

# TMUX6136 $\pm 16.5$ -V, Low Capacitance, Low-Leakage-Current, Precision, Dual SPDT Switch

## 1 Features

- Wide supply range:  $\pm 5$  V to  $\pm 16.5$  V (dual) or 10 V to 16.5 V (single)
- Latch-up performance meets 100 mA per JESD78 Class II Level A on all pins
- Low on-capacitance: 5.5 pF
- Low input leakage: 0.5 pA
- Low charge injection:  $-0.4$  pC
- Rail-to-rail operation
- Low on-resistance: 120  $\Omega$
- Fast transition time: 66 ns
- Break-before-make switching action
- SELx pin connectable to  $V_{DD}$  with integrated pull-down
- Logic levels: 2 V to  $V_{DD}$
- Low supply current: 17  $\mu$ A
- Human Body Model (HBM) ESD Protection:  $\pm 2$  kV on all pins
- Industry-standard TSSOP package

## 2 Applications

- [Factory automation and industrial process controls](#)
- Programmable logic controllers (PLC)
- [Analog input modules](#)
- [ATE test equipment](#)
- [Digital multimeters](#)
- [Battery monitoring systems](#)

## 3 Description

The TMUX6136 is a complementary metal-oxide semiconductor (CMOS) analog switch containing two independently selectable SPDT switches. The devices work well with dual supplies ( $\pm 5$  V to  $\pm 16.5$  V), a single supply (10 V to 16.5 V), or asymmetric supplies. The digital select pin (SELx) has transistor-transistor logic (TTL) compatible thresholds, ensuring TTL/CMOS logic compatibility.

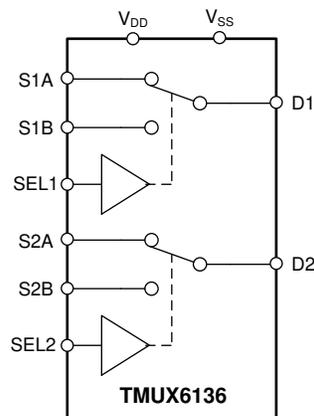
The TMUX6136 switches one of two inputs ( $S_x$ ) to a common output (D), depending on the status of the SELx pins. Each switch conducts equally well in both directions in the ON position and supports input signal range up to the supplies. In the OFF condition, signal levels up to the supplies are blocked. All switches exhibit break-before-make (BBM) switching action.

The TMUX6136 is part of Texas Instruments precision switches and multiplexers family. The device has very low leakage current and charge injection, allowing them to be used in high-precision measurement applications. The device also provides excellent isolation by blocking signal levels up to the supplies when the switches are in the OFF position. Low supply current of 17  $\mu$ A enables usage in portable applications.

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

PART NUMBER	PACKAGE	BODY SIZE (NOM)
TMUX6136	PW (TSSOP, 16)	5.00 mm $\times$ 4.40 mm

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



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### Simplified Schematic



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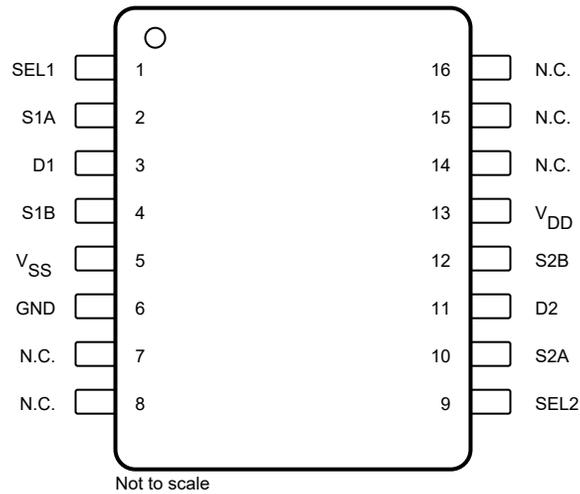
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## 4 Revision History

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

Changes from Revision * (November 2018) to Revision A (October 2022)	Page
• Updated the numbering format for tables, figures, and cross-references throughout the document.....	1
• Updated the <i>Transition-Time Measurement Setup</i> figure .....	13

## 5 Pin Configuration and Functions



**Figure 5-1. PW Package, 16-Pin TSSOP (Top View)**

**Table 5-1. Pin Functions**

PIN		TYPE <sup>(1)</sup>	DESCRIPTION
NAME	NO.		
SEL1	1	I	Select line 0
S1A	2	I/O	Source pin 1A. Can be an input or output.
D1	3	I/O	Drain pin D1. Can be an input or output.
S1B	4	I/O	Source pin 1B. Can be an input or output.
V <sub>SS</sub>	5	P	Negative power supply. This pin is the most negative power-supply potential. In single-supply applications, this pin can be connected to ground. For reliable operation, connect a decoupling capacitor ranging from 0.1 $\mu$ F to 10 $\mu$ F between V <sub>SS</sub> and GND.
GND	6		Ground (0 V) reference
N.C.	7, 8, 14, 15, 16	No Connect	No internal connection
SEL2	9	I	Select line 1
S2A	10	I/O	Source pin 2A. Can be an input or output.
D2	11	I/O	Drain pin D2. Can be an input or output.
S2B	12	I/O	Source pin 2B. Can be an input or output.
V <sub>DD</sub>	13	P	Positive power supply. This pin is the most positive power-supply potential. For reliable operation, connect a decoupling capacitor ranging from 0.1 $\mu$ F to 10 $\mu$ F between V <sub>DD</sub> and GND.

(1) I = input, O = output, P = power

## 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> to V <sub>SS</sub>	Supply voltage		36	V
V <sub>DD</sub> to GND		-0.3	18	V
V <sub>SS</sub> to GND		-18	0.3	V
V <sub>DIG</sub>	Digital input pin (SEL1, SEL2) voltage	GND -0.3	V <sub>DD</sub> +0.3	V
I <sub>DIG</sub>	Digital input pin (SEL1, SEL2) current	-30	30	mA
V <sub>ANA_IN</sub>	Analog input pin (Sx) voltage	V <sub>SS</sub> -0.3	V <sub>DD</sub> +0.3	V
I <sub>ANA_IN</sub>	Analog input pin (Sx) current	-30	30	mA
V <sub>ANA_OUT</sub>	Analog output pin (D) voltage	V <sub>SS</sub> -0.3	V <sub>DD</sub> +0.3	V
I <sub>ANA_OUT</sub>	Analog output pin (D) current	-30	30	mA
T <sub>A</sub>	Ambient temperature	-55	140	°C
T <sub>J</sub>	Junction temperature		150	°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>	±2000	V
		Charged device model (CDM), per JEDEC specification JESD22-C101, all pins <sup>(2)</sup>	±500	

- (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 Thermal Information

THERMAL METRIC <sup>(1)</sup>		TMUX6136	UNIT
		PW (TSSOP)	
		16 PINS	
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	111.0	°C/W
R <sub>θJC(top)</sub>	Junction-to-case (top) thermal resistance	41.7	°C/W
R <sub>θJB</sub>	Junction-to-board thermal resistance	57.2	°C/W
Ψ <sub>JT</sub>	Junction-to-top characterization parameter	4.1	°C/W
Ψ <sub>JB</sub>	Junction-to-board characterization parameter	56.6	°C/W
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.

## 6.4 Recommended Operating Conditions

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

		MIN	NOM	MAX	UNIT
$V_{DD}$ to $V_{SS}$ <sup>(1)</sup>	Power supply voltage differential	10		33	V
$V_{DD}$ to GND	Positive power supply voltage (single supply, $V_{SS} = 0$ V)	10		16.5	V
$V_{DD}$ to GND	Positive power supply voltage (dual supply)	5		16.5	V
$V_{SS}$ to GND	Negative power supply voltage (dual supply)	-16.5		-5	V
$V_S$ <sup>(1)</sup>	Source pins voltage	$V_{SS}$		$V_{DD}$	V
$V_D$	Drain pin voltage	$V_{SS}$		$V_{DD}$	V
$V_{DIG}$	Digital input pin (SEL1, SEL2) voltage	0		$V_{DD}$	V
$I_{CH}$	Channel current ( $T_A = 25^\circ\text{C}$ )	-25		25	mA
$T_A$	Ambient temperature	-40		125	$^\circ\text{C}$

(1)  $V_{DD}$  and  $V_{SS}$  can be any value as long as  $10\text{ V} \leq (V_{DD} - V_{SS}) \leq 33\text{ V}$ .

## 6.5 Electrical Characteristics (Dual Supplies: $\pm 15$ V)

at  $T_A = 25^\circ\text{C}$ ,  $V_{DD} = 15\text{ V}$ , and  $V_{SS} = -15\text{ V}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TEST CONDITIONS	MIN	TYP	MAX	UNIT		
<b>ANALOG SWITCH</b>									
$V_A$	Analog signal range		$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$	$V_{SS}$		$V_{DD}$	V		
$R_{ON}$	On-resistance	$V_S = 0\text{ V}$ , $I_S = 1\text{ mA}$			120	135	$\Omega$		
					140	160	$\Omega$		
		$V_S = \pm 10\text{ V}$ , $I_S = 1\text{ mA}$	$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$		210	$\Omega$			
		$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$			245	$\Omega$			
$\Delta R_{ON}$	On-resistance mismatch between channels	$V_S = \pm 10\text{ V}$ , $I_S = 1\text{ mA}$			2.5	6	$\Omega$		
			$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$			9	$\Omega$		
			$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$			11	$\Omega$		
$R_{ON\_FLAT}$	On-resistance flatness	$V_S = -10\text{ V}$ , $0\text{ V}$ , $+10\text{ V}$ , $I_S = 1\text{ mA}$			23	33	$\Omega$		
			$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$			35	$\Omega$		
			$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$			37	$\Omega$		
$R_{ON\_DRIFT}$	On-resistance drift	$V_S = 0\text{ V}$			0.42		$\%/^\circ\text{C}$		
$I_{S(OFF)}$	Source off leakage current <sup>(1)</sup>	Switch state is off, $V_S = +10\text{ V}/-10\text{ V}$ , $V_D = -10\text{ V}/+10\text{ V}$			-0.05	0.005	0.05	nA	
			$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$			-0.17		0.1	nA
			$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$			-1		0.25	nA
$I_{D(ON)}$	Drain on leakage current	Switch state is on, $V_S = +10\text{ V}/-10\text{ V}$ , $V_D = -10\text{ V}/+10\text{ V}$			-0.06	0.008	0.06	nA	
			$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$			-0.25		0.15	nA
			$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$			-1.6		0.4	nA
<b>DIGITAL INPUT (SELx pins)</b>									
$V_{IH}$	Logic voltage high			2			V		
$V_{IL}$	Logic voltage low					0.8	V		

## 6.5 Electrical Characteristics (Dual Supplies: ±15 V) (continued)

 at  $T_A = 25^\circ\text{C}$ ,  $V_{DD} = 15\text{ V}$ , and  $V_{SS} = -15\text{ V}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$R_{PD(SELx)}$	Pull-down resistance on SELx pins				6		$\text{M}\Omega$
<b>POWER SUPPLY</b>							
$I_{DD}$	$V_{DD}$ supply current	$V_A = 0\text{ V}$ or $3.3\text{ V}$ , $V_S = 0\text{ V}$	$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$		17	21	$\mu\text{A}$
			$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$			22	$\mu\text{A}$
			$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$			23	$\mu\text{A}$
$I_{SS}$	$V_{SS}$ supply current	$V_A = 0\text{ V}$ or $3.3\text{ V}$ , $V_S = 0\text{ V}$	$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$		8	10	$\mu\text{A}$
			$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$			11	$\mu\text{A}$
			$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$			12	$\mu\text{A}$

 (1) When  $V_S$  is positive,  $V_D$  is negative, and vice versa.

