

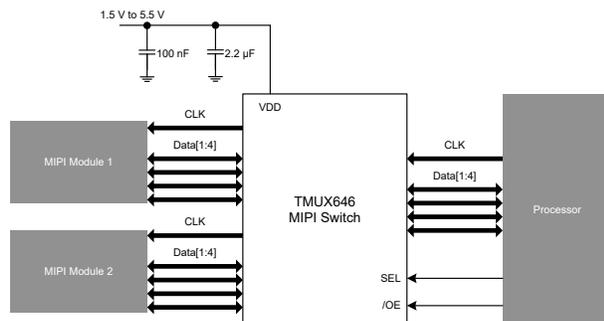
# TMUX646 6 GHz, 5 V, 2:1 (SPDT) 10-Channel MIPI Switch with 1.8-V Logic Support

## 1 Features

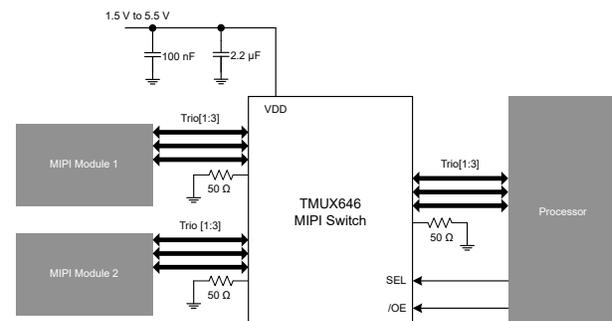
- Supply range of 1.5 V to 5.5 V
- 10-Channel 2:1 bidirectional switch
- Supports MIPI CSI/DSI, SATA, LVDS, RGMII, DDR, ethernet interfaces
- **Powered-off protection:**  
I/Os Hi-Z when  $V_{DD} = 0$  V
- Low  $R_{ON}$ : 6- $\Omega$  typical
- High bandwidth : 6 GHz
- Ultra low crosstalk: -40 dB
- **Low power disable mode**
- **1.2 V logic compatible**
- **Bidirectional signal path**
- ESD protection:
  - 6-kV human body model (HBM)
  - 2-kV human body model (CDM)

## 2 Applications

- **Mobile phones**
- **Tablet**
- **PC and notebooks**
- **Virtual and augmented reality**
- **Drones**
- **Camera-based carcode scanner**
- **Medical**
- **IP netcam**



**Simplified D-PHY Schematic**



**Simplified C-PHY Schematic**

## 3 Description

The TMUX646 is an optimized 10-channel (5 differential) single-pole, double-throw bi-directional switch for use in high speed applications. The TMUX646 is designed to facilitate multiple MIPI compliant devices to connect to a single CSI/DSI, C-PHY/D-PHY module. The device also supports SATA, SAS, MIPI DSI/CSI, LVDS, RGMII, DDR and Ethernet interfaces.

The device has a bandwidth of 6 GHz, low channel-to-channel skew with little signal degradation, and wide margins to compensate for layout losses. The device's low current consumption meets the needs of low power applications, including mobile phones and other personal electronics.

### Device Information<sup>(1)</sup>

PART NUMBER	PACKAGE	BODY SIZE (NOM)
TMUX646	nFBGA (ZEC)	2.45 mm × 2.45 mm

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



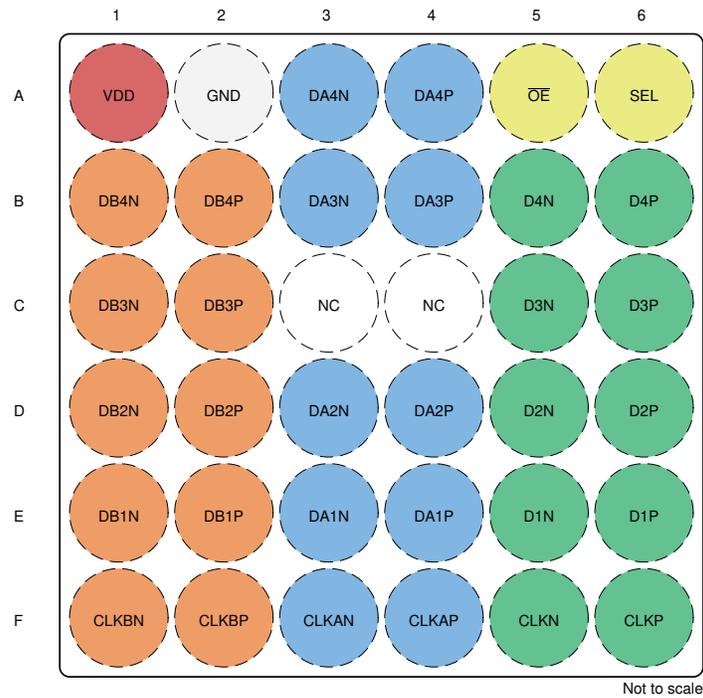
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## 4 Revision History

DATE	REVISION	NOTES
June 2021	*	Initial Release

## 5 Pin Configuration and Functions



**Figure 5-1. nFBGA Package 36 Pin (ZEC) Top View**

**Table 5-1. Pin Functions**

PIN		I/O	DESCRIPTION
NAME	NO.		
CLKAN	F3	I/O	Differential I/O
CLKAP	F4	I/O	Differential I/O
CLKBN	F1	I/O	Differential I/O
CLKBP	F2	I/O	Differential I/O
CLKN	F5	I/O	Differential I/O
CLKP	F6	I/O	Differential I/O
D1N	E5	I/O	Differential I/O
D1P	E6	I/O	Differential I/O
D2N	D5	I/O	Differential I/O
D2P	D6	I/O	Differential I/O
D3N	C5	I/O	Differential I/O
D3P	C6	I/O	Differential I/O
D4N	B5	I/O	Differential I/O
D4P	B6	I/O	Differential I/O
DA1N	E3	I/O	Differential I/O
DA1P	E4	I/O	Differential I/O
DA2N	D3	I/O	Differential I/O
DA2P	D4	I/O	Differential I/O
DA3N	B3	I/O	Differential I/O
DA3P	B4	I/O	Differential I/O
DA4N	A3	I/O	Differential I/O
DA4P	A4	I/O	Differential I/O

**Table 5-1. Pin Functions (continued)**

PIN		I/O	DESCRIPTION
NAME	NO.		
DB1N	E1	I/O	Differential I/O
DB1P	E2	I/O	Differential I/O
DB2N	D1	I/O	Differential I/O
DB2P	D2	I/O	Differential I/O
DB3N	C1	I/O	Differential I/O
DB3P	C2	I/O	Differential I/O
DB4N	B1	I/O	Differential I/O
DB4P	B2	I/O	Differential I/O
GND	A2	P	Device Ground
NC	C3	—	No internal connection
NC	C4	—	No internal connection
$\overline{\text{OE}}$	A5	I	Output enable (active low), has internal pull-down resistor
SEL	A6	I	Channel select, has internal pull-down resistor
VDD	A1	P	Power supply input

## 6 Specifications

### 6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

		MIN	MAX	UNIT
V <sub>DD</sub>	Supply Voltage	-0.5	6	V
V <sub>SW</sub>	Switch signal voltage (CLKP/N, CLKAP/N, CLKBP/N, DxP/N, DAxP/N, DBxP/N)	-0.5	4	V
V <sub>SEL</sub> , V <sub>OE</sub>	Logic control input pin voltage (SEL, $\overline{OE}$ )	-0.5	6	V
T <sub>J</sub>	Junction temperature	-65	125	°C
T <sub>stg</sub>	Storage temperature	-65	150	°C

- (1) Stresses beyond those listed under *Absolute Maximum Rating* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Condition*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

### 6.2 ESD Ratings

		VALUE	UNIT
V <sub>(ESD)</sub>	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/ JEDEC JS-001, all pins <sup>(1)</sup>	±6000
		Charged device model (CDM), per JEDEC specification JESD22-C101, all pins <sup>(2)</sup>	±2000

- (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.

### 6.3 Recommended Operating Conditions

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

		MIN	NOM	MAX	UNIT
V <sub>DD</sub>	Supply Voltage	1.5		5.5	V
V <sub>SW</sub>	Switch signal voltage (CLKP/N, CLKAP/N, CLKBP/N, DxP/N, DAxP/N, DBxP/N)	0		3.6	V
V <sub>(SEL)</sub> V <sub>(OE)</sub>	Logic control input pin voltage	0		5.5	V
I <sub>S</sub> or I <sub>D</sub> (CONT)	Continuous current through switch	-35 <sup>(1)</sup>		35 <sup>(1)</sup>	mA
T <sub>A</sub>	Operating ambient temperature	-40		85	°C

- (1) At T<sub>J</sub> = 85°C

### 6.4 Thermal Information

THERMAL METRIC <sup>(1)</sup>		TMUX646	UNIT
		ZEC (nFBGA)	
		36 PINS	
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	111.7	°C/W
R <sub>θJC(top)</sub>	Junction-to-case (top) thermal resistance	49.2	°C/W
R <sub>θJB</sub>	Junction-to-board thermal resistance	54.9	°C/W
Ψ <sub>JT</sub>	Junction-to-top characterization parameter	2.0	°C/W
Ψ <sub>JB</sub>	Junction-to-board characterization parameter	54.7	°C/W

## 6.4 Thermal Information (continued)

THERMAL METRIC <sup>(1)</sup>		TMUX646	UNIT
		ZEC (nFBGA)	
		36 PINS	
R <sub>θJC(bot)</sub>	Junction-to-case (bottom) thermal resistance	N/A	°C/W

(1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics](#) application report.

## 6.5 Electrical Characteristics

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

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>POWER SUPPLY</b>					
I <sub>DD</sub>	VDD active supply current V <sub>DD</sub> = 1.5 V to 5.5 V OE = 0 V SEL = 0 V or 5.5 V Dn, CLKn = 0 V		30	55	μA
I <sub>DD_PD</sub>	Power-down supply current V <sub>DD</sub> = 1.5 V to 5.5 V OE = V <sub>DD</sub> SEL = 0 V or 5.5 V Dn, CLKn = 0 V		0.1	1	μA
ΔI <sub>DD</sub>	Increase in supply current per logic pin at 1.8 V V <sub>DD</sub> = 2.5 V OE = 1.8 V SEL = 0 V or V <sub>DD</sub> Dn, CLKn = 0 V		1.3		μA
	V <sub>DD</sub> = 5 V OE = 1.8 V SEL = 0 V or V <sub>DD</sub> Dn, CLKn = 0 V		2.5		μA
<b>DC CHARACTERISTICS</b>					
R <sub>ON_HS</sub>	On-state resistance V <sub>DD</sub> = 1.5 V to 5.5 V OE = 0 V, SEL = 0 V or V <sub>DD</sub> , Dn, CLKn = –8 mA, 0.2 V DAn, DBn, CLKAn, CLKBn = 0.2 V, –8 mA		6	9	Ω
R <sub>ON_LP</sub>	On-state resistance V <sub>DD</sub> = 1.5 V to 5.5 V OE = 0 V, SEL = 0 V or V <sub>DD</sub> , Dn, CLKn = –8 mA, 1.2 V DAn, DBn, CLKAn, CLKBn = 1.2 V, –8 mA		6	10	Ω
R <sub>ON_flat_HS</sub>	On-state resistance flatness V <sub>DD</sub> = 1.5 V to 5.5 V OE = 0 V, SEL = 0 V or V <sub>DD</sub> , Dn, CLKn = –8 mA, 0 V to 0.3 V DAn, DBn, CLKAn, CLKBn = 0 V to 0.3 V, –8 mA		0.1		Ω
R <sub>ON_flat_LP</sub>	On-state resistance flatness V <sub>DD</sub> = 1.5 V to 5.5 V OE = 0 V, SEL = 0 V or V <sub>DD</sub> , Dn, CLKn = –8 mA, 0 V to 1.3 V DAn, DBn, CLKAn, CLKBn = 0 V to 1.3 V, –8 mA		0.9		Ω
D <sub>RON_HS</sub>	On-state resistance match between + and – paths V <sub>DD</sub> = 1.5 V to 5.5 V OE = 0 V, SEL = 0 V or V <sub>DD</sub> , Dn, CLKn = –8 mA, 0.2 V DAn, DBn, CLKAn, CLKBn = 0.2 V, –8 mA		0.1		Ω
D <sub>RON_LP</sub>	On-state resistance match between + and – paths V <sub>DD</sub> = 1.5 V to 5.5 V OE = 0 V, SEL = 0 V or V <sub>DD</sub> , Dn, CLKn = –8 mA, 1.3 V DAn, DBn, CLKAn, CLKBn = 1.3 V, –8 mA		0.1		Ω

