

## MUX50x

### 36-V, Low-Capacitance, Low-Charge-Injection, Precision, Analog Multiplexers

#### 1 Features

- Low On-Capacitance
  - MUX508: 9.4 pF
  - MUX509: 6.7 pF
- Low Input Leakage: 10 pA
- Low Charge Injection: 0.3 pC
- Rail-to-Rail Operation
- Wide Supply Range:  $\pm 5$  V to  $\pm 18$  V, 10 V to 36 V
- Low On-Resistance: 125  $\Omega$
- Transition Time: 92 ns
- Break-Before-Make Switching Action
- EN Pin Connectable to  $V_{DD}$
- Logic Levels: 2 V to  $V_{DD}$
- Low Supply Current: 45  $\mu$ A
- ESD Protection HBM: 2000 V
- Industry-Standard TSSOP and SOIC Packages

#### 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 MUX508 and MUX509 (MUX50x) are modern, complementary metal-oxide semiconductor (CMOS), analog multiplexers (muxes). The MUX508 offers 8:1 single-ended channels, whereas the MUX509 offers differential 4:1 or dual 4:1 single-ended channels. The MUX508 and MUX509 work equally well with either dual supplies ( $\pm 5$  V to  $\pm 18$  V) or a single supply (10 V to 36 V). They also perform well with symmetric supplies (such as  $V_{DD} = 12$  V,  $V_{SS} = -12$  V), and unsymmetric supplies (such as  $V_{DD} = 12$  V,  $V_{SS} = -5$  V). All digital inputs have TTL-logic compatible thresholds, ensuring both TTL and CMOS logic compatibility when operating in the valid supply voltage range.

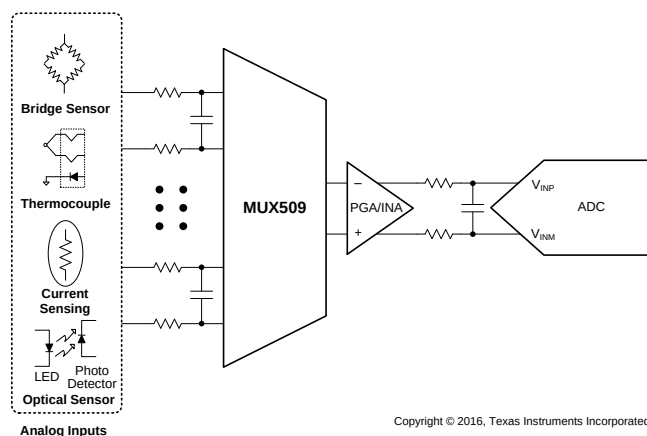
The MUX508 and MUX509 have very low on and off leakage currents, allowing these multiplexers to switch signals from high input impedance sources with minimal error. A low supply current of 45  $\mu$ A allows for use in portable applications.

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

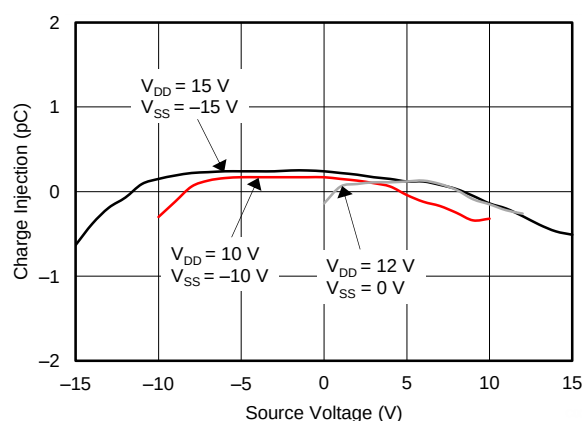
| PART NUMBER | PACKAGE    | BODY SIZE (NOM)          |
|-------------|------------|--------------------------|
| MUX50x      | TSSOP (16) | 5.00 mm $\times$ 4.40 mm |
|             | SOIC (16)  | 9.90 mm $\times$ 3.91 mm |

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

#### Simplified Schematic



#### Charge Injection vs Source Voltage



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## 4 Revision History

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

| Changes from Revision B (July 2016) to Revision C                                                                                                                                                                                 | Page |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| Added D (SOIC) package to document                                                                                                                                                                                                | 1    |
| Changed last Features bullet to include SOIC package                                                                                                                                                                              | 1    |
| Changed second sentence of <i>Description</i> section                                                                                                                                                                             | 1    |
| Added SOIC package to <i>Device Information</i> table                                                                                                                                                                             | 1    |
| Changed MUX509 description in <i>Device Comparison Table</i>                                                                                                                                                                      | 4    |
| Added D package to <i>Pin Configuration and Functions</i> section                                                                                                                                                                 | 4    |
| Added D package to <i>Thermal Information</i> table                                                                                                                                                                               | 7    |
| Changed Analog Switch, $I_D$ parameter in <i>Electrical Characteristics: Dual Supply</i> table: split parameter into $I_{D(OFF)}$ and $I_{D(ON)}$ parameters, changed symbols, parameter names, and test conditions               | 7    |
| Changed <i>On-resistance drift</i> parameter in <i>Electrical Characteristics: Single Supply</i> table: changed $V_S$ value in test conditions                                                                                    | 9    |
| Changed Analog Switch, $I_D$ parameter in <i>Electrical Characteristics: Single Supply</i> table: split parameter into $I_{D(OFF)}$ and $I_{D(ON)}$ parameters, changed symbols, parameter names, and $I_{D(ON)}$ test conditions | 9    |
| Changed <a href="#">Figure 26</a> : changed switch symbol to a closed switch symbol                                                                                                                                               | 16   |
| Changed <a href="#">Figure 32</a> : added 0 V line, flipped $V_S$ supply symbol                                                                                                                                                   | 20   |
| Changed description of MUX509 in <i>Overview</i> section                                                                                                                                                                          | 23   |
| Changed <a href="#">Figure 42</a> : changed OPA140 amplifier and charge kickback filter box                                                                                                                                       | 27   |
| Added D package description to <i>Layout Guidelines</i> section                                                                                                                                                                   | 30   |