## 6.6 Switching Characteristics (Dual Supplies: ±15 V)

 at  $T_A = 25^\circ\text{C}$ ,  $V_{DD} = 15\text{ V}$ , and  $V_{SS} = -15\text{ V}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{\text{TRAN}}$	Transition time	$V_S = 10\text{ V}$ , $R_L = 300\ \Omega$ , $C_L = 35\text{ pF}$		66	78	ns
		$V_S = 10\text{ V}$ , $R_L = 300\ \Omega$ , $C_L = 35\text{ pF}$ , $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$			107	ns
		$V_S = 10\text{ V}$ , $R_L = 300\ \Omega$ , $C_L = 35\text{ pF}$ , $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$			117	ns
$t_{\text{BBM}}$	Break-before-make time delay	$V_S = 10\text{ V}$ , $R_L = 300\ \Omega$ , $C_L = 35\text{ pF}$ , $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$	20	40		ns
$Q_J$	Charge injection	$V_S = 0\text{ V}$ , $R_S = 0\ \Omega$ , $C_L = 1\text{ nF}$		-0.4		pC
$O_{\text{ISO}}$	Off-isolation	$R_L = 50\ \Omega$ , $C_L = 5\text{ pF}$ , $f = 1\text{ MHz}$		-85		dB
$X_{\text{TALK}}$	Channel-to-channel crosstalk	$R_L = 50\ \Omega$ , $C_L = 5\text{ pF}$ , $f = 1\text{ MHz}$ (Inter-channel: S1x and S2x)		-105		dB
		$R_L = 50\ \Omega$ , $C_L = 5\text{ pF}$ , $f = 1\text{ MHz}$ (Intra-channel: SxA and SxB)		-92		dB
$I_L$	Insertion loss	$R_L = 50\ \Omega$ , $C_L = 5\text{ pF}$ , $f = 1\text{ MHz}$		-7		dB
ACPSRR	AC Power Supply Rejection Ratio	$R_L = 10\text{ k}\Omega$ , $C_L = 5\text{ pF}$ , $V_{PP} = 0.62\text{ V}$ on $V_{DD}$ , $f = 1\text{ MHz}$		-59		dB
		$R_L = 10\text{ k}\Omega$ , $C_L = 5\text{ pF}$ , $V_{PP} = 0.62\text{ V}$ on $V_{SS}$ , $f = 1\text{ MHz}$		-59		dB
BW	-3dB Bandwidth	$R_L = 50\ \Omega$ , $C_L = 5\text{ pF}$		670		MHz
THD	Total harmonic distortion + noise	$R_L = 10\text{ k}\Omega$ , $C_L = 5\text{ pF}$ , $f = 20\text{ Hz}$ to $20\text{ kHz}$		0.08		%
$C_{\text{IN}}$	Digital input capacitance	$V_{\text{IN}} = 0\text{ V}$ or $V_{DD}$		1.5		pF
$C_{\text{S(OFF)}}$	Source off-capacitance	$V_S = 0\text{ V}$ , $f = 1\text{ MHz}$		2.4	3.3	pF
$C_{\text{S(ON)}}$ , $C_{\text{D(ON)}}$	Source and drain on-capacitance	$V_S = 0\text{ V}$ , $f = 1\text{ MHz}$		5.5	7.5	pF

## 6.7 Electrical Characteristics (Single Supply: 12 V)

at  $T_A = 25^\circ\text{C}$ ,  $V_{DD} = 12\text{ V}$ , and  $V_{SS} = 0\text{ V}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT		
<b>ANALOG SWITCH</b>								
$V_A$	Analog signal range		$V_{SS}$		$V_{DD}$	V		
$R_{ON}$	On-resistance	$V_S = 10\text{ V}$ , $I_S = 1\text{ mA}$		235	345	$\Omega$		
			$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$			400	$\Omega$	
			$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$			440	$\Omega$	
$\Delta R_{ON}$	On-resistance mismatch between channels	$V_S = 10\text{ V}$ , $I_S = 1\text{ mA}$		4	12	$\Omega$		
			$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$			19	$\Omega$	
			$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$			23	$\Omega$	
$R_{ON\_DRIFT}$	On-resistance drift	$V_S = 0\text{ V}$		0.47		%/ $^\circ\text{C}$		
$I_{S(OFF)}$	Source off leakage current <sup>(1)</sup>	Switch state is off, $V_S = 10\text{ V}$ / $1\text{ V}$ , $V_D = 1\text{ V}$ / $10\text{ V}$		-0.03	0.005	0.03	nA	
			$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$		-0.1		0.07	nA
			$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$		-0.8		0.2	nA
$I_{D(ON)}$	Drain on leakage current	Switch state is on, $V_S =$ floating, $V_D = 1\text{ V}$ / $10\text{ V}$		-0.04	0.01	0.04	nA	
			$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$		-0.16		0.09	nA
			$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$		-1.2		0.3	nA
<b>DIGITAL INPUT (SELx pins)</b>								
$V_{IH}$	Logic voltage high		2			V		
$V_{IL}$	Logic voltage low				0.8	V		
$R_{PD(SELx)}$	Pull-down resistance on SELx pins			6		M $\Omega$		
<b>POWER SUPPLY</b>								
$I_{DD}$	$V_{DD}$ supply current	$V_A = 0\text{ V}$ or $3.3\text{ V}$ , $V_S = 0\text{ V}$		13	16	$\mu\text{A}$		
			$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$			17	$\mu\text{A}$	
			$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$			18	$\mu\text{A}$	

(1) When  $V_S$  is positive,  $V_D$  is negative, and vice versa.

## 6.8 Switching Characteristics (Single Supply: 12 V)

at  $T_A = 25^\circ\text{C}$ ,  $V_{DD} = 12\text{ V}$ , and  $V_{SS} = 0\text{ V}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{TRAN}$	Transition time	$V_S = 8\text{ V}$ , $R_L = 300\ \Omega$ , $C_L = 35\text{ pF}$		72	84	ns
		$V_S = 8\text{ V}$ , $R_L = 300\ \Omega$ , $C_L = 35\text{ pF}$ , $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$			117	ns
		$V_S = 8\text{ V}$ , $R_L = 300\ \Omega$ , $C_L = 35\text{ pF}$ , $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$			128	ns
$t_{BBM}$	Break-before-make time delay	$V_S = 8\text{ V}$ , $R_L = 300\ \Omega$ , $C_L = 35\text{ pF}$ , $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$	20	40		ns
$Q_J$	Charge injection	$V_S = 6\text{ V}$ , $R_S = 0\ \Omega$ , $C_L = 1\text{ nF}$		-0.7		pC
$O_{ISO}$	Off-isolation	$R_L = 50\ \Omega$ , $C_L = 5\text{ pF}$ , $f = 1\text{ MHz}$		-85		dB
$X_{TALK}$	Channel-to-channel crosstalk	$R_L = 50\ \Omega$ , $C_L = 5\text{ pF}$ , $f = 1\text{ MHz}$ (Inter-channel: S1x and S2x)		-110		dB
		$R_L = 50\ \Omega$ , $C_L = 5\text{ pF}$ , $f = 1\text{ MHz}$ (Intra-channel: SxA and SxB)		-95		dB
$I_L$	Insertion loss	$R_L = 50\ \Omega$ , $C_L = 5\text{ pF}$ , $f = 1\text{ MHz}$		-13		dB
ACPSRR	AC Power Supply Rejection Ratio	$R_L = 10\text{ k}\Omega$ , $C_L = 5\text{ pF}$ , $V_{PP} = 0.62\text{ V}$ , $f = 1\text{ MHz}$		-58		dB
BW	-3dB Bandwidth	$R_L = 50\ \Omega$ , $C_L = 5\text{ pF}$		650		MHz

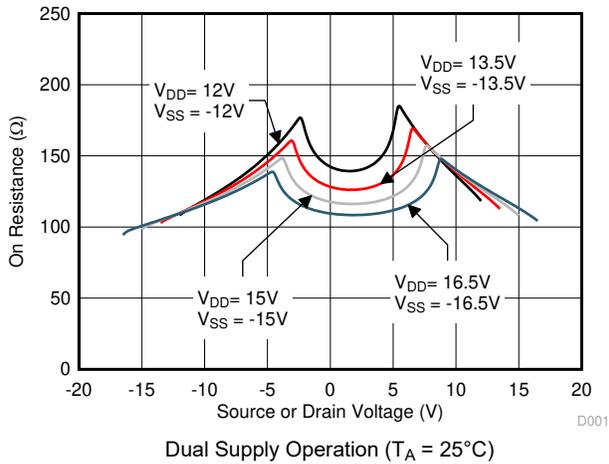
## 6.8 Switching Characteristics (Single Supply: 12 V) (continued)

at  $T_A = 25^\circ\text{C}$ ,  $V_{DD} = 12\text{ V}$ , and  $V_{SS} = 0\text{ V}$  (unless otherwise noted)