## 6.5 Electrical Characteristics (continued)

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$I_{OFF}$	Switch off leakage current	$V_{DD} = 1.5\text{ V to }5.5\text{ V}$ $\overline{OE} = 0\text{ V or }5.5\text{ V}$ $SEL = 0\text{ V or }5.5\text{ V}$ $D_n, CLK_n = 0\text{ V to }1.3\text{ V}$ $DAn, DBn, CLKAn, CLKBn = 0\text{ V to }1.3\text{ V}$	-0.5		0.5	$\mu\text{A}$
$I_{OFF\_3\_6}$	Switch off leakage current	$V_{DD} = 0\text{ V, }1.5\text{ V, }1.65\text{ V, }3.3\text{ V, }5.5\text{ V}$ $\overline{OE} = 0\text{ V or }5.5\text{ V}$ $SEL = 0\text{ V or }5.5\text{ V}$ $DX, CLKX = 3.6\text{ V}$ $DAX, DBx, CLKAX, CLKBX = 3.6\text{ V}$	-10		10	$\mu\text{A}$
$I_{ON}$	Switch on leakage current	$V_{DD} = 1.5\text{ V to }5.5\text{ V}$ $\overline{OE} = 0\text{ V}$ $SEL = 0\text{ V or }5.5\text{ V}$ $D_n, CLK_n = 0\text{ V to }1.3\text{ V}$ $DAn, DBn, CLKAn, CLKBn = 0\text{ V to }1.3\text{ V}$	-0.5		0.5	$\mu\text{A}$
$I_{ON\_3\_6}$	Switch on leakage current	$V_{DD} = 1.5\text{ V to }5.5\text{ V}$ $\overline{OE} = 0\text{ V}$ $SEL = 0\text{ V or }5.5\text{ V}$ $DX, CLKX = 3.6\text{ V}$ $DAX, DBx, CLKAX, CLKBX = 3.6\text{ V}$	-50		50	$\mu\text{A}$
<b>DYNAMIC CHARACTERISTICS</b>						
$t_{SWITCH}$	Switching time SEL to output	$V_{DD} = 1.5\text{ V to }5.5\text{ V}$ $\overline{OE} = 0\text{ V}$ $D_n, CLK_n = 1.2\text{ V}$ $DAn, DBn, CLKAn, CLKBn:$ $R_L = 50\ \Omega, C_L = 15\text{ pF}$			1.5	$\mu\text{s}$
$t_{ON\_OE}$	Turnon time from $\overline{OE}$ to output	$V_{DD} = 1.5\text{ V to }5.5\text{ V}$ $D_n, CLK_n = 1.2\text{ V}$ $DAn, DBn, CLKAn, CLKBn:$ $R_L = 50\ \Omega, C_L = 15\text{ pF}$		50	300	$\mu\text{s}$
$t_{OFF\_OE}$	Turnoff time from $\overline{OE}$ to output	$V_{DD} = 1.5\text{ V to }5.5\text{ V}$ $D_n, CLK_n = 1.2\text{ V}$ $DAn, DBn, CLKAn, CLKBn:$ $R_L = 50\ \Omega, C_L = 15\text{ pF}$		0.5	1	$\mu\text{s}$
$f_{SEL\_MAX}$	Maximum toggling frequency for the SEL line	$V_{DD} = 1.5\text{ V to }5.5\text{ V}$ $D_n, CLK_n = 1.2\text{ V}$ $DAn, DBn, CLKAn, CLKBn:$ $R_L = 50\ \Omega, C_L = 2\text{ pF}$			100	kHz
$t_{ON\_VDD}$	Turnon time from VDD to output	$V_{DD} = 0\text{ V to }5.5\text{ V}$ $V_{DD}$ ramp rate = $1\ \mu\text{s}$ $D_n, CLK_n = 1.2\text{ V}$ $DAn, DBn, CLKAn, CLKBn:$ $R_L = 50\ \Omega, C_L = 15\text{ pF}$		50	300	$\mu\text{s}$
$t_{OFF\_VDD}$	Turnoff time from VDD to output	$V_{DD} = 5\text{ V to }0\text{ V}$ $D_n, CLK_n = 1.2\text{ V}$ $DAn, DBn, CLKAn, CLKBn:$ $R_L = 50\ \Omega, C_L = 15\text{ pF}$		0.5	1	ms
$t_{MIN\_OE}$	Minimum pulse width for $\overline{OE}$	$V_{DD} = 1.5\text{ V to }5.5\text{ V}$ $D_n, CLK_n = 1.2\text{ V}$ $DAn, DBn, CLKAn, CLKBn:$ $R_L = 50\ \Omega, C_L = 2\text{ pF}$	500			ns
$t_{BBM}$	Break before make time	$V_{DD} = 1.5\text{ V to }5.5\text{ V}$ $\overline{OE} = 0\text{ V}$ $D_n, CLK_n = R_L = 50\ \Omega, C_L = 15\text{ pF}$ $DAn, DBn, CLKAn, CLKBn: 1.2\text{ V}$	50			ns

## 6.5 Electrical Characteristics (continued)

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{\text{SKEW}}$	Intrapair skew (opposite transitions of same output)	$V_{\text{DD}} = 1.5 \text{ V to } 5.5 \text{ V}$ $\overline{\text{OE}} = 0 \text{ V}$ Dn, CLKn = 0.3 V DnX, DBn, CLKAn, CLKBn: $R_{\text{L}} = 50 \Omega, C_{\text{L}} = 5 \text{ pF}$		1		ps
$t_{\text{SKEW}}$	Interpair Skew (Channel-to-Channel Skew)	$V_{\text{DD}} = 1.5 \text{ V to } 5.5 \text{ V}$ $\overline{\text{OE}} = 0 \text{ V}$ Dn, CLKn = 0.3 V DAn, DBn, CLKAn, CLKBn: $R_{\text{L}} = 50 \Omega, C_{\text{L}} = 5 \text{ pF}$		4		ps
$t_{\text{PD}}$	Propagation delay with 100 ps rise time	$V_{\text{DD}} = 1.5 \text{ V to } 5.5 \text{ V}$ $\overline{\text{OE}} = 0 \text{ V}$ Dn, CLKn = 1.2 V DAn, DBn, CLKAn, CLKBn: $R_{\text{L}} = 50 \Omega, C_{\text{L}} = 5 \text{ pF}$ $t_{\text{RISE}} = 100 \text{ ps}$		40		ps
$O_{\text{ISO}}$	Differential off isolation	$V_{\text{DD}} = 1.5 \text{ V to } 5.5 \text{ V}$ $\overline{\text{OE}} = 0 \text{ V}, V_{\text{DD}}$ SEL = 0 V, $V_{\text{DD}}$ Dn, CLKn, DAn, DBn, CLKAn, CLKBn: $R_{\text{S}} = 50 \Omega, R_{\text{L}} = 50 \Omega, C_{\text{L}} = 5 \text{ pF}$ $V_{\text{SW}} = 200 \text{ mVpp}$ (differential) $f = 1250 \text{ MHz}$		-20		dB
$X_{\text{TALK}}$	Differential channel to channel crosstalk	$V_{\text{DD}} = 1.5 \text{ V to } 5.5 \text{ V}$ $\overline{\text{OE}} = 0 \text{ V}, V_{\text{DD}}$ SEL = 0 V, $V_{\text{DD}}$ Dn, CLKn, DAn, DBn, CLKAn, CLKBn: $R_{\text{S}} = 50 \Omega, R_{\text{L}} = 50 \Omega, C_{\text{L}} = 5 \text{ pF}$ $V_{\text{SW}} = 200 \text{ mVpp}$ (differential) $f = 1250 \text{ MHz}$		-40		dB
BW	Differential Bandwidth	$V_{\text{DD}} = 1.5 \text{ V to } 5.5 \text{ V}$ $\overline{\text{OE}} = 0 \text{ V}$ SEL = 0 V, $V_{\text{DD}}$ Dn, CLKn, DAn, DBn, CLKAn, CLKBn: $V_{\text{SW}} = 200 \text{ mVpp}$ (differential) $f = 1250 \text{ MHz}$		6		GHz
$I_{\text{LOSS}}$	Insertion Loss	$V_{\text{DD}} = 1.5 \text{ V to } 5.5 \text{ V}$ $\overline{\text{OE}} = 0 \text{ V}$ SEL = 0 V, $V_{\text{DD}}$ Dn, CLKn, DAn, DBn, CLKAn, CLKBn: $R_{\text{S}} = 50 \Omega, R_{\text{L}} = 50 \Omega, C_{\text{L}} = 5 \text{ pF}$ $V_{\text{SW}} = 200 \text{ mVpp}$ (differential) $f = 100 \text{ kHz}$		-0.65		dB
$C_{\text{OFF}}$	Off capacitance	$V_{\text{DD}} = 1.5 \text{ V to } 5.5 \text{ V}$ $\overline{\text{OE}} = 0 \text{ V}, V_{\text{DD}}$ SEL = 0 V, $V_{\text{DD}}$ Dn, CLKn, DAn, DBn, CLKAn, CLKBn = 0 V, 0.2 V $f = 1250 \text{ MHz}$		1.5		pF
$C_{\text{ON}}$	On capacitance	$V_{\text{DD}} = 1.5 \text{ V to } 5.5 \text{ V}$ $\overline{\text{OE}} = 0 \text{ V}$ SEL = 0 V, $V_{\text{DD}}$ Dn, CLKn, DAn, DBn, CLKAn, CLKBn = 0 V, 0.2 V $f = 1250 \text{ MHz}$		1.5		pF
<b>DIGITAL CHARACTERISTICS</b>						
$V_{\text{IH}}$	Input logic high	SEL, $\overline{\text{OE}}$	1		5.5	V
$V_{\text{IL}}$	Input logic low	SEL, $\overline{\text{OE}}$	0		0.4	V
$I_{\text{IH}}$	Input high leakage current	SEL, $\overline{\text{OE}}$	-5		5	$\mu\text{A}$

## 6.5 Electrical Characteristics (continued)

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$I_{IL}$	Input low leakage current	SEL, $\overline{OE}$	-5		5	$\mu A$
$R_{PD}$	Internal pull-down resistance on digital input pins	SEL, $\overline{OE}$		6		$M\Omega$
$C_i$	Digital Input capacitance	$V_{SEL} = 0 V, 1.8 V$ or $V_{DD}$ $f = 1 MHz$		5		$pF$

## 6.6 Typical Characteristics

At  $T_A = 25^\circ\text{C}$  (unless otherwise noted).

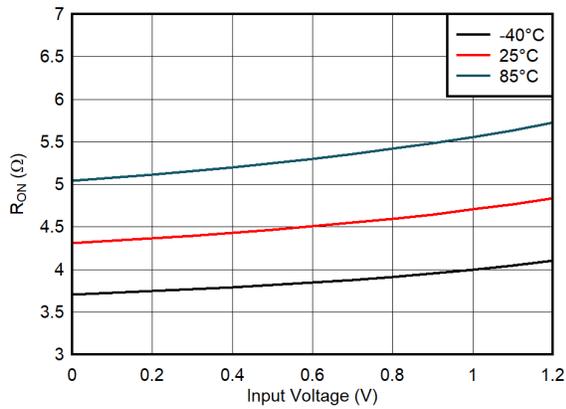


Figure 6-1.  $R_{ON}$  vs Input Voltage.  $V_{DD} = 1.5\text{ V}$

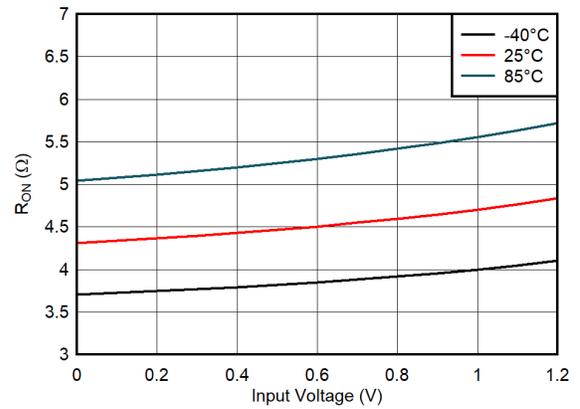


Figure 6-2.  $R_{ON}$  vs Input Voltage.  $V_{DD} = 3.3\text{ V}$

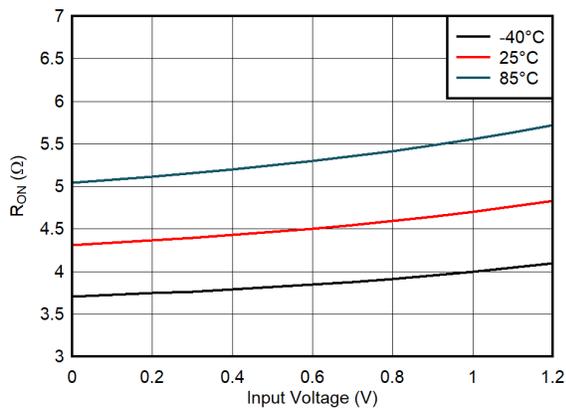


Figure 6-3.  $R_{ON}$  vs Input Voltage.  $V_{DD} = 5.5\text{ V}$

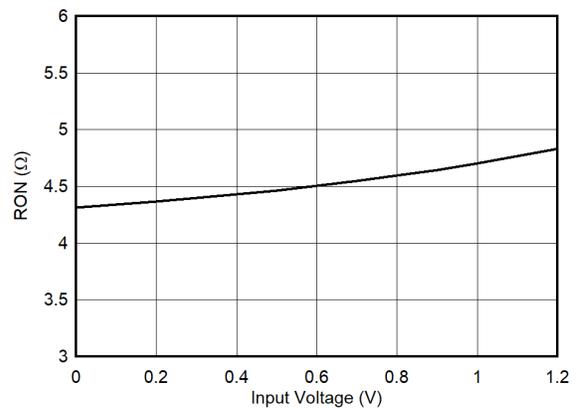


Figure 6-4.  $R_{ON}$  vs Input Voltage,  $V_{DD} = 1.5\text{ V to }5.5\text{ V}$

