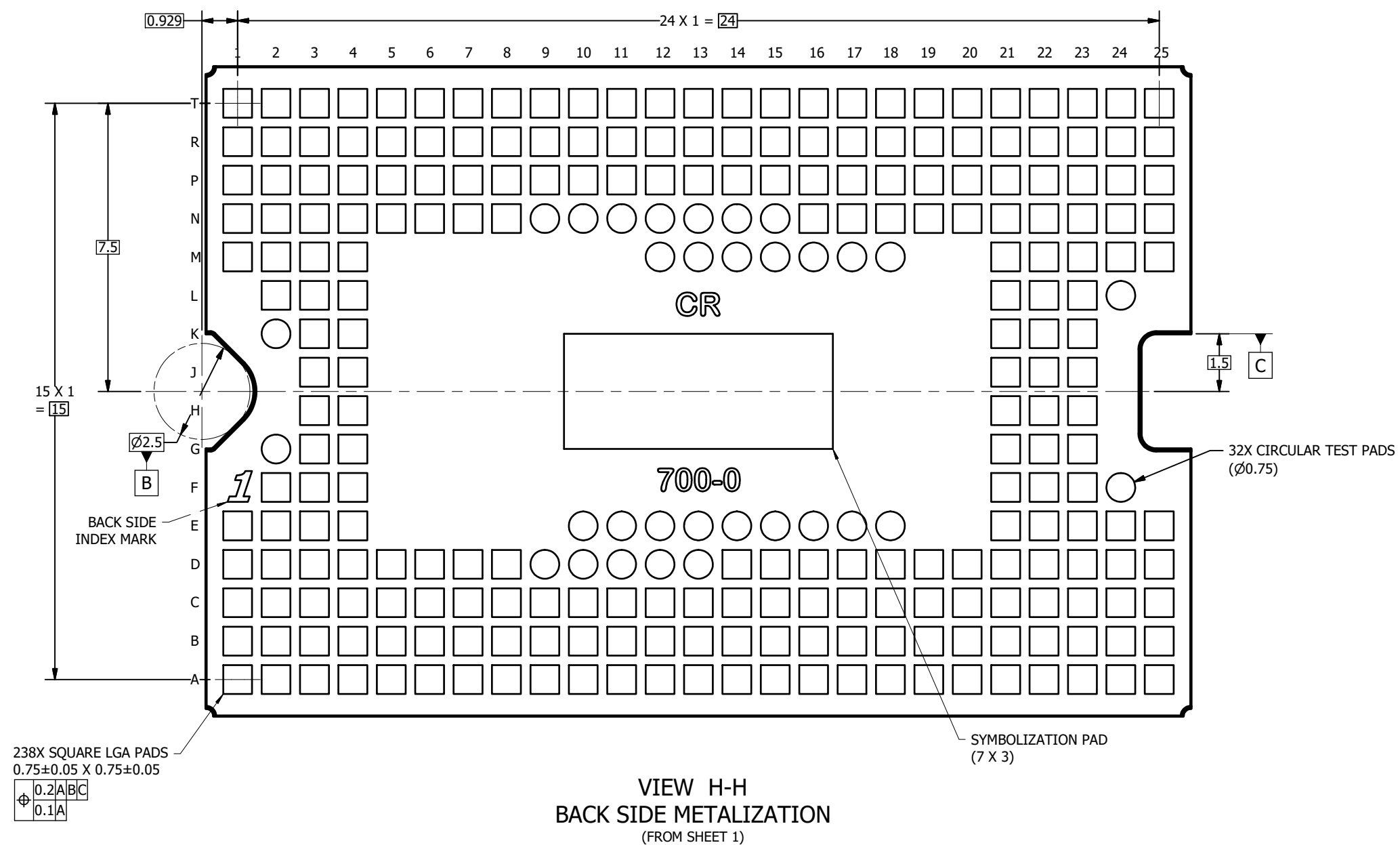


D

C

B

A



## 重要通知和免责声明

TI“按原样”提供技术和可靠性数据（包括数据表）、设计资源（包括参考设计）、应用或其他设计建议、网络工具、安全信息和其他资源，不保证没有瑕疵且不做任何明示或暗示的担保，包括但不限于对适销性、与某特定用途的适用性或不侵犯任何第三方知识产权的暗示担保。

这些资源可供使用 TI 产品进行设计的熟练开发人员使用。您将自行承担以下全部责任：(1) 针对您的应用选择合适的 TI 产品，(2) 设计、验证并测试您的应用，(3) 确保您的应用满足相应标准以及任何其他安全、安保法规或其他要求。

这些资源如有变更，恕不另行通知。TI 授权您仅可将这些资源用于研发本资源所述的 TI 产品的相关应用。严禁以其他方式对这些资源进行复制或展示。您无权使用任何其他 TI 知识产权或任何第三方知识产权。对于因您对这些资源的使用而对 TI 及其代表造成的任何索赔、损害、成本、损失和债务，您将全额赔偿，TI 对此概不负责。

TI 提供的产品受 [TI 销售条款](#)、[TI 通用质量指南](#) 或 [ti.com](#) 上其他适用条款或 TI 产品随附的其他适用条款的约束。TI 提供这些资源并不会扩展或以其他方式更改 TI 针对 TI 产品发布的适用的担保或担保免责声明。除非德州仪器 (TI) 明确将某产品指定为定制产品或客户特定产品，否则其产品均为按确定价格收入目录的标准通用器件。

TI 反对并拒绝您可能提出的任何其他或不同的条款。

版权所有 © 2025，德州仪器 (TI) 公司

最后更新日期：2025 年 10 月