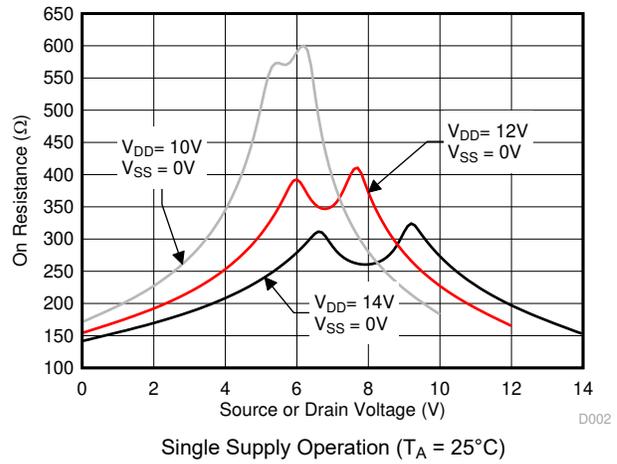
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$C_{IN}$	Digital input capacitance	$V_{IN} = 0\text{ V}$ or $V_{DD}$		1.7		pF
$C_{S(OFF)}$	Source off-capacitance	$V_S = 6\text{ V}$ , $f = 1\text{ MHz}$		2.6	3.7	pF
$C_{S(ON)}$ , $C_{D(ON)}$	Source and drain on-capacitance	$V_S = 6\text{ V}$ , $f = 1\text{ MHz}$		6.3	8.5	pF

## Typical Characteristics

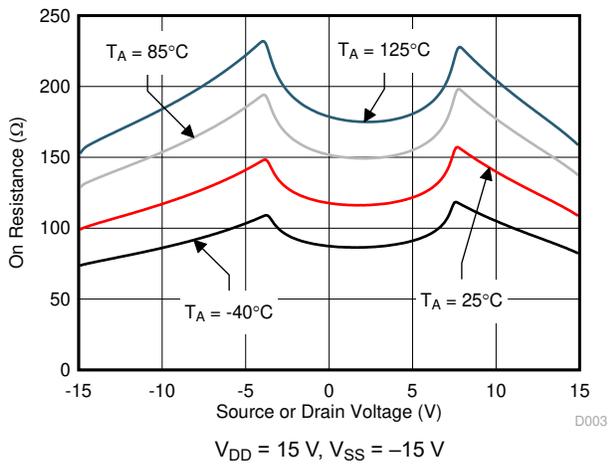
at  $T_A = 25^\circ\text{C}$ ,  $V_{DD} = 15\text{ V}$ , and  $V_{SS} = -15\text{ V}$  (unless otherwise noted)



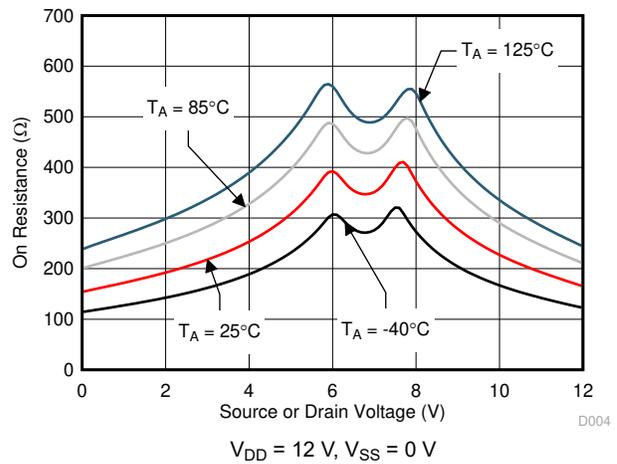
Dual Supply Operation ( $T_A = 25^\circ\text{C}$ )  
**Figure 6-1. On-Resistance vs Source or Drain Voltage**



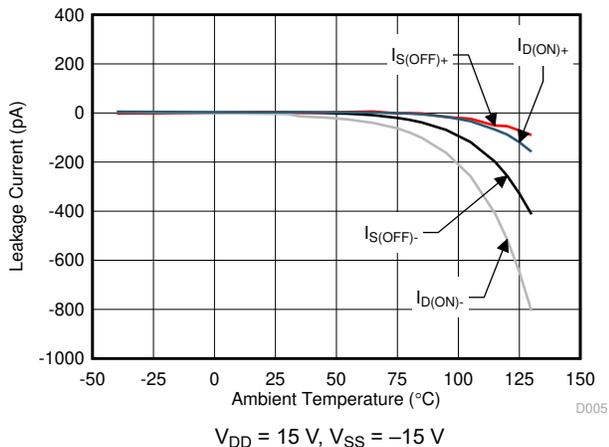
Single Supply Operation ( $T_A = 25^\circ\text{C}$ )  
**Figure 6-2. On-Resistance vs Source or Drain Voltage**



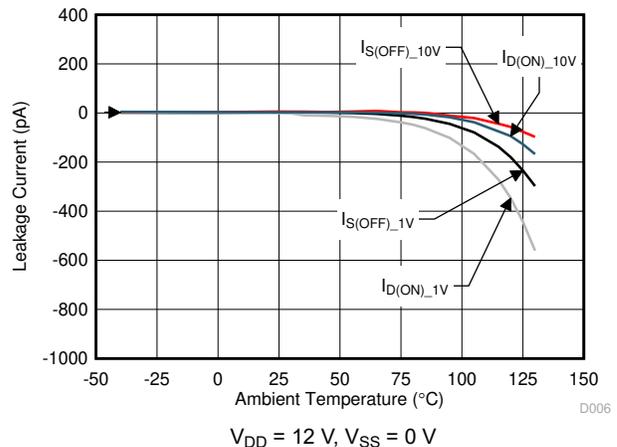
$V_{DD} = 15\text{ V}$ ,  $V_{SS} = -15\text{ V}$   
**Figure 6-3. On-Resistance vs Source or Drain Voltage**



$V_{DD} = 12\text{ V}$ ,  $V_{SS} = 0\text{ V}$   
**Figure 6-4. On-Resistance vs Source or Drain Voltage**



$V_{DD} = 15\text{ V}$ ,  $V_{SS} = -15\text{ V}$   
**Figure 6-5. Leakage Current vs Temperature**



$V_{DD} = 12\text{ V}$ ,  $V_{SS} = 0\text{ V}$   
**Figure 6-6. Leakage Current vs Temperature**

## Typical Characteristics

at  $T_A = 25^\circ\text{C}$ ,  $V_{DD} = 15\text{ V}$ , and  $V_{SS} = -15\text{ V}$  (unless otherwise noted)