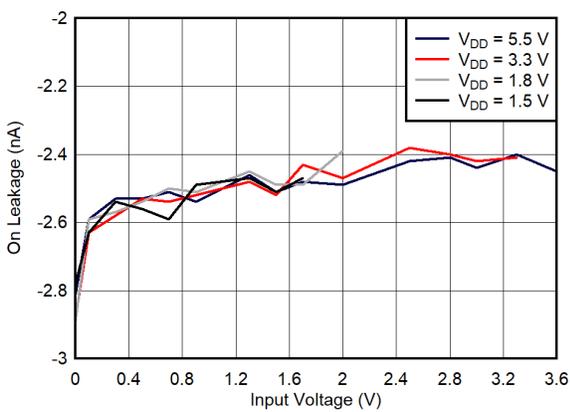


Figure 6-5. On-Leakage vs Input Voltage

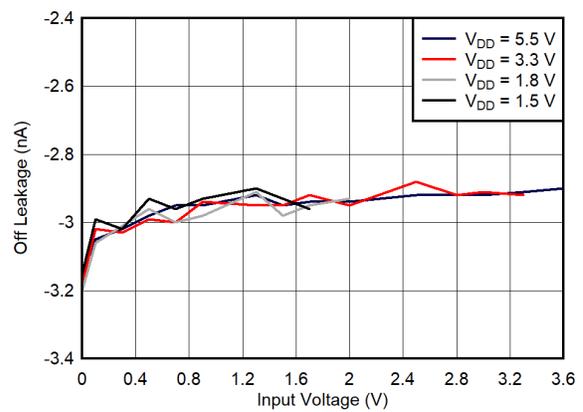


Figure 6-6. Off-Leakage vs Input Voltage

## 6.6 Typical Characteristics (continued)

At  $T_A = 25^\circ\text{C}$  (unless otherwise noted).

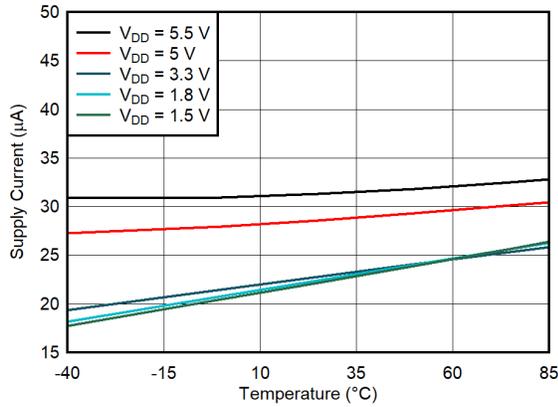


Figure 6-7. Supply Current vs Temperature

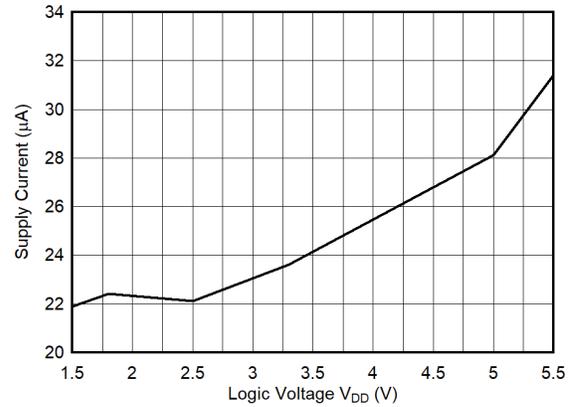


Figure 6-8. Supply Current vs Logic Voltage

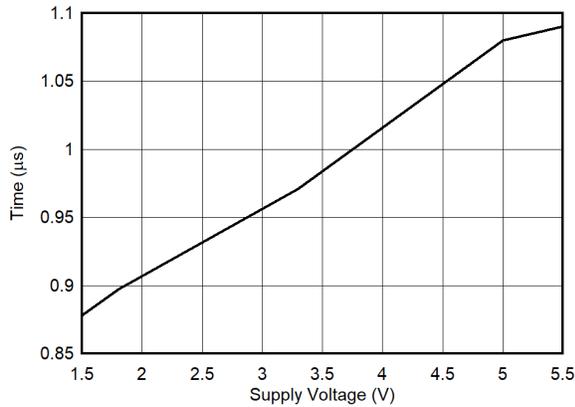


Figure 6-9. Switching Time ( $t_{\text{SWITCH}}$ ) vs Supply Voltage

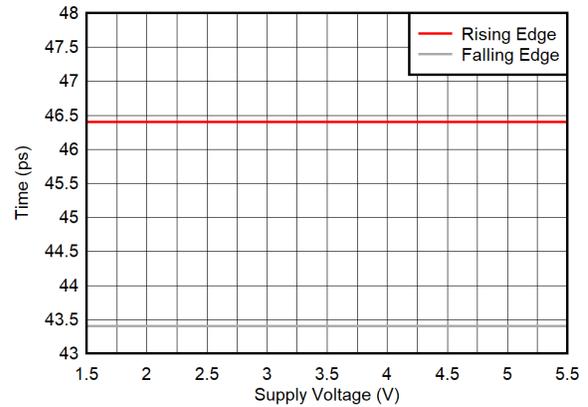


Figure 6-10. Propagation Delay ( $t_{\text{PD}}$ ) vs Supply Voltage

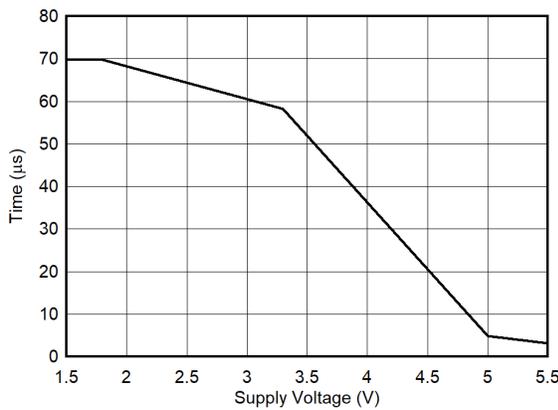


Figure 6-11.  $t_{\text{ON\_VDD}}$  vs Supply Voltage

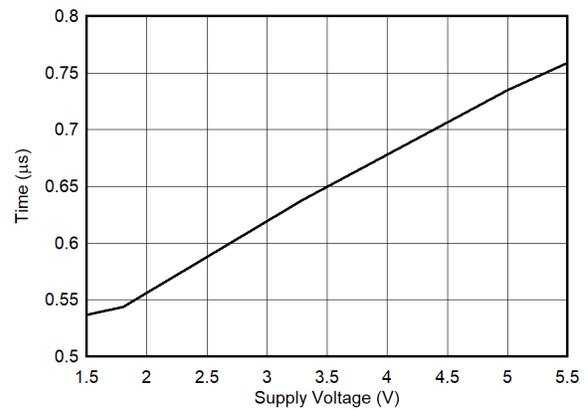


Figure 6-12.  $t_{\text{OFF\_VDD}}$  vs Supply Voltage

## 6.6 Typical Characteristics (continued)

At  $T_A = 25^\circ\text{C}$  (unless otherwise noted).