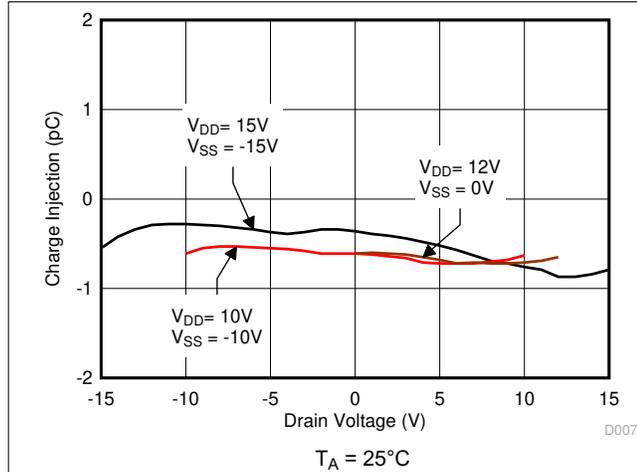


Figure 6-7. Charge Injection vs Source Voltage

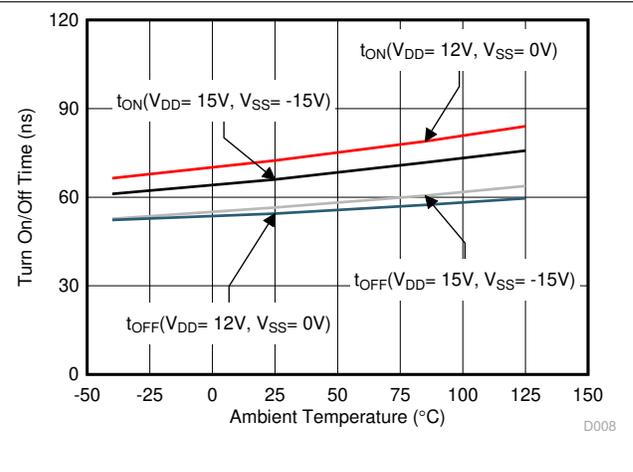


Figure 6-8. Transition Times vs Temperature

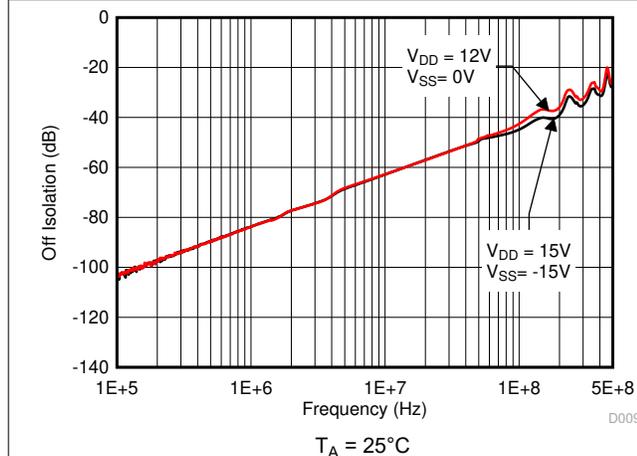


Figure 6-9. Off Isolation vs Frequency

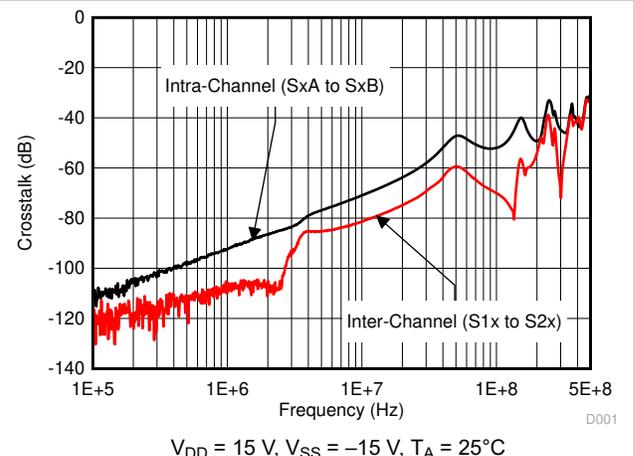


Figure 6-10. Crosstalk vs Frequency

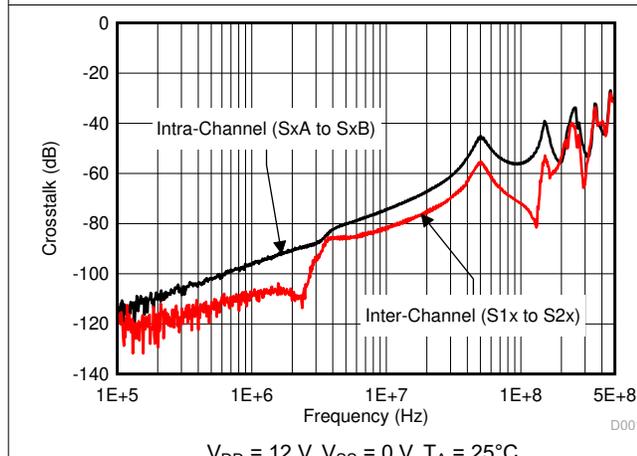


Figure 6-11. Crosstalk vs Frequency

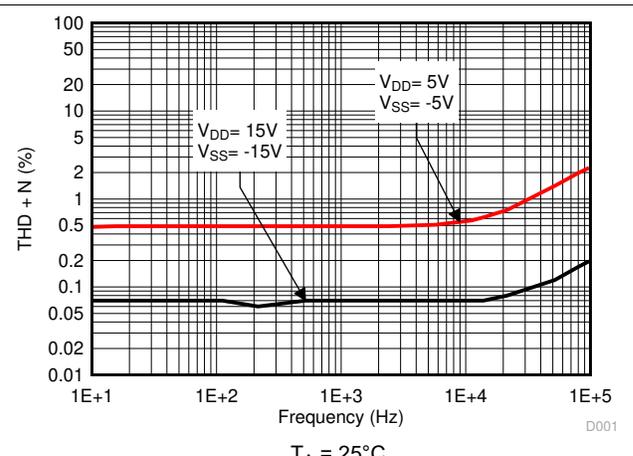
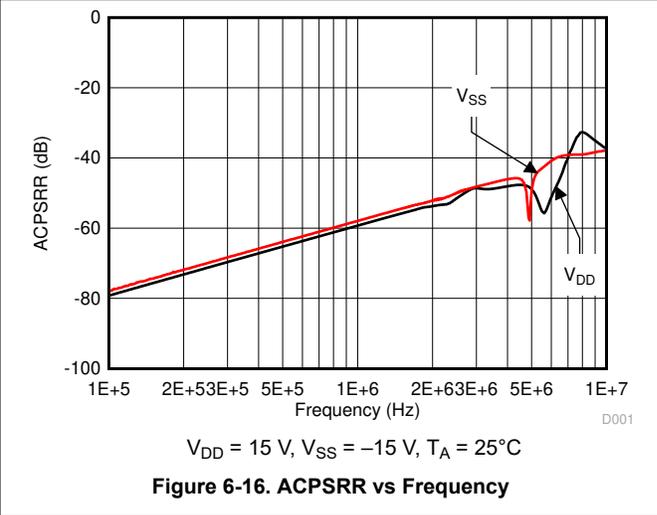
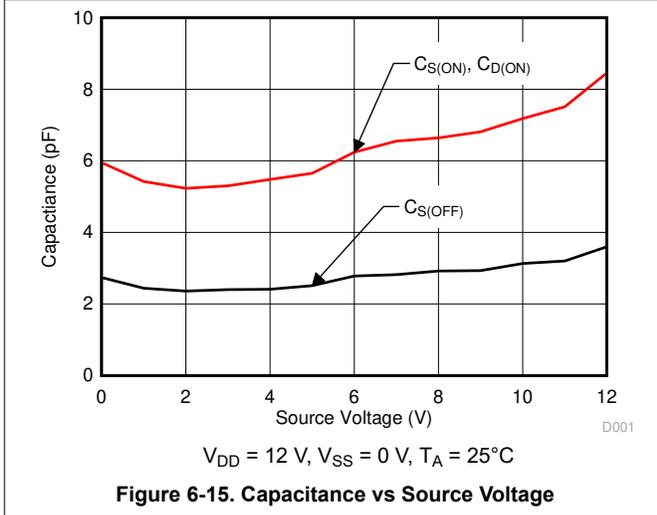
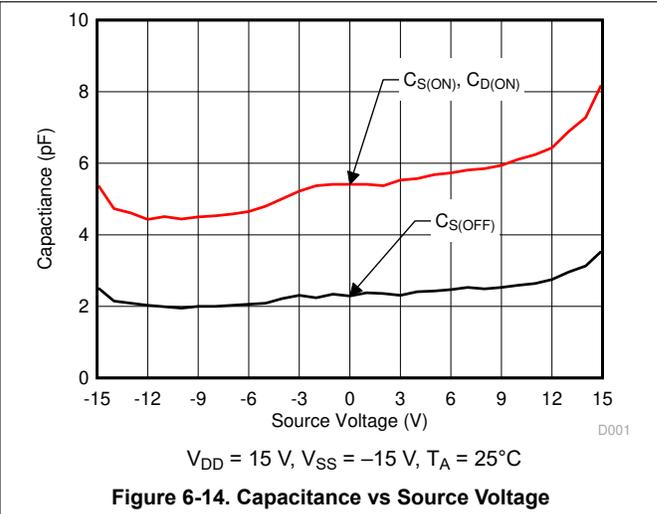
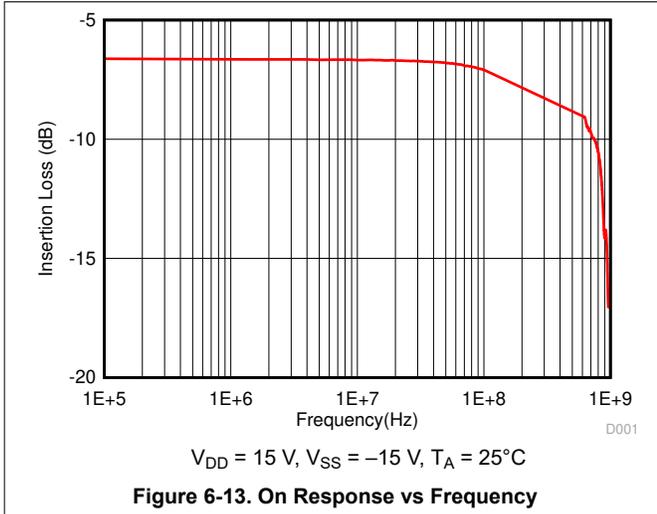


Figure 6-12. THD+N vs Frequency

### Typical Characteristics

at  $T_A = 25^\circ\text{C}$ ,  $V_{DD} = 15\text{ V}$ , and  $V_{SS} = -15\text{ V}$  (unless otherwise noted)



## 7 Detailed Description

### 7.1 Overview

#### 7.1.1 On-Resistance

The on-resistance of the TMUX6136 is the ohmic resistance across the source (Sx) and drain (D) pins of the device. The on-resistance varies with input voltage and supply voltage. The symbol  $R_{ON}$  is used to denote on-resistance. The measurement setup used to measure  $R_{ON}$  is shown in Figure 7-1. Voltage (V) and current ( $I_{CH}$ ) are measured using this setup, and  $R_{ON}$  is computed as shown in Equation 1.

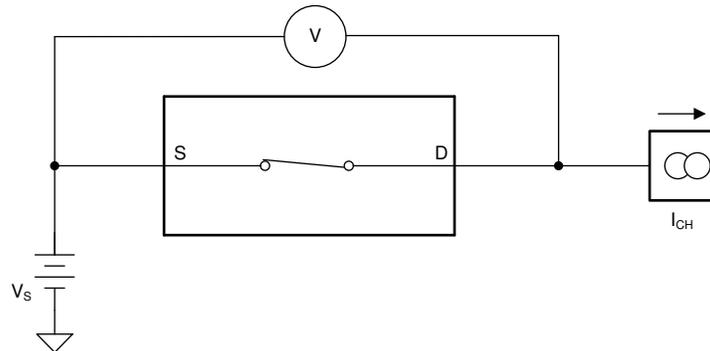


Figure 7-1. On-Resistance Measurement Setup

$$R_{ON} = V / I_{CH} \quad (1)$$

#### 7.1.2 Off-Leakage Current

Source off-leakage current is defined as the leakage current that flows into or out of the source pin when the switch is in the off state. This current is denoted by the symbol  $I_{S(OFF)}$ . Drain off-leakage measurement is not characterization since the drain pin is always connected to one of the two source pins.

The setup used to measure both off-leakage currents is shown in Figure 7-2.

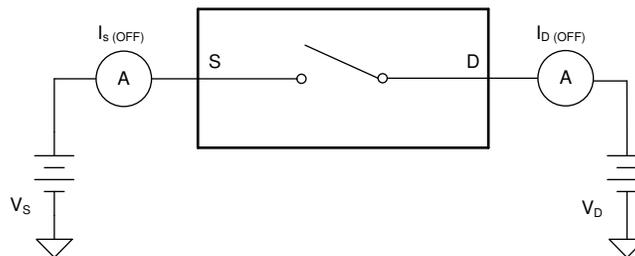
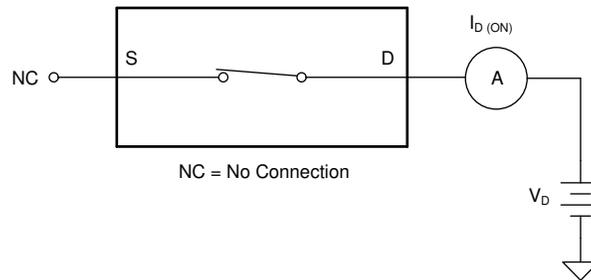


Figure 7-2. Off-Leakage Measurement Setup

### 7.1.3 On-Leakage Current

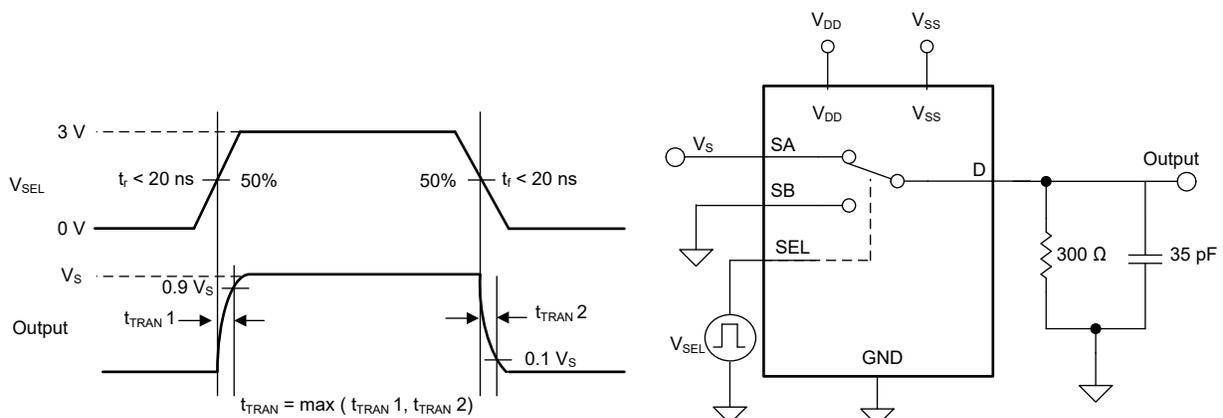
On-leakage current is defined as the leakage current that flows into or out of the drain pin when the switch is in the on state. The source pin is left floating during the measurement. Figure 7-3 shows the circuit used for measuring the on-leakage current, denoted by  $I_{D(ON)}$ .