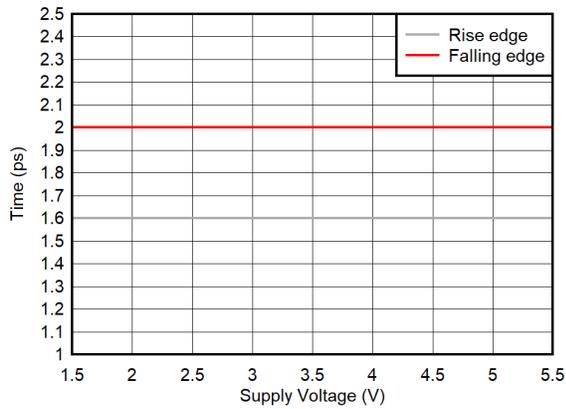


Figure 6-13. Interpair Skew vs Supply Voltage

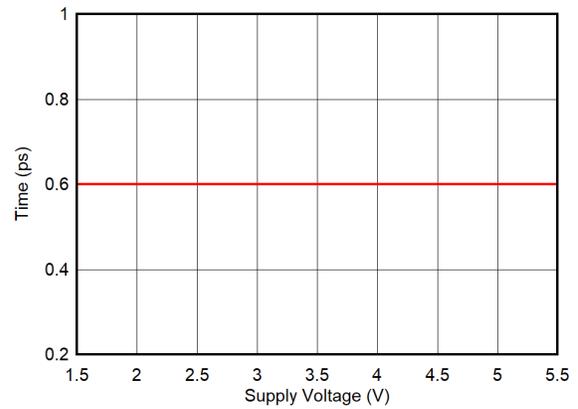


Figure 6-14. Intrapair Skew vs Supply Voltage

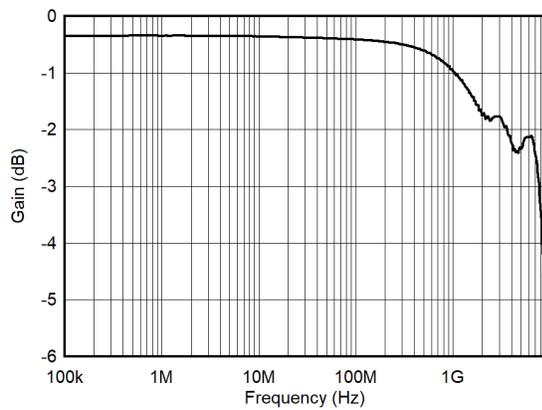


Figure 6-15. Differential Bandwidth

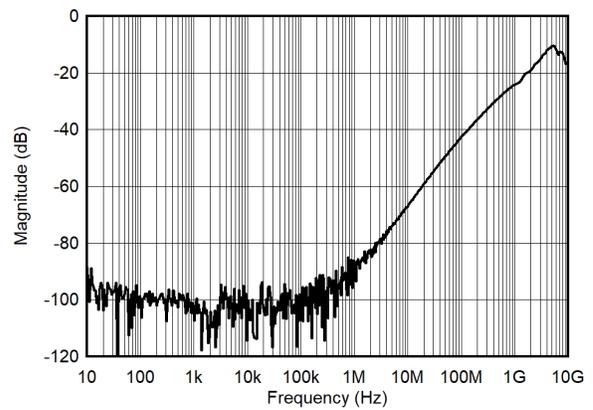


Figure 6-16. Off Isolation

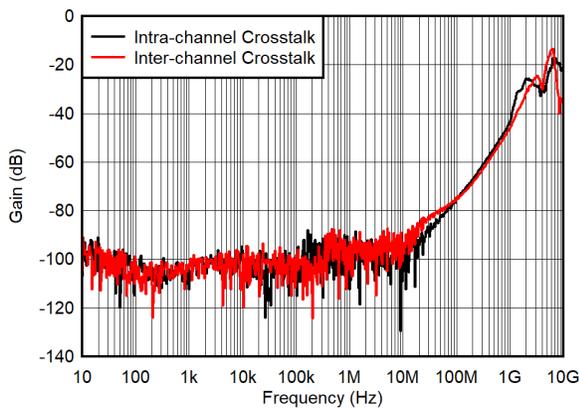


Figure 6-17. Differential Crosstalk

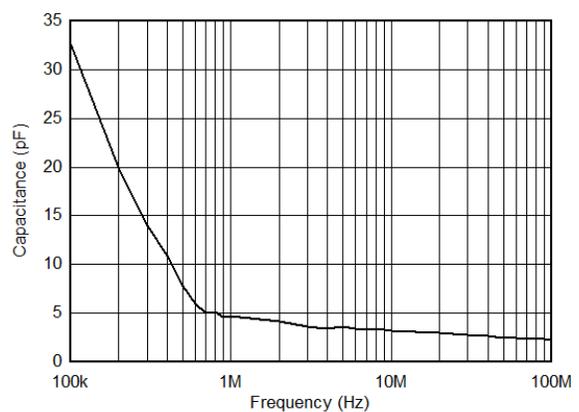


Figure 6-18. Capacitance vs Frequency

## 7 Parameter Measurement Information

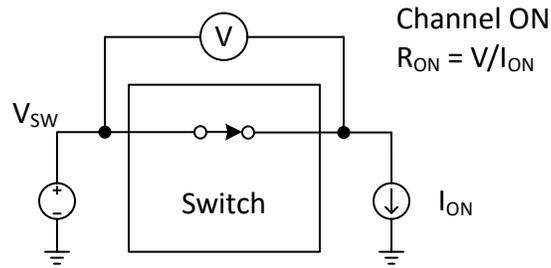


Figure 7-1. On Resistance

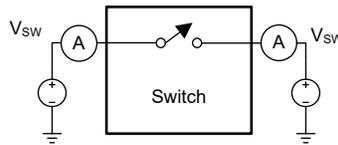


Figure 7-2. Off Leakage

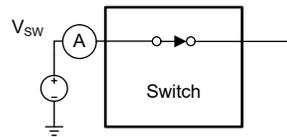
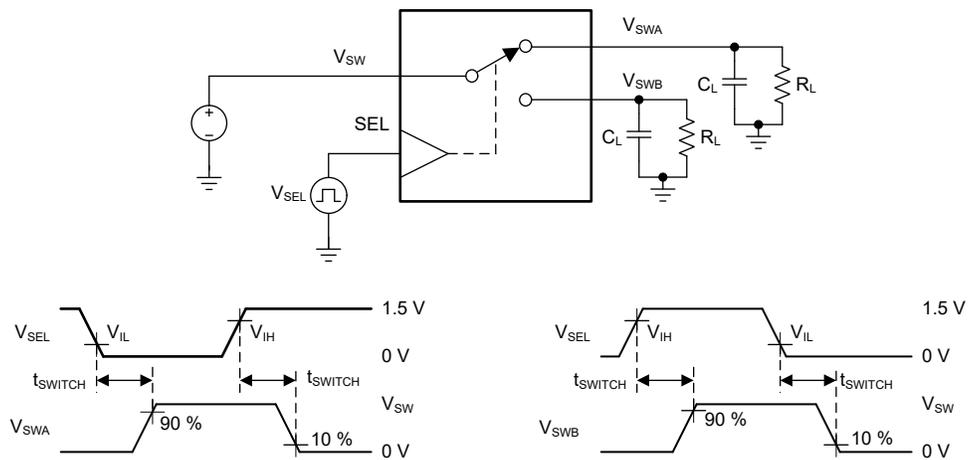
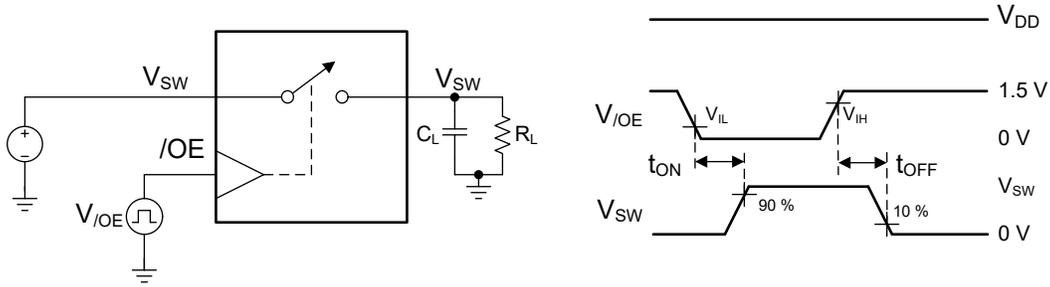


Figure 7-3. On Leakage



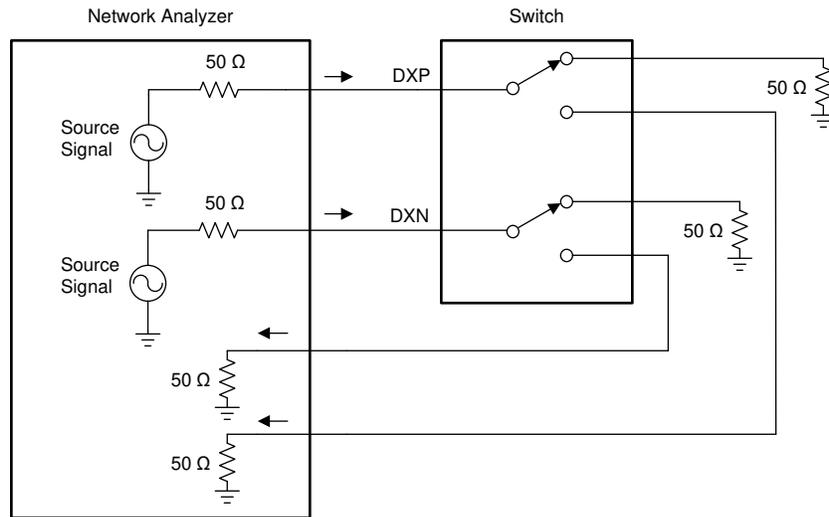
- A. All input pulses are supplied by generators having the following characteristics: PRR  $\leq$  10 MHz,  $Z_O = 50 \Omega$ ,  $t_r = 3$  ns,  $t_f = 3$  ns.
- B.  $C_L$  includes probe and jig capacitance.

Figure 7-4.  $t_{SWITCH}$  Timing



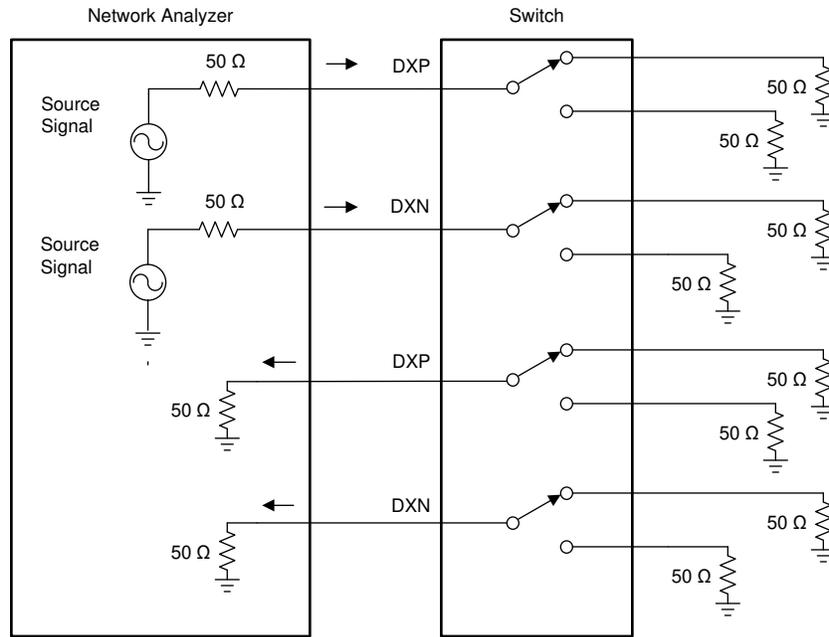
- A. All input pulses are supplied by generators having the following characteristics:  $PRR \leq 10 \text{ MHz}$ ,  $Z_0 = 50 \Omega$ ,  $t_r = 3 \text{ ns}$ ,  $t_f = 3 \text{ ns}$ .
- B.  $C_L$  includes probe and jig capacitance.

**Figure 7-5.  $t_{ON}$  and  $t_{OFF}$  Timing for  $\overline{OE}$**



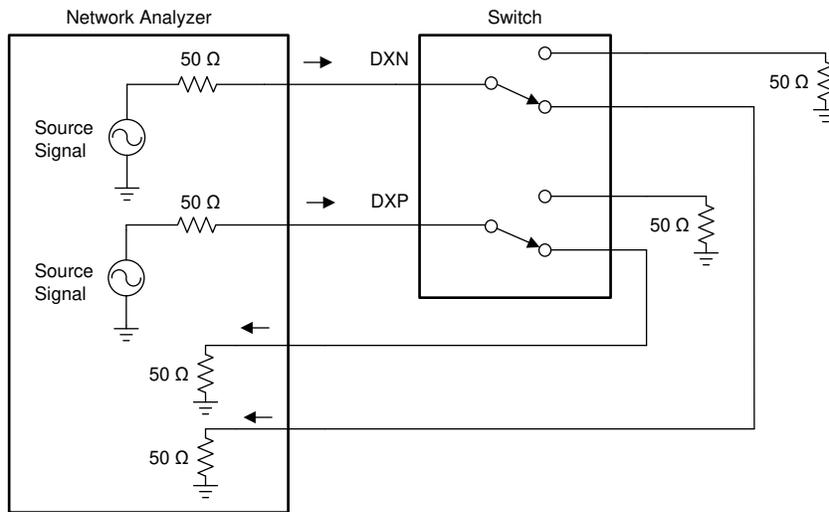
Copyright © 2018, Texas Instruments Incorporated

**Figure 7-6. Off Isolation**



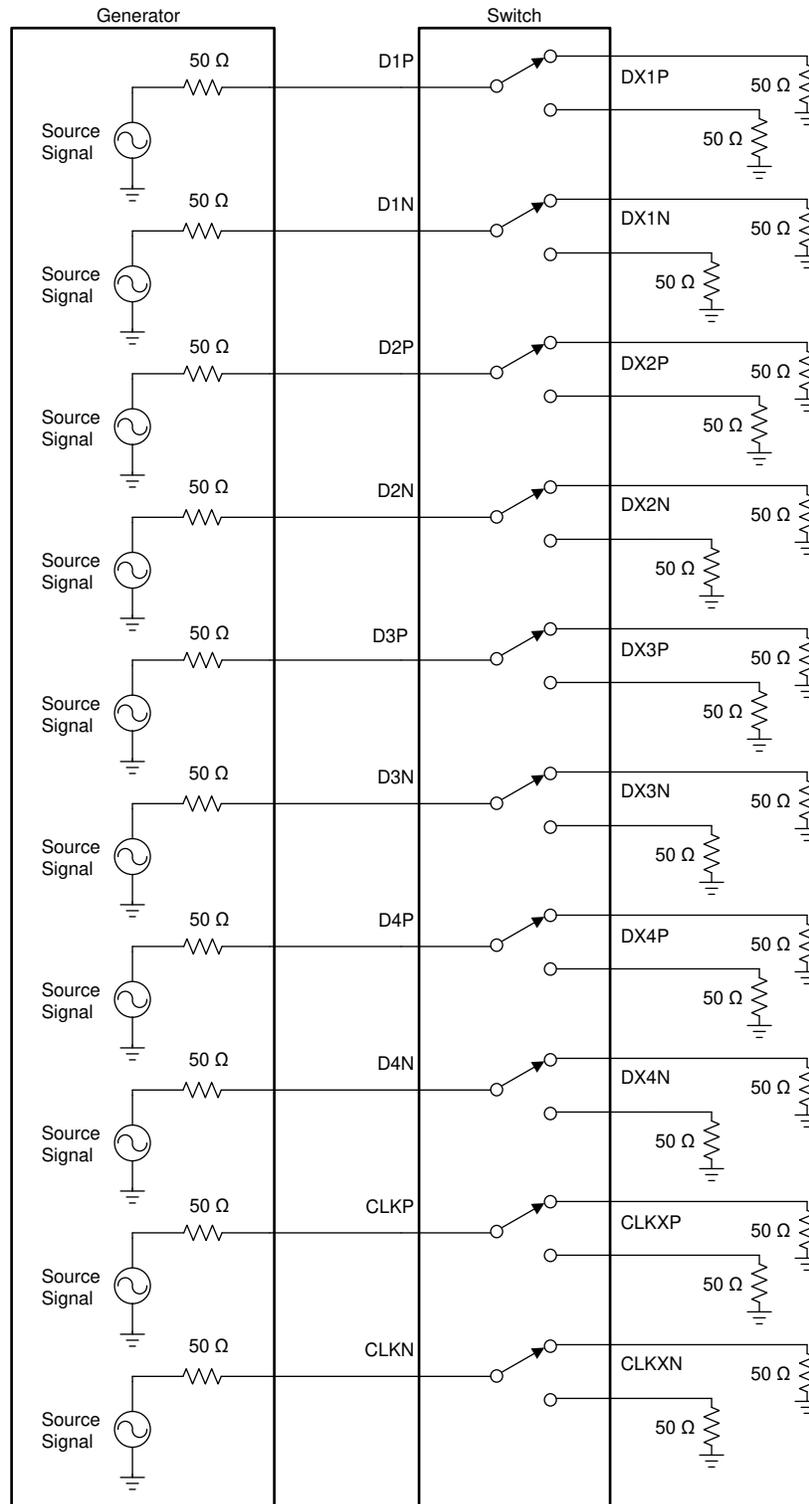
Copyright © 2018, Texas Instruments Incorporated