**Figure 7-3. On-Leakage Measurement Setup**

### 7.1.4 Transition Time

Transition time is defined as the time taken by the output of the TMUX6136 to rise or fall to 90% of the transition after the digital address signal has fallen or risen to 50% of the transition. Figure 7-4 shows the setup used to measure transition time, denoted by the symbol  $t_{TRAN}$ .



**Figure 7-4. Transition-Time Measurement Setup**

### 7.1.5 Break-Before-Make Delay

Break-before-make delay is a safety feature that prevents two inputs from connecting when the TMUX6136 is switching. The TMUX6136 output first breaks from the on-state switch before making the connection with the next on-state switch. The time delay between the *break* and the *make* is known as break-before-make delay. Figure 7-5 shows the setup used to measure break-before-make delay, denoted by the symbol  $t_{BBM}$ .

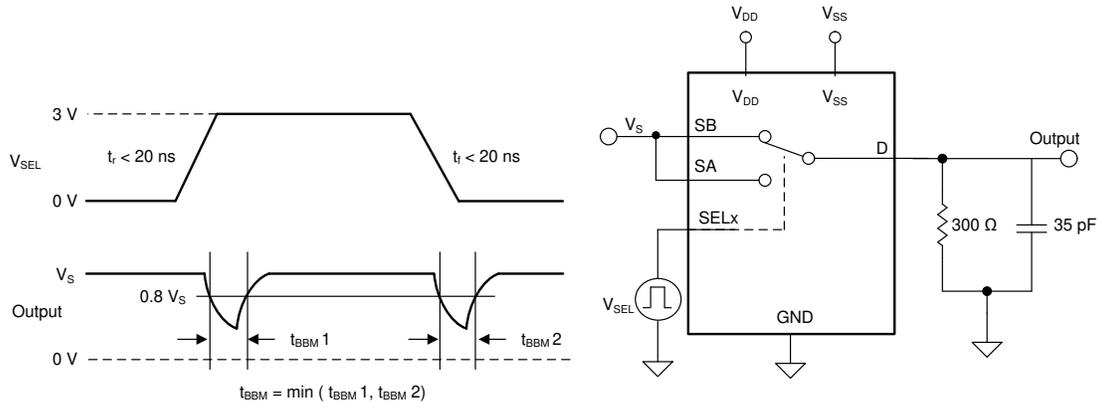


Figure 7-5. Break-Before-Make Delay Measurement Setup

### 7.1.6 Charge Injection

The TMUX6136 have a simple transmission-gate topology. Any mismatch in capacitance between the NMOS and PMOS transistors results in a charge injected into the drain or source during the falling or rising edge of the gate signal. The amount of charge injected into the source of the device is known as charge injection, and is denoted by the symbol  $Q_{INJ}$ . Figure 7-6 shows the setup used to measure charge injection from drain (D) to source (Sx).

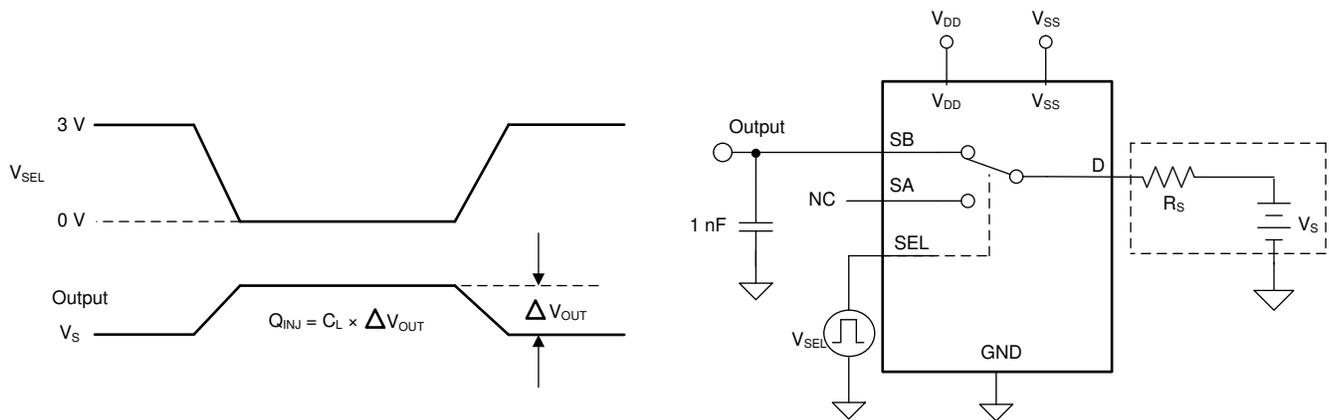
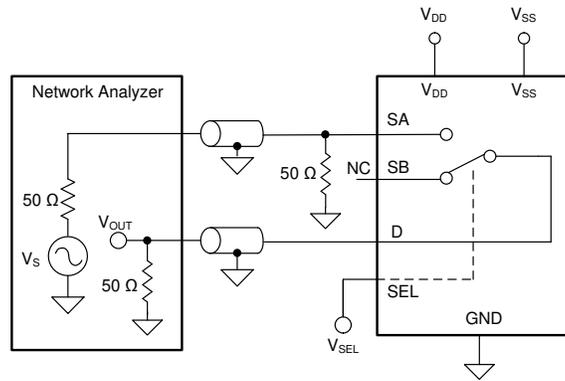


Figure 7-6. Charge-Injection Measurement Setup

### 7.1.7 Off Isolation

Off isolation is defined as the voltage at the drain pin (D) of the TMUX6136 when a  $1-V_{RMS}$  signal is applied to the source pin (Sx) of an off-channel. Figure 7-7 shows the setup used to measure off isolation. Use Equation 2 to compute off isolation.



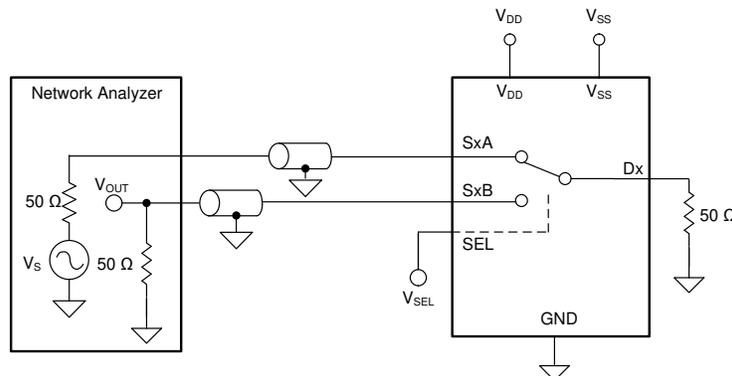
**Figure 7-7. Off Isolation Measurement Setup**

$$\text{Off Isolation} = 20 \cdot \text{Log} \left( \frac{V_{\text{OUT}}}{V_S} \right) \quad (2)$$

### 7.1.8 Channel-to-Channel Crosstalk

There are two types of crosstalk that can be defined for the TMUX6136:

1. Intra-channel crosstalk: the voltage at the source pin (S<sub>x</sub>) of an off-switch input, when a 1-V<sub>RMS</sub> signal is applied at the source pin of an on-switch input in the same channel, as shown in [Figure 7-8](#).
2. Inter-channel crosstalk: the voltage at the source pin (S<sub>x</sub>) of an on-switch input, when a 1-V<sub>RMS</sub> signal is applied at the source pin of an on-switch input in a different channel, as shown in [Figure 7-9](#).



**Figure 7-8. Intra-Channel Crosstalk Measurement Setup**

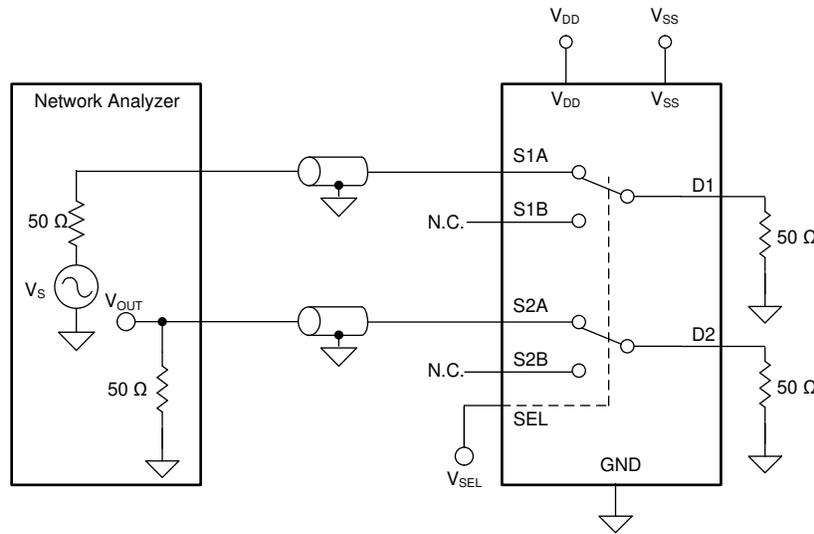


Figure 7-9. Inter-Channel Crosstalk Measurement Setup

$$\text{Channel-to-Channel Crosstalk} = 20 \cdot \text{Log} \left( \frac{V_{\text{OUT}}}{V_s} \right) \tag{3}$$

### 7.1.9 Bandwidth

Bandwidth is defined as the range of frequencies that are attenuated by < 3 dB when the input is applied to the source pin (Sx) of an on-channel, and the output is measured at the drain pin (D) of the TMUX6136. Figure 7-10 shows the setup used to measure bandwidth of the mux. Use Equation 4 to compute the attenuation.