**Figure 7-7. Crosstalk**



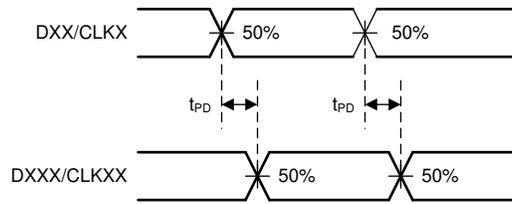
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**Figure 7-8. Bandwidth and Insertion Loss**



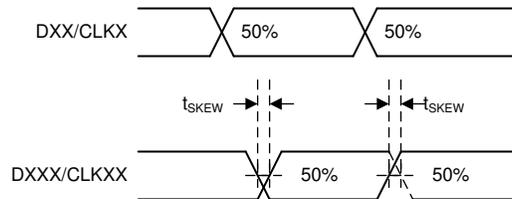
Copyright © 2017, Texas Instruments Incorporated

**Figure 7-9.  $t_{PD}$ ,  $t_{SKEW(INTRA)}$  and  $t_{SKEW(INTER)}$  Setup**



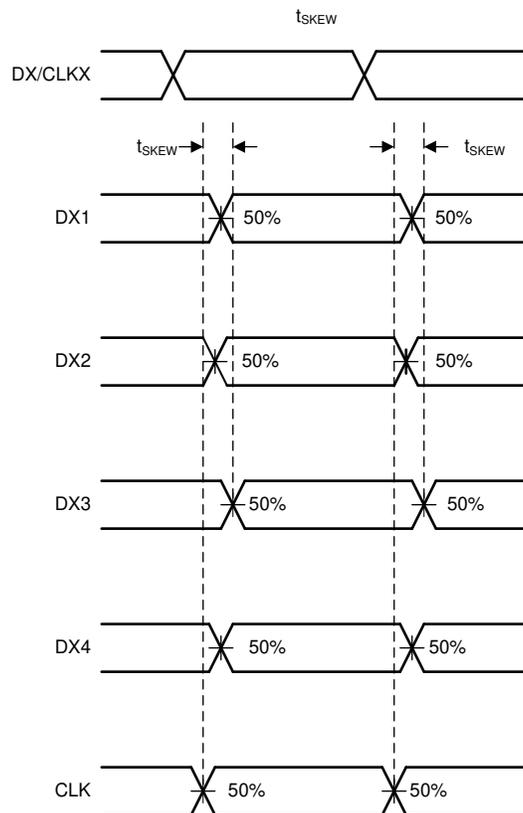
- A. All input pulses are supplied by generators having the following characteristics:  $PRR \leq 10 \text{ MHz}$ ,  $Z_O = 50 \Omega$ ,  $t_r = 100 \text{ ps}$ ,  $t_f = 100 \text{ ps}$ .
- B.  $C_L$  includes probe and jig capacitance.

**Figure 7-10.  $t_{PD}$**



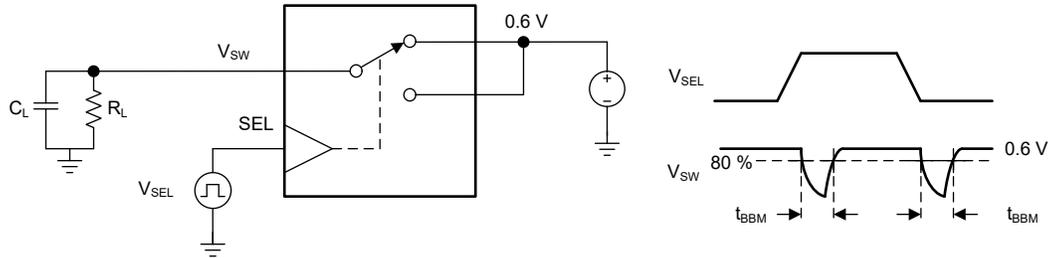
- A. All input pulses are supplied by generators having the following characteristics:  $PRR \leq 10 \text{ MHz}$ ,  $Z_O = 50 \Omega$ ,  $t_r = 100 \text{ ps}$ ,  $t_f = 100 \text{ ps}$ .
- B.  $C_L$  includes probe and jig capacitance.

**Figure 7-11.  $t_{SKEW(INTRA)}$**



- A. All input pulses are supplied by generators having the following characteristics:  $PRR \leq 10 \text{ MHz}$ ,  $Z_O = 50 \Omega$ ,  $t_r = 100 \text{ ps}$ ,  $t_f = 100 \text{ ps}$ .
- B.  $C_L$  includes probe and jig capacitance.
- C.  $t_{SKEW}$  is the maximum skew between all channels. The diagram exaggerates  $t_{SKEW}$  to show the measurement technique.

**Figure 7-12.  $t_{SKEW(INTER)}$**



- A. All input pulses are supplied by generators having the following characteristics: PRR  $\leq$  10 MHz,  $Z_O = 50 \Omega$ ,  $t_r = 3$  ns,  $t_f = 3$  ns.
- B.  $C_L$  includes probe and jig capacitance.

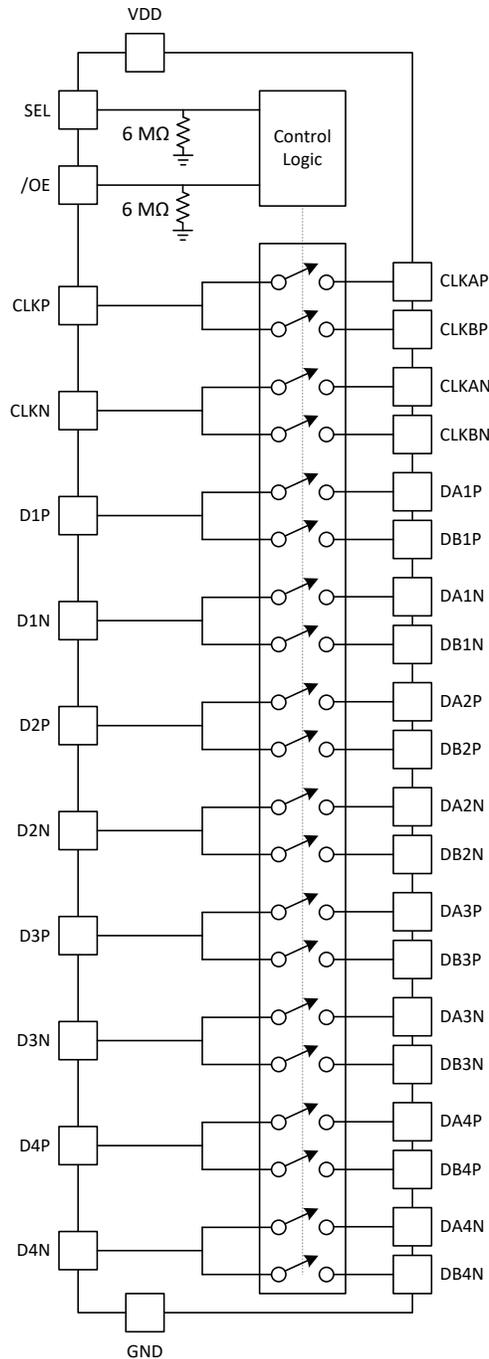
**Figure 7-13.  $t_{BBM}$**

## 8 Detailed Description

### 8.1 Overview

The TMUX646 is a high-speed 4 data lane 2:1 MIPI Switch. The device includes 10 channels (5 differential) with 4 differential data lanes and 1 differential clock lane for D-PHY, CSI or DSI. The clock and data lanes can be interchanged as necessary to facilitate the best layout possible for the application. The switch allows a single MIPI port to interface between two MIPI modules, expanding the number of potential MIPI devices that can be used within a system that is MIPI port limited.

### 8.2 Functional Block Diagram



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## 8.3 Feature Description

### 8.3.1 1.2-V Logic Compatible Inputs

The TMUX646 has 1.2-V logic compatible control inputs. Regardless of the  $V_{DD}$  voltage, the 1.2-V logic level inputs allow the TMUX646 to interface with processors that have lower logic I/O rails and eliminates the need for an external voltage translator, which saves both space and BOM cost. For more information on 1.2 V and 1.8 V logic implementations, refer to [Simplifying Design with 1.8 V logic Muxes and Switches](#).

### 8.3.2 Bidirectional Operation

The TMUX646 conducts equally well from A to COM, B to COM, COM to A, or COM to B. Each channel has very similar characteristics in both directions and supports analog and digital signals.

### 8.3.3 Powered-Off Protection

When the TMUX646 is powered off ( $V_{DD} = 0$  V) the I/Os and digital logic pins of the device remains in a high impedance state. The crosstalk, off-isolation, and leakage will remain within the electrical specifications. This prevents errant voltages from reaching the rest of the system and maintains isolation when the system is powering up:

Figure 8-1 shows an example system containing a switch without powered-off protection with the following system level scenario.

1. Subsystem A powers up and starts sending information to Subsystem B that remains unpowered.
2. The I/O voltage back powers the supply rail in Subsystem B.
3. The digital logic is back powered and turns on the switch. The signal is transmitted to Subsystem B before it is powered and damages it.

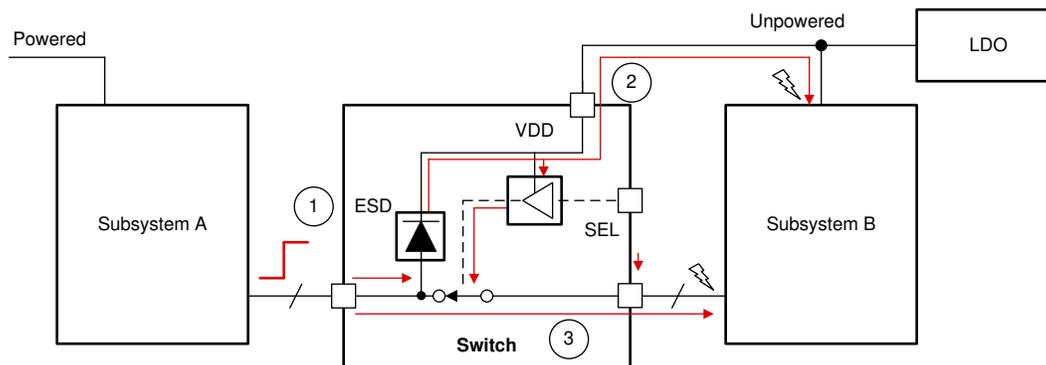


Figure 8-1. System Without Powered-Off Protection

With powered-off protection, the switch prevents back powering the supply and the switch remains high-impedance. Subsystem B remains protected.

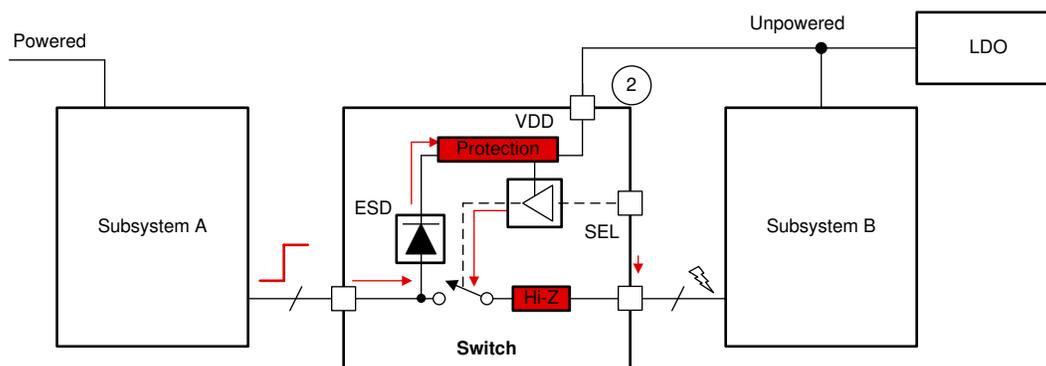


Figure 8-2. System With Powered-Off Protection

This features has the following system level benefits:

- Protects the system from damage.
- Prevents data from being transmitted unintentionally.
- Eliminates the need for power sequencing solutions, reducing BOM count and cost, simplifying system design, and improving reliability.

### 8.3.4 Low Power Disable Mode

The TMUX646 has a low power mode that places all the signal paths in a high impedance state and lowers the current consumption while the device is not in use. To put the device in low power mode and disable the switch, the output enable pin  $\overline{OE}$  must be supplied with a logic high signal.

## 8.4 Device Functional Modes

### 8.4.1 Pin Functions

The SEL and  $\overline{OE}$  pins have a weak 6-M $\Omega$  pull-down to prevent floating input logic.

**Table 8-1. Function Table**

OE	SEL	Function
H	X	I/O pins High-Impedance
L	L	CLK(P/N) = CLKA(P/N)
		Dn(P/N) = DAN(P/N)
L	H	CLK(P/N) = CLKB(P/N)
		Dn(P/N) = DBn(P/N)

### 8.4.2 Low Power Disable Mode

While the output enable pin  $\overline{OE}$  is supplied with a logic high, the device remains in the low power disabled state. This reduces the current consumption substantially and the switches are high impedance. The SEL pin is ignored while the  $\overline{OE}$  remains high. Upon exiting low power mode, the switch status reflects the SEL pin as seen in [Table 8-1](#).