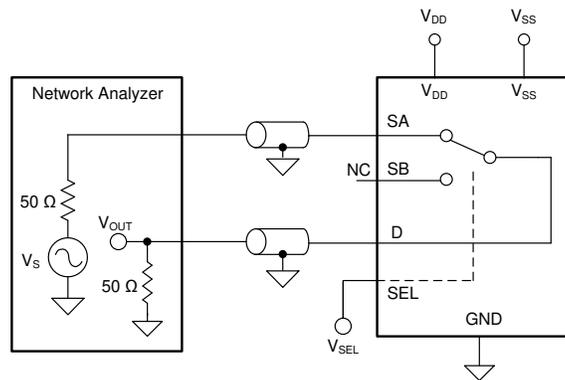


Figure 7-10. Bandwidth Measurement Setup

$$\text{Attenuation} = 20 \cdot \text{Log} \left( \frac{V_2}{V_1} \right) \tag{4}$$

### 7.1.10 THD + Noise

The total harmonic distortion (THD) of a signal is a measurement of the harmonic distortion, and is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency at the mux output. The on-resistance of the TMUX6136 varies with the amplitude of the input signal and results in distortion when the drain pin is connected to a low-impedance load. Total harmonic distortion plus noise is denoted as THD+N.

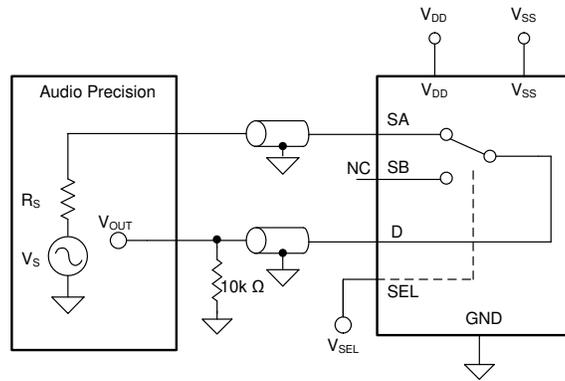


Figure 7-11. THD+N Measurement Setup

### 7.1.11 AC Power Supply Rejection Ratio (AC PSRR)

AC PSRR measures the ability of a device to prevent noise and spurious signals that appear on the supply voltage pin from coupling to the output of the switch. The DC voltage on the device supply is modulated by a sine wave of 620 mV<sub>PP</sub>. The ratio of the amplitude of signal on the output to the amplitude of the modulated signal is the AC PSRR.

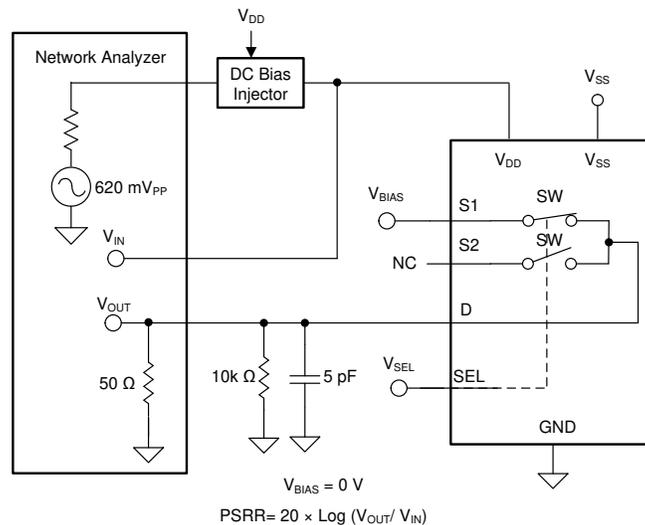
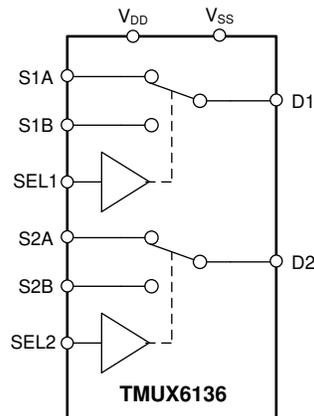


Figure 7-12. AC PSRR Measurement Setup

For a top-level block diagram of the TMUX6136, see [Section 7.2](#). The TMUX6136 is a 4-channel, single-ended, analog multiplexer. Each channel is turned on or turned off based on the state of the address lines and enable pin.

## 7.2 Functional Block Diagram



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## 7.3 Feature Description

### 7.3.1 Ultralow Leakage Current

The TMUX6136 provides extremely low on- and off-leakage currents. The TMUX6136 is capable of switching signals from high source-impedance inputs into a high input-impedance op amp with minimal offset error because of the ultralow leakage currents. Figure 7-13 shows typical leakage currents of the TMUX6136 versus temperature.

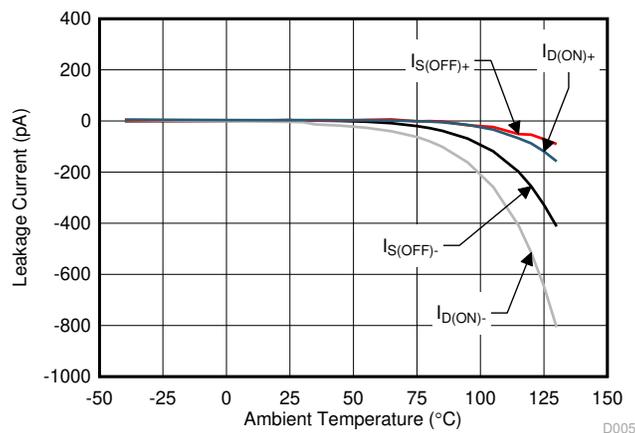
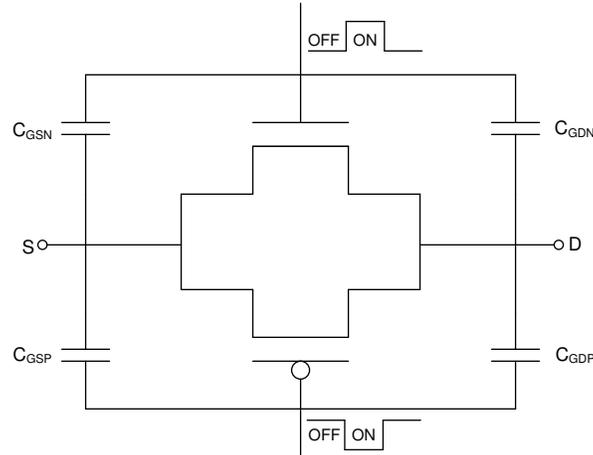


Figure 7-13. Leakage Current vs Temperature

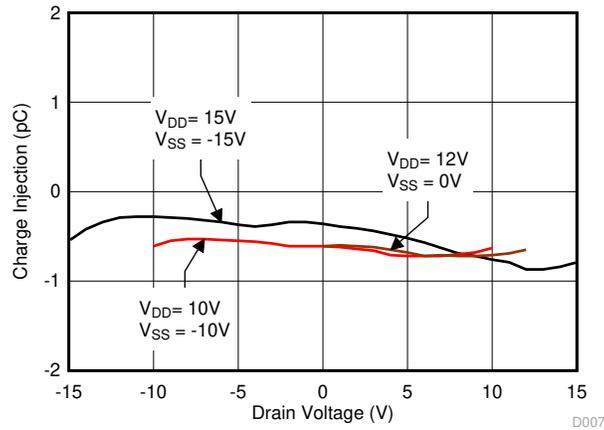
### 7.3.2 Ultralow Charge Injection

The TMUX6136 is implemented with simple transmission gate topology, as shown in Figure 7-14. Any mismatch in the stray capacitance associated with the NMOS and PMOS causes an output level change whenever the switch is opened or closed.



**Figure 7-14. Transmission Gate Topology**

The TMUX6136 utilizes special charge-injection cancellation circuitry that reduces the drain (D)-to-source (Sx) charge injection to as low as  $-0.4$  pC at  $V_S = 0$  V, as shown in Figure 7-15.



**Figure 7-15. Charge Injection vs Drain Voltage**

### 7.3.3 Bidirectional and Rail-to-Rail Operation

The TMUX6136 conducts equally well from source (Sx) to drain (D) or from drain (D) to source (Sx). Each TMUX6136 channel has very similar characteristics in both directions. The valid analog signal for TMUX6136 ranges from  $V_{SS}$  to  $V_{DD}$ . The input signal to the TMUX6136 swings from  $V_{SS}$  to  $V_{DD}$  without any significant degradation in performance.

## 7.4 Device Functional Modes

### 7.4.1 Truth Table

**Table 7-1. TMUX6136 Truth Table**

SELx	Switch A (S1A to D1 or S2A to D2)	Switch B (S1B to D1 or S2B to D2)
0	OFF	ON
1	ON	OFF

## 8 Application and Implementation

### Note

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

### 8.1 Application Information

The TMUX6136 offers outstanding input and output leakage currents and ultralow charge injection. The device operates up to 33 V ( $V_{DD}$  to  $V_{SS}$  dual supply) or 16.5 V ( $V_{DD}$  single supply), and offers true rail-to-rail input and output. The on-capacitance of the TMUX6136 is low. These features make the TMUX6136 a precision, robust, high-performance analog multiplexer for high-voltage, industrial applications.

### 8.2 Typical Application

One example of the TMUX6136 precision performance to take advantage of is the implementation of parametric measurement unit (PMU) in the semiconductor automatic test equipment (ATE) application. The PMU is frequently used to characterize and measure the digital pin's DC characteristics of a device under test (DUT). Among all the PMU's capabilities, force voltage measure current (FVMC) and force current measure voltage (FCMV) are the two most typical configurations in DC characterizations.