### 8.4.3 Switch Enabled Mode

While the output enable pin  $\overline{OE}$  is supplied with a logic low, the device remains in switch enabled mode.

## 9 Application and Implementation

### Note

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

### 9.1 Application Information

The TMUX646 is a 2:1, 10 channel MIPI switch designed to facilitate multiple MIPI compliant devices to connect to a single CSI/DSI, C-PHY/D-PHY module.

### 9.2 Typical Application

Figure 9-1 represents a typical application of the TMUX646 MIPI switch. The TMUX646 is used to switch signals between multiple MIPI modules and a single MIPI port on a processor. This expands the capabilities of a single port to handle multiple MIPI modules.

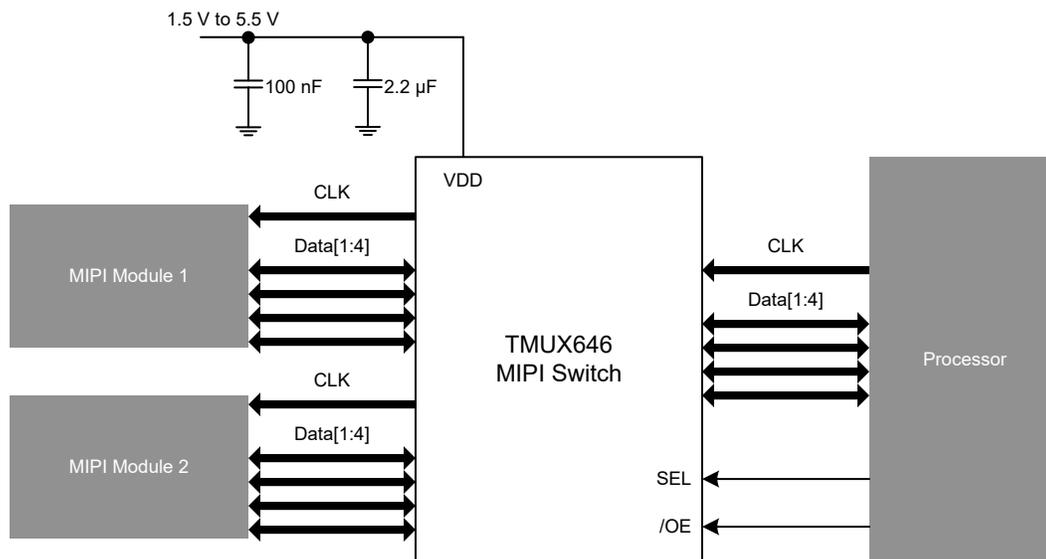
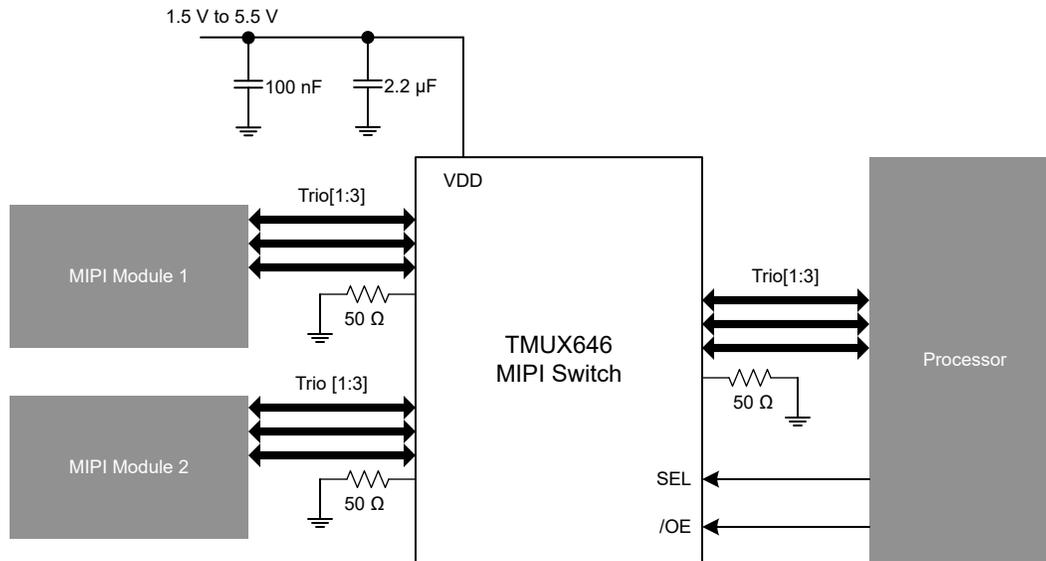


Figure 9-1. Typical D-PHY Application



**Figure 9-2. Typical C-PHY Application**

### 9.2.1 Design Requirements

Design requirements of the MIPI standard must be followed. Supply pin decoupling capacitors of 2.2  $\mu\text{F}$  and 100 nF are recommended for best performance. The TMUX646 has internal 6-M $\Omega$  pull-down resistors on SEL and  $\overline{\text{OE}}$ . The pull-down on these pins ensure that the digital remains in a non-floating state during system power-up to prevent shoot through current spikes and an unknown switch status. By default the switch will power up enabled and with the A path selected until driven externally by the processor.

### 9.2.2 Detailed Design Procedure

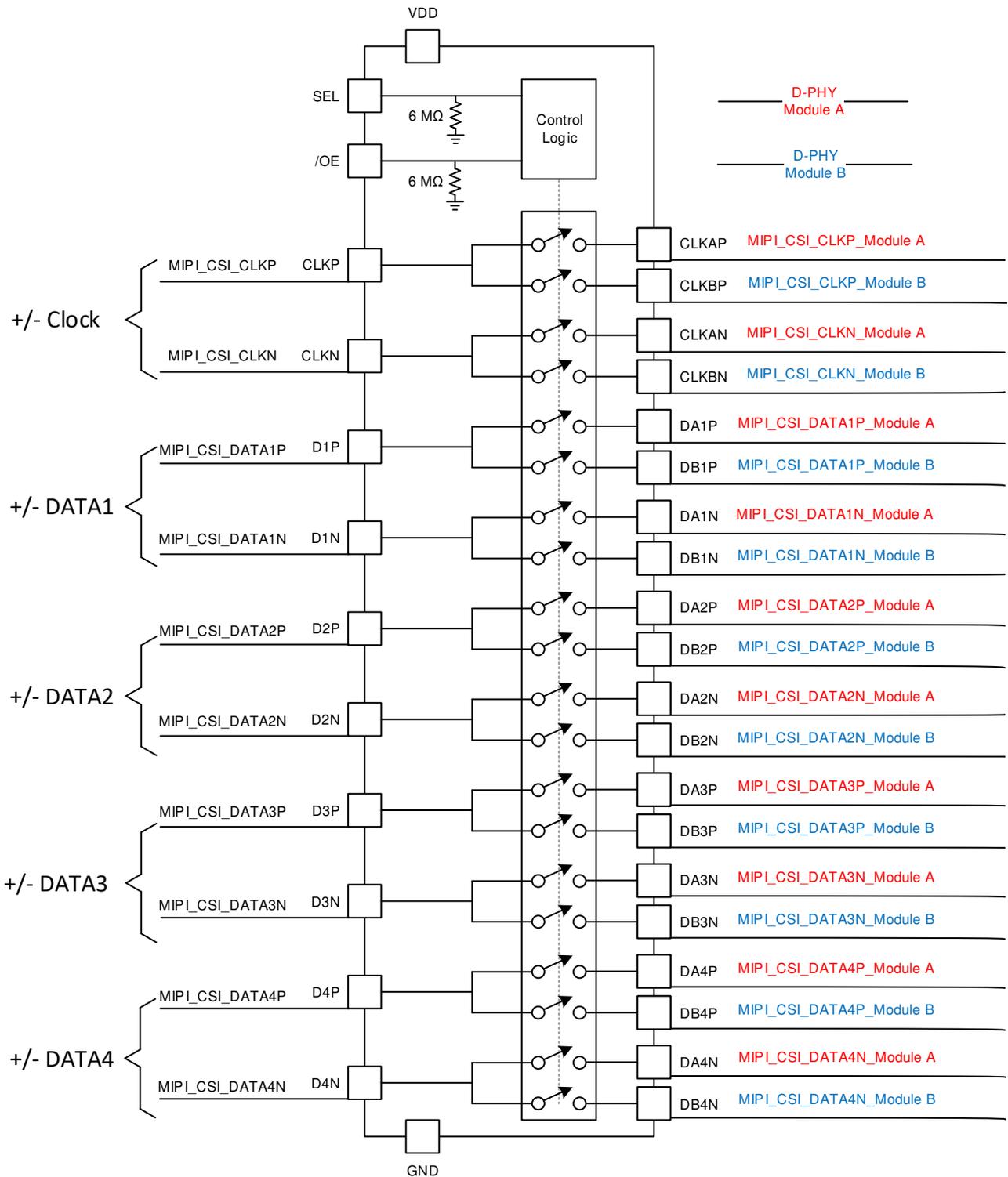
The TMUX646 can be properly operated without any external components. However, TI recommends that unused I/O signal pins be connected to ground through a 50  $\Omega$  resistor to prevent signal reflections and maintain device performance. The NC pins of the device do not require any external connections or terminations and have no connection to the rest of the device internally.

The clock and data lanes can be interchanged as necessary to facilitate the best layout possible for the application. For example, the clock can be placed on the D1 channel and a data lane can be used on the CLK channel if this improves the layout. In addition, the signal lines of the TMUX646 are routed single ended on the chip die. This makes the device suitable for differential and single-ended high-speed systems.

#### 9.2.2.1 MIPI D-PHY Application

The clock and data lanes can be interchanged as necessary to facilitate the best layout possible for the application. In addition, the signal lines of the TMUX646 are routed single ended on the chip die. This makes the device suitable for differential and single-ended high-speed systems. This also allows the positive and negative lines to be interchanged as necessary to facilitate the best layout possible for the application.

D-PHY application includes a differential clock and 4 differential data lanes. All the channels of the device perform similar and the clock or data signals can be interchanged as necessary to facilitate the best layout possible for the application.



**Figure 9-3. MIPI D-PHY Example Pinout**

### **9.2.2.2 MIPI C-PHY Application**

The clock and data lanes can be interchanged as necessary to facilitate the best layout possible for the application. In addition, the signal lines of the TMUX646 are routed single ended on the chip die. This makes the device suitable for differential and single-ended high-speed systems. This also allows the positive and negative lines to be interchanged as necessary to facilitate the best layout possible for the application.

C-PHY application includes 3 trios of signals, which may be routed on any channel, which means there will be one unused channel on the TMUX646. TI recommends that the unused I/O signal pin be connected to ground through a 50  $\Omega$  resistor to prevent signal reflections and maintain device performance.