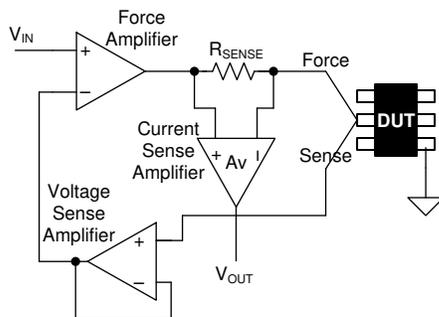


Figure 8-1. FVMC Measurement in PMU

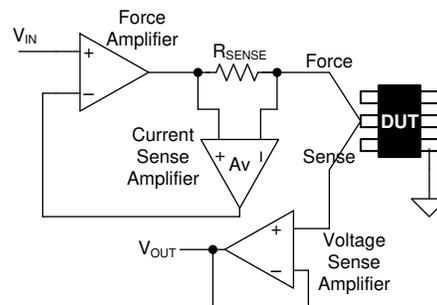


Figure 8-2. FCMV Measurement in PMU

Figure 8-1 shows a simplified diagram of the PMU in FVMC configuration. The control loop consists of the force amplifier with the voltage sense amplifier (unity gain in this example) making up the feedback path. Current flowing through the DUT is measured by sensing the current flowing through a sense resistor ( $R_{SENSE}$ ) in series with the DUT. The current sense amplifier with a gain of  $A_v$  generates a voltage ( $V_{OUT}$ ) at its output and the voltage can then be measured by an ADC. The voltage produced at the DUT pin stays at the input voltage level ( $V_{IN}$ ) as long as the force amplifier does not rail out (for example,  $I_{DUT} \times R_{SENSE} \times A_v$  stays within the input voltage range of the force amplifier). Depending on the level of the DUT current to be measured, different gain settings need to be configured for the current sense amplifier.

Figure 8-2 shows a simplified diagram of the PMU in FCMV mode. The voltage  $V_{IN}$  is now converted to a current through the following relationship:

$$\text{Force Current} = V_{IN} / (R_{SENSE} \times A_v) \quad (5)$$

The control loop consists of the force amplifier with the current sense amplifier making up the feedback path. The voltage at the DUT is sensed across the voltage sense amplifier (unity gain in this example) and presented at the output for sample.

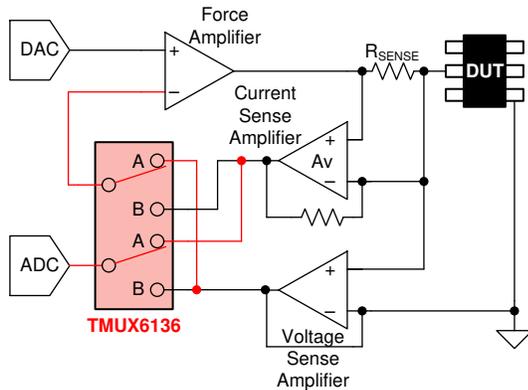
### 8.2.1 Design Requirements

The goal of this design example is to simplify the FVMC and FCMV functions of a PMU design using a SPDT switch. The FVMC configuration is useful to test a device being used as a power supply, or in continuity or leakage testing. In this configuration, the input voltage is directly applied to the DUT pin, and the current into or out of the DUT pin is converted to a voltage by a sense resistor and measured by an analog to digital converter (ADC). In the FCMV mode, an input current is forced to the DUT and the produced voltage on the DUT pin is directly measured. In this example, the PMU design is required to meet the following specifications:

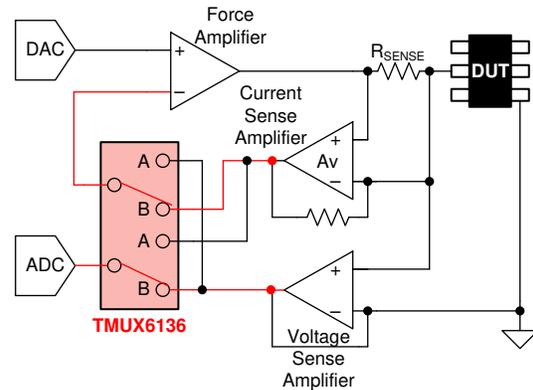
- Force voltage range: –15 volts to +15 volts
- Force current range:  $\pm 5 \mu\text{A}$  to  $\pm 50 \text{ mA}$
- Measure voltage range: –15 volts to +15 volts
- Measure current range:  $\pm 5 \mu\text{A}$  to  $\pm 50 \text{ mA}$

In addition to the voltage and current requirements, fast throughput is also a key requirement in ATE because it relates directly to the cost of manufacturing the DUT.

### 8.2.2 Detailed Design Procedure



**Figure 8-3. FVMC Implementation in PMU Using the TMUX6136**



**Figure 8-4. FCMV Implementation in PMU Using the TMUX6136**

The implementation of the FVMC and FCMV modes can be combined with the use of a dual SPDT switch such as the TMUX6136. [Figure 8-3](#) and [Figure 8-4](#) shows simplified diagrams of such implementations. In the FVMC mode, the switch is toggled to position A and this allows the voltage sense amplifier to become part of the feedback loop and the voltage output of the current sense amplifier to be sampled by the ADC. In the FCMV mode, the switch is toggled to position B, and this allows the current sense amplifier to become part of the feedback loop and the voltage output of the voltage sense amplifier to be sampled by the ADC.

### 8.2.3 Application Curve

The fast transition time of the TMUX6136 and low input or output parasitic capacitance help minimize the settling time, making the TMUX6136 an excellent candidate to implement the FVMC and FCMV functions of the PMU. Figure 8-5 shows the plot for the transition time versus temperature for the TMUX6136.

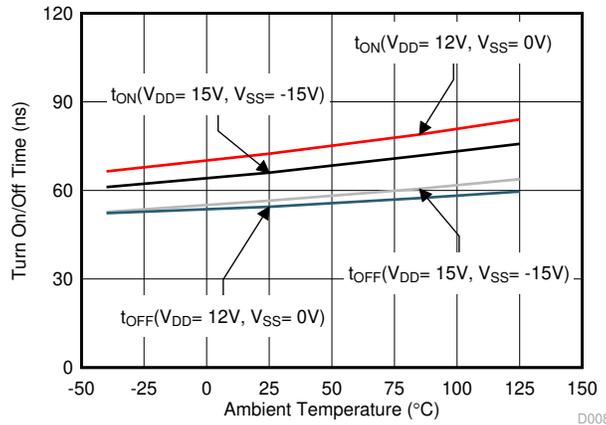


Figure 8-5. Transition Time vs Temperature for TMUX6136

## 9 Power Supply Recommendations

The TMUX6136 operates across a wide supply range of  $\pm 5$  V to  $\pm 16.5$  V (10 V to 16.5 V in single-supply mode). The device also performs well with unsymmetric supplies such as  $V_{DD} = 12$  V and  $V_{SS} = -5$  V. For reliable operation, use a supply decoupling capacitor ranging between 0.1  $\mu$ F to 10  $\mu$ F at both the  $V_{DD}$  and  $V_{SS}$  pins to ground.

## 10 Layout

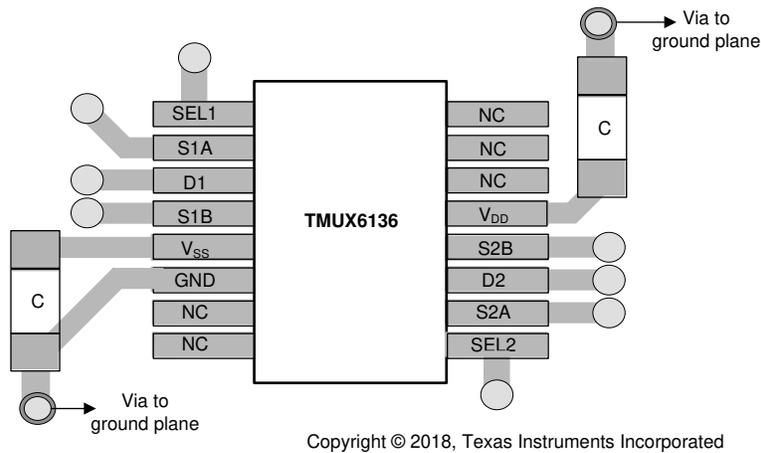
### 10.1 Layout Guidelines

Figure 10-1 shows an example of a PCB layout with the TMUX6136.

Some key considerations are as follows:

1. Decouple the  $V_{DD}$  and  $V_{SS}$  pins with a 0.1- $\mu\text{F}$  capacitor, placed as close to the pin as possible. Make sure that the capacitor voltage rating is sufficient for the  $V_{DD}$  and  $V_{SS}$  supplies.
2. Keep the input lines as short as possible.
3. Use a solid ground plane to help distribute heat and reduce electromagnetic interference (EMI) noise pickup.
4. Do not run sensitive analog traces in parallel with digital traces. Avoid crossing digital and analog traces if possible, and only make perpendicular crossings when necessary.

### 10.2 Layout Example



**Figure 10-1. TMUX6136 Layout Example**

## 11 Device and Documentation Support

### 11.1 Documentation Support

#### 11.1.1 Related Documentation

For related documentation, see the following:

- Texas Instruments, [ADS8664 12-Bit, 500-kSPS, 4- and 8-Channel, Single-Supply, SAR ADCs with Bipolar Input Ranges](#)
- Texas Instruments, [OPA192 36-V, Precision, Rail-to-Rail Input/Output, Low Offset Voltage, Low Input Bias Current Op Amp with e-Trim™](#)

#### 11.2 Receiving Notification of Documentation Updates

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

#### 11.3 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.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

#### 11.4 Trademarks

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All trademarks are the property of their respective owners.

#### 11.5 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.

#### 11.6 Glossary

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

## 12 Mechanical, Packaging, and Orderable Information

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

**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="#">TMUX6136PWR</a>	Active	Production	TSSOP (PW)   16	2000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	MUX6136
TMUX6136PWR.B	Active	Production	TSSOP (PW)   16	2000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	MUX6136
TMUX6136PWRG4	Active	Production	TSSOP (PW)   16	2000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	MUX6136
TMUX6136PWRG4.B	Active	Production	TSSOP (PW)   16	2000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	MUX6136

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

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

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

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

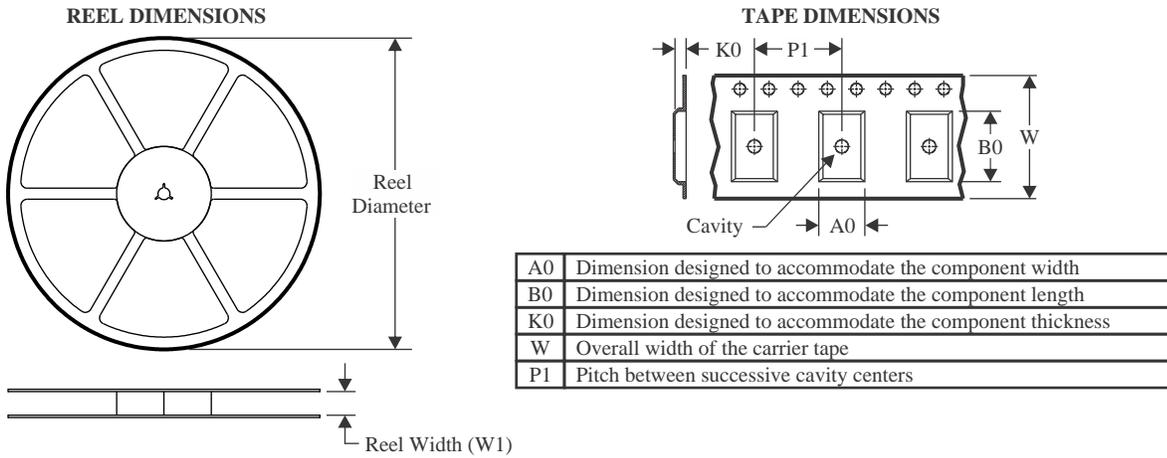
(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will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

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

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

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**TAPE AND REEL INFORMATION**

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

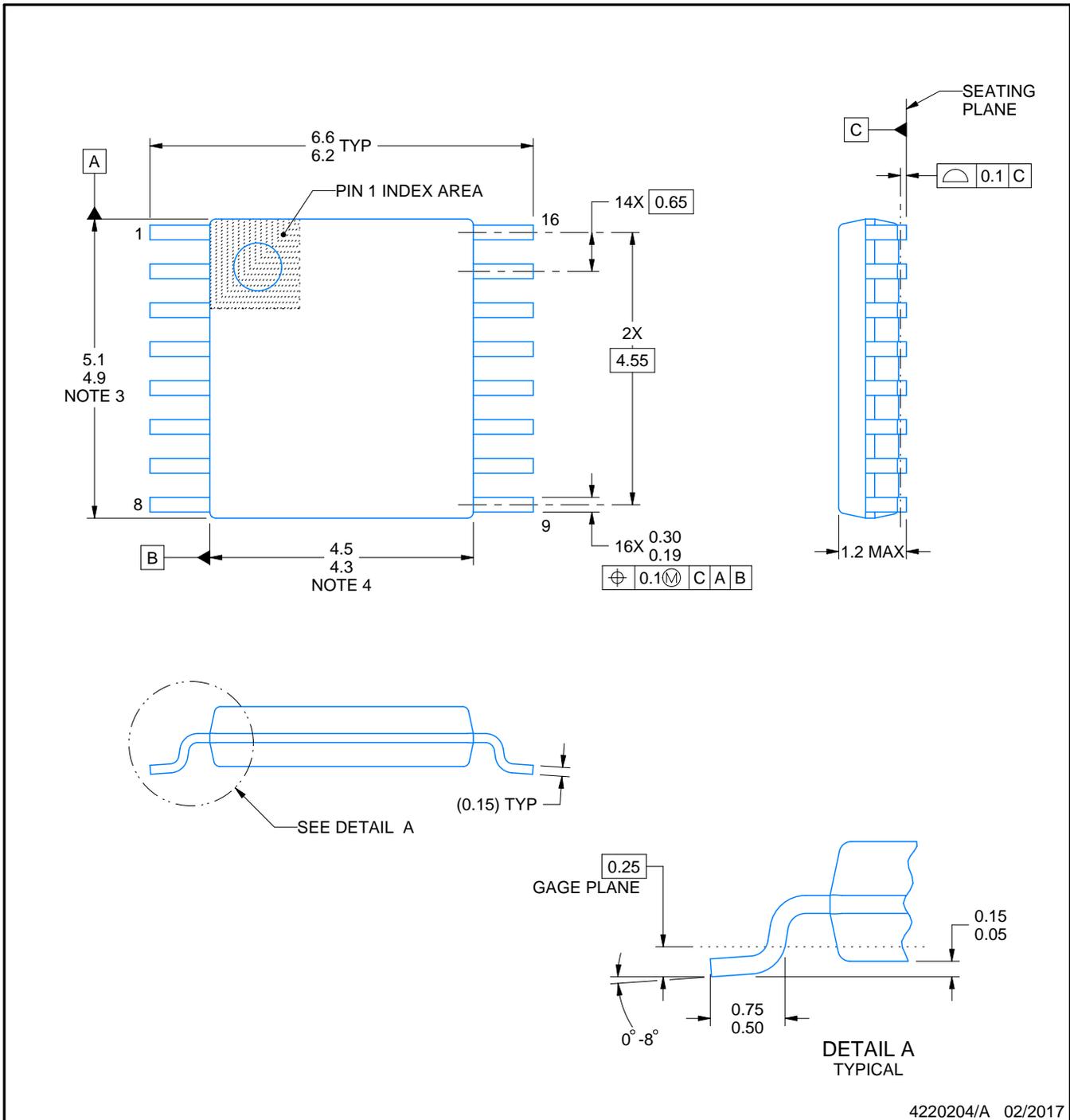

\*All dimensions are nominal

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
TMUX6136PWR	TSSOP	PW	16	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
TMUX6136PWRG4	TSSOP	PW	16	2000	330.0	12.4	6.9	5.6	1.6	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)
TMUX6136PWR	TSSOP	PW	16	2000	356.0	356.0	35.0
TMUX6136PWRG4	TSSOP	PW	16	2000	356.0	356.0	35.0



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NOTES:

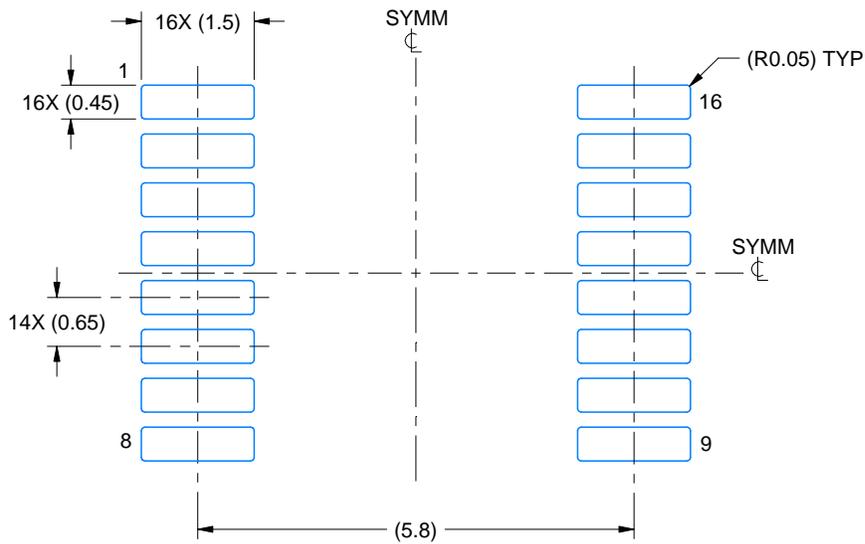
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-153.

# EXAMPLE BOARD LAYOUT

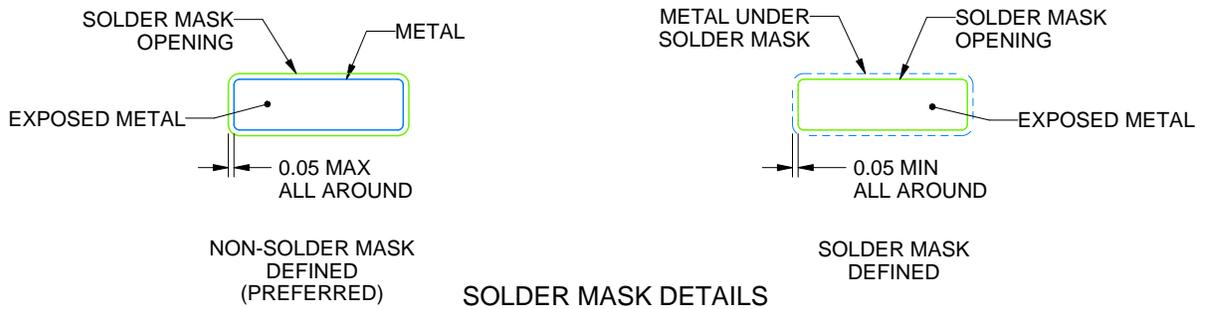
PW0016A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 10X



SOLDER MASK DETAILS

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NOTES: (continued)

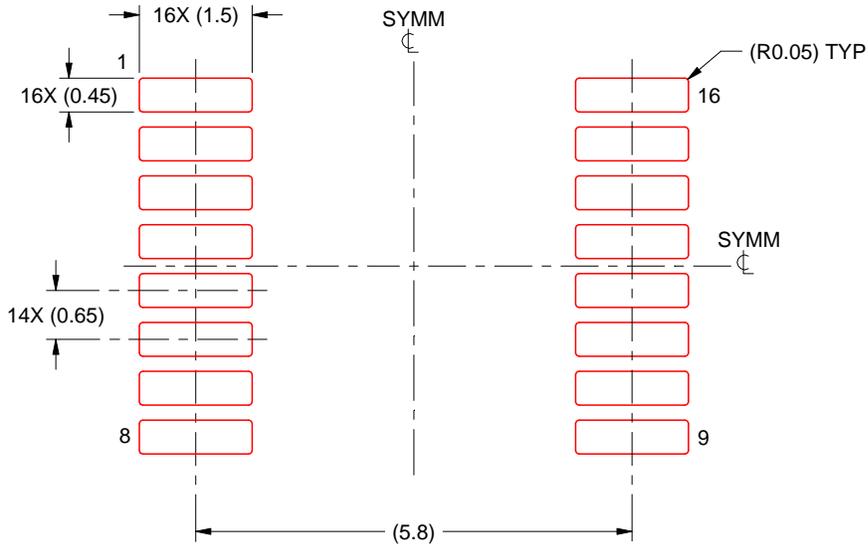
- 6. Publication IPC-7351 may have alternate designs.
- 7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

# EXAMPLE STENCIL DESIGN

PW0016A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE: 10X

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NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

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