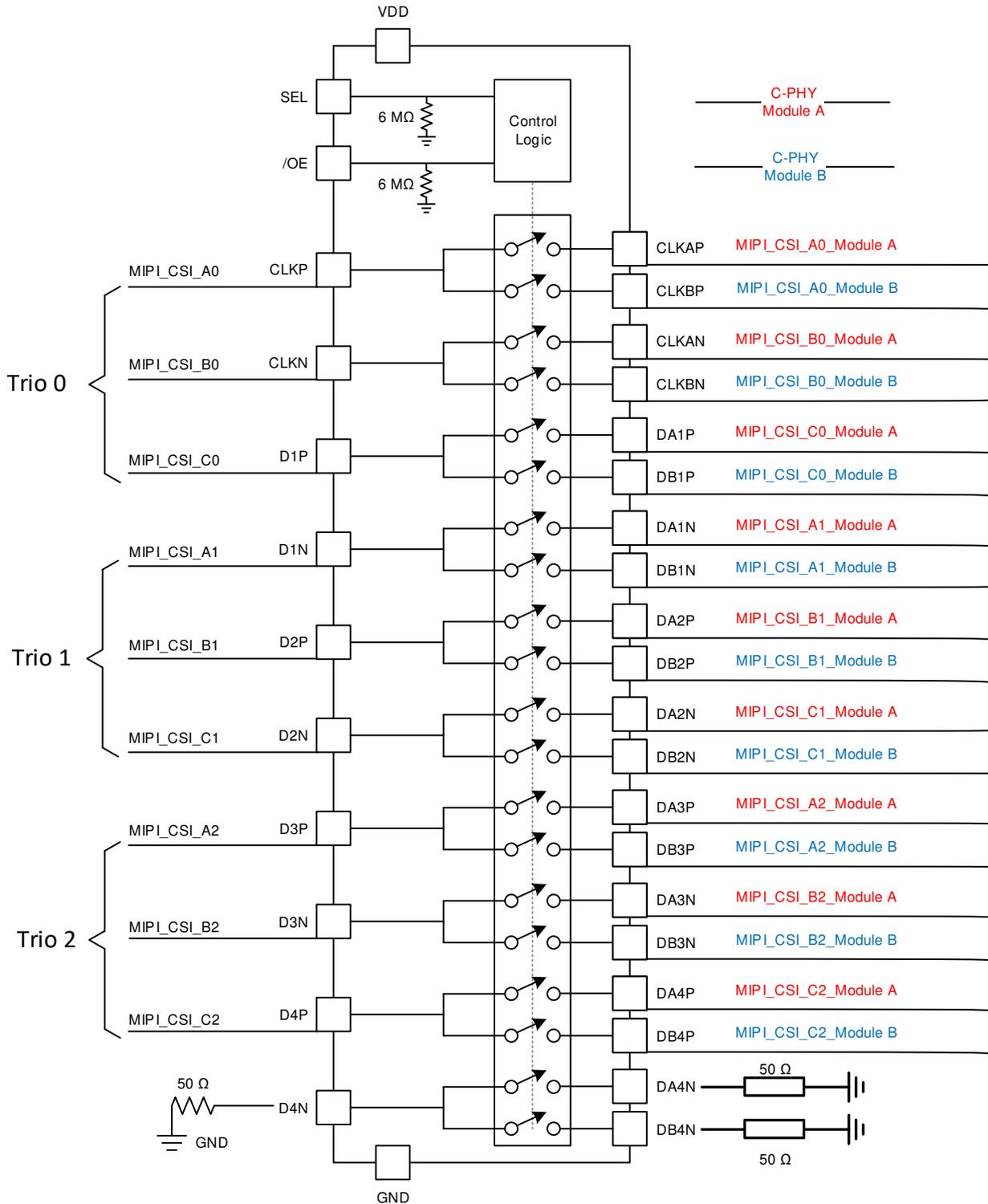


Figure 9-4. MIPI C-PHY Example Pinout

### 9.2.3 Application Curves

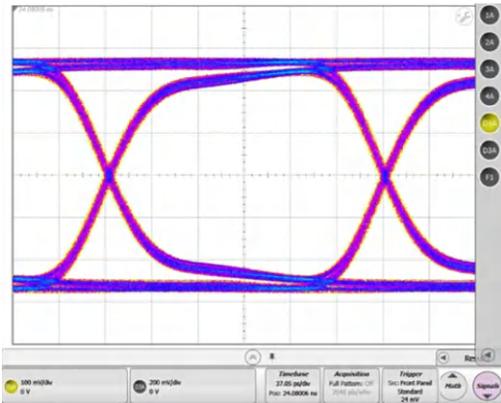


Figure 9-5. 4.5 Gbps Through Path (500-mV<sub>pp</sub>)

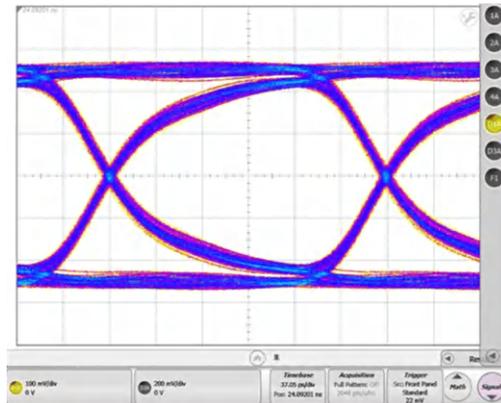


Figure 9-6. 4.5 Gbps with TMUX646 (500-mV<sub>pp</sub>)

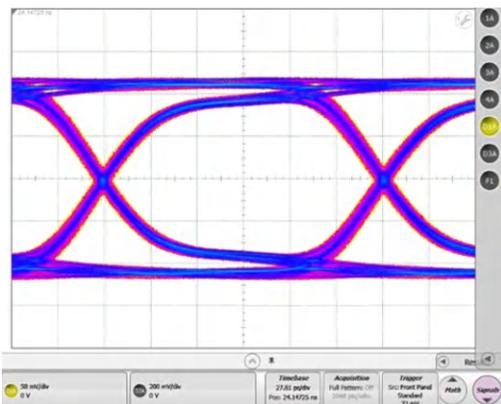


Figure 9-7. 6 Gbps Through Path (200-mV<sub>pp</sub>)

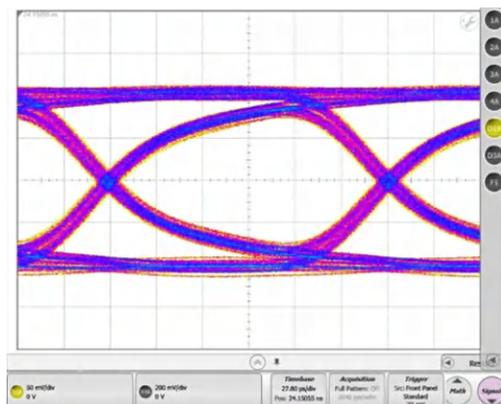


Figure 9-8. 6 Gbps with TMUX646 (200-mV<sub>pp</sub>)

## 10 Power Supply Recommendations

When the TMUX646 is powered off ( $V_{DD} = 0\text{ V}$ ), the I/Os of the device remains in a high-Z state. The crosstalk, off-isolation, and leakage remain within the electrical characteristics [Section 6](#). Power to the device is supplied through the VDD pin. Decoupling capacitors of 100 nF and 2.2  $\mu\text{F}$  are recommended on the supply.

## 11 Layout

### 11.1 Layout Guidelines

Place the supply de-coupling capacitors as close to the VDD and GND pin as possible. The spacing between the power traces, supply and ground, and the signal I/O lines, clock and data, should be a minimum of three times the trace width of the signal I/O lines to maintain signal integrity.

The characteristic impedance of one or more traces must match that of the receiver and transmitter to maintain signal integrity. Route the high-speed traces using a minimum amount of vias and corners. This will reduce the amount of impedance changes.

When it becomes necessary to make the traces turn 90°, use two 45° turns or an arc instead of making a single 90° turn.

Do not route high-speed traces near crystals, oscillators, external clock signals, switching regulators, mounting holes or magnetic devices.

Avoid stubs on the signal lines.

All I/O signal traces should be routed over a continuous ground plane with no interruptions. The minimum width from the edge of the trace to any break in the ground plane must be 3 times the trace width. When routing on PCB inner signal layers, the high speed traces should be between two ground planes and maintain characteristic impedance.

High speed signal traces must be length matched as much as possible to minimize skew between data and clock lines.

### 11.2 Layout Example

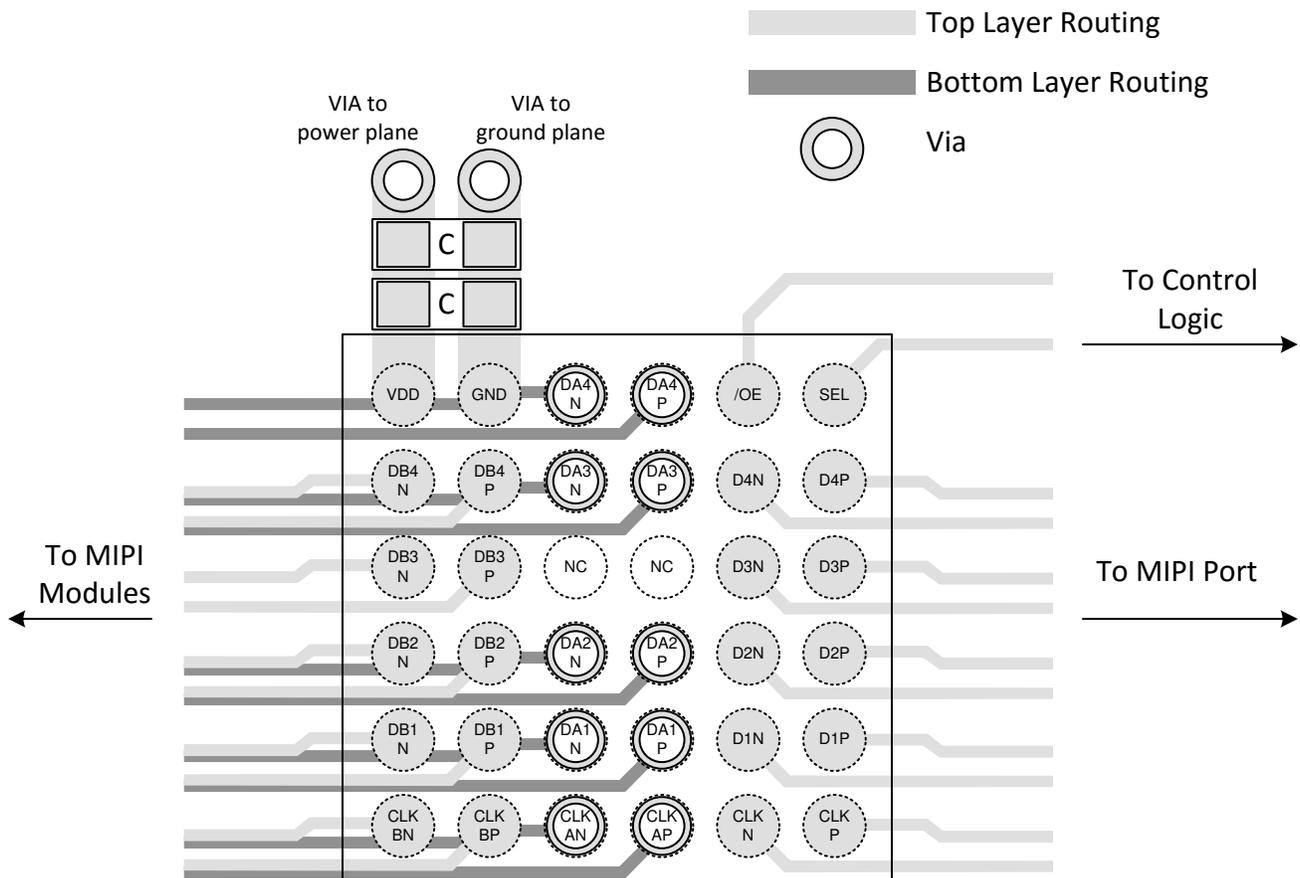


Figure 11-1. Layout Example

## 12 Device and Documentation Support

### 12.1 Documentation Support

#### 12.1.1 Related Documentation

See the following for related documentation:

- Texas Instruments, [1.8 V Logic for Muxes and Signal Switches application brief](#)
- Texas Instruments, [High-Speed Interface Layout Guidelines application report](#)
- Texas Instruments, [High-Speed Layout Guidelines application report](#)
- Texas Instruments, [Multiplexers and Signal Switches Glossary application report](#)
- Texas Instruments, [nFBGA Packaging application report](#)
- Texas Instruments, [Small Body nFBGA Packages application report](#)

#### 12.2 Receiving Notification of Documentation Updates

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

#### 12.3 Support Resources

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

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#### 12.4 Trademarks

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#### 12.5 Electrostatic Discharge Caution



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

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

#### 12.6 Glossary

[TI Glossary](#) This glossary lists and explains terms, acronyms, and definitions.

## 13 Mechanical, Packaging, and Orderable Information

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

**PACKAGING INFORMATION**

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TMUX646NZECR	ACTIVE	NFBGA	ZEC	36	2500	RoHS & Green	SNAGCU	Level-2-260C-1 YEAR	-40 to 85	T646	<a href="#">Samples</a>
TMUX646ZECR	ACTIVE	NFBGA	ZEC	36	2500	RoHS & Green	SNAGCU	Level-2-260C-1 YEAR	-40 to 85	T646	<a href="#">Samples</a>

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

**ACTIVE:** Product device recommended for new designs.

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

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

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

**OBSOLETE:** TI has discontinued the production of the device.

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

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

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

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

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

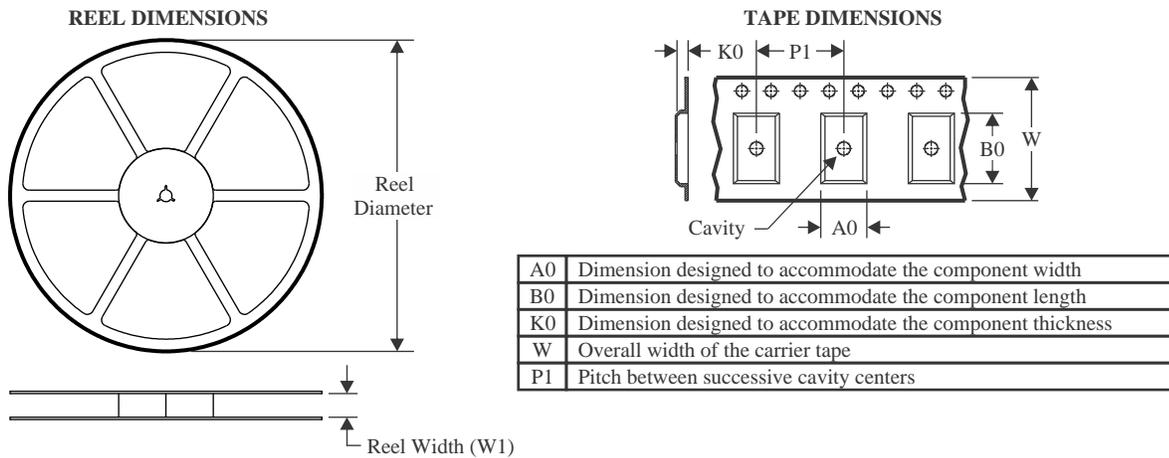
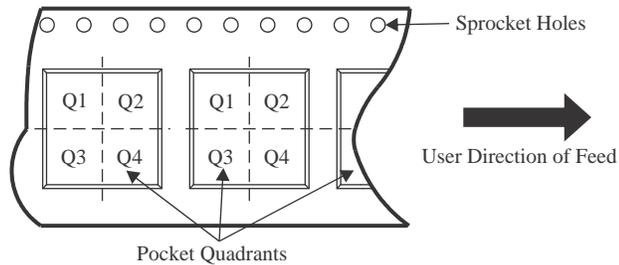
(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices 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.

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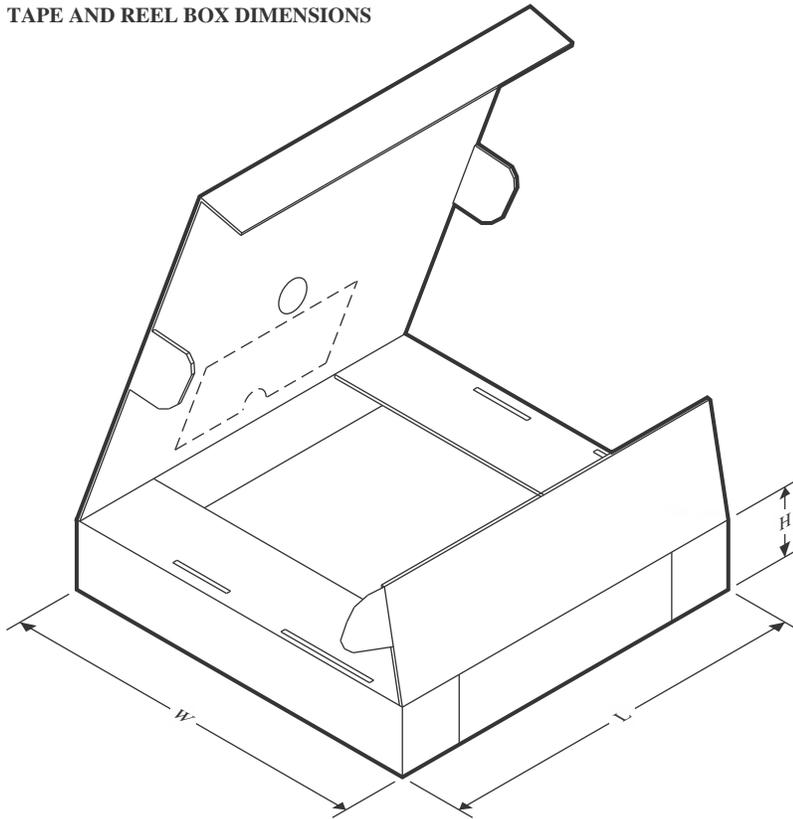
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.



**TAPE AND REEL INFORMATION**

**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**


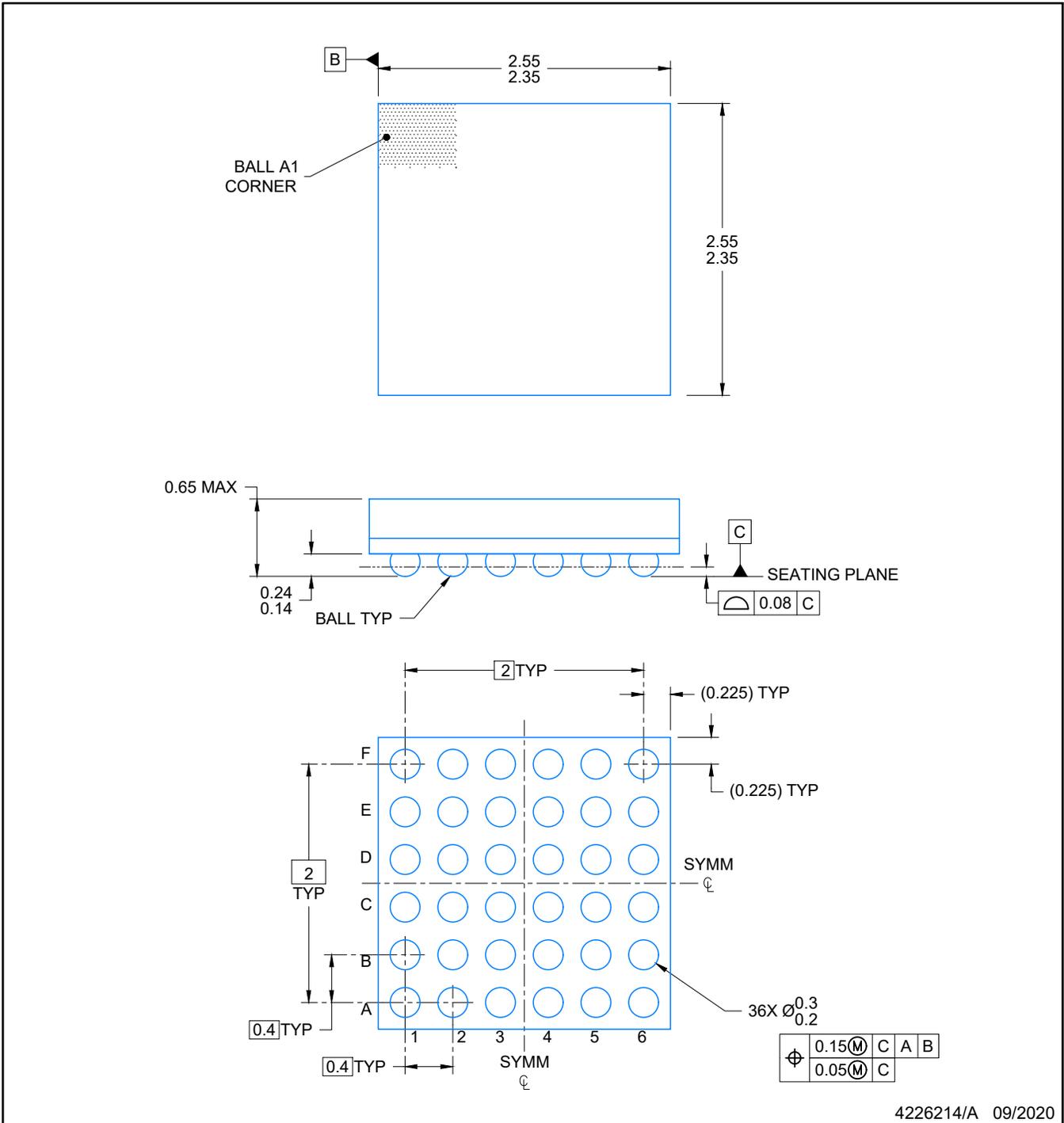
\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TMUX646NZECR	NFBGA	ZEC	36	2500	330.0	8.4	2.62	2.62	0.78	4.0	8.0	Q1
TMUX646ZECR	NFBGA	ZEC	36	2500	330.0	12.4	2.8	2.8	0.8	8.0	12.0	Q1

**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TMUX646NZECR	NFBGA	ZEC	36	2500	338.1	338.1	20.6
TMUX646ZECR	NFBGA	ZEC	36	2500	336.6	336.6	31.8

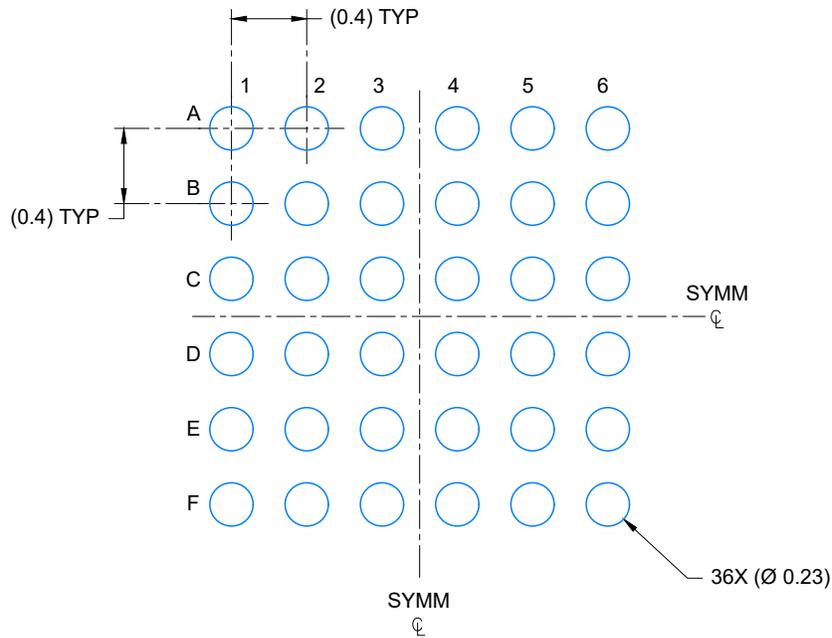


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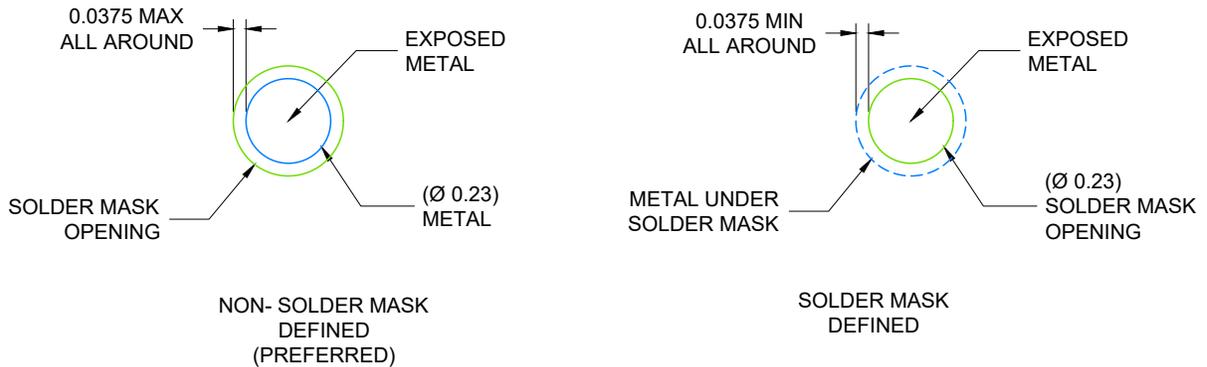
NOTES:

NanoFree is a trademark of Texas Instruments.

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 25X

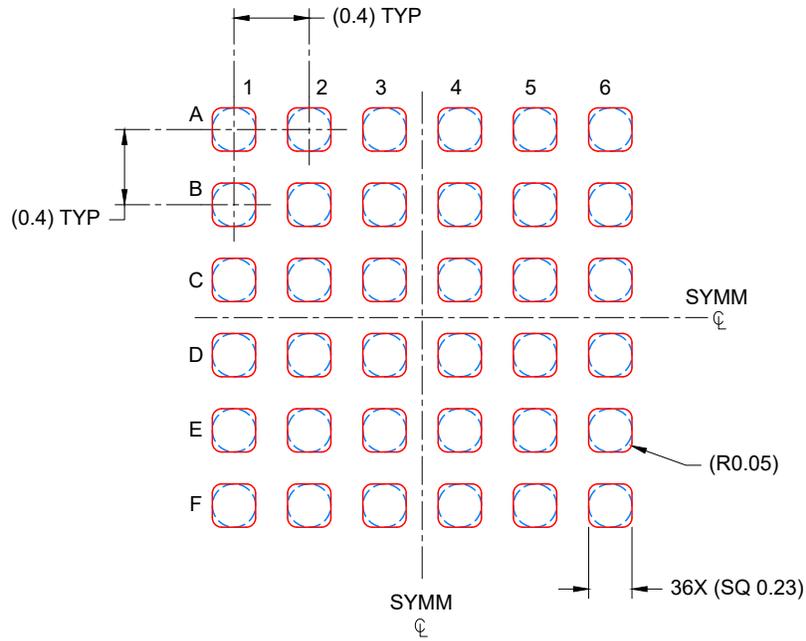


SOLDER MASK DETAILS  
NOT TO SCALE

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NOTES: (continued)

- Final dimensions may vary due to manufacturing tolerance considerations and also routing constraints. Refer to Texas Instruments Literature number SNVA009 ([www.ti.com/lit/snva009](http://www.ti.com/lit/snva009)).



SOLDER PASTE EXAMPLE  
BASED ON 0.100 mm THICK STENCIL  
SCALE: 25X

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NOTES: (continued)

- 4. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release.

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