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**Changes from Revision A (March 2016) to Revision B**
**Page**

- Added TI Design ..... [1](#)
  - Changed Analog Switch,  $I_{S(OFF)}$  and  $I_D$  parameter specifications in *Electrical Characteristics: Single Supply* table..... [9](#)
- 

**Changes from Original (January 2016) to Revision A**
**Page**

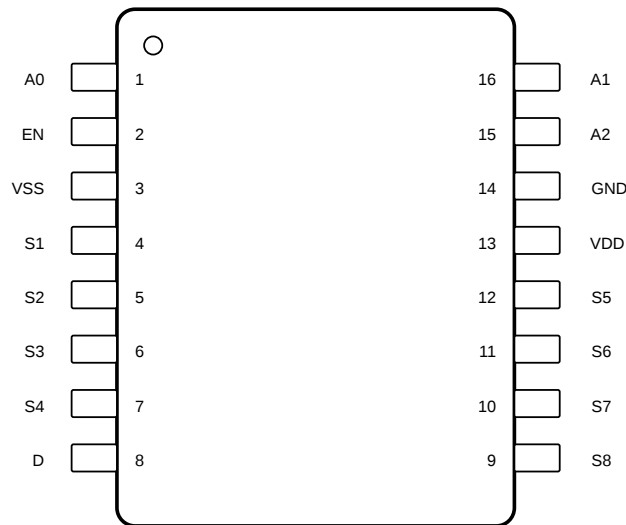
- Changed from product preview to production data ..... [1](#)
-

## 5 Device Comparison Table

| PRODUCT | DESCRIPTION                                                                  |
|---------|------------------------------------------------------------------------------|
| MUX508  | 8-channel, single-ended analog multiplexer (8:1 mux)                         |
| MUX509  | 4-channel differential or dual 4:1 single-ended analog multiplexer (8:2 mux) |

## 6 Pin Configuration and Functions

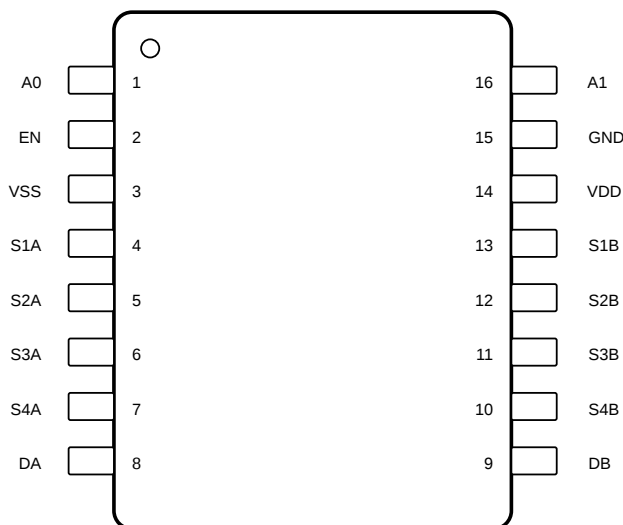
**MUX508: PW and D Packages**  
**16-Pin TSSOP and SOIC**  
**Top View**



**Pin Functions: MUX508**

| PIN  |     | TYPE                   | DESCRIPTION                                                                                                                                                                                                                                                         |
|------|-----|------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NAME | NO. |                        |                                                                                                                                                                                                                                                                     |
| A0   | 1   | Digital input          | Address line 0                                                                                                                                                                                                                                                      |
| A1   | 16  | Digital input          | Address line 1                                                                                                                                                                                                                                                      |
| A2   | 15  | Digital input          | Address line 2                                                                                                                                                                                                                                                      |
| D    | 8   | Analog input or output | Drain pin. Can be an input or output.                                                                                                                                                                                                                               |
| EN   | 2   | Digital input          | Active high digital input. When this pin is low, all switches are turned off. When this pin is high, the A[2:0] logic inputs determine which switch is turned on.                                                                                                   |
| GND  | 14  | Power supply           | Ground (0 V) reference                                                                                                                                                                                                                                              |
| S1   | 4   | Analog input or output | Source pin 1. Can be an input or output.                                                                                                                                                                                                                            |
| S2   | 5   | Analog input or output | Source pin 2. Can be an input or output.                                                                                                                                                                                                                            |
| S3   | 6   | Analog input or output | Source pin 3. Can be an input or output.                                                                                                                                                                                                                            |
| S4   | 7   | Analog input or output | Source pin 4. Can be an input or output.                                                                                                                                                                                                                            |
| S5   | 12  | Analog input or output | Source pin 5. Can be an input or output.                                                                                                                                                                                                                            |
| S6   | 11  | Analog input or output | Source pin 6. Can be an input or output.                                                                                                                                                                                                                            |
| S7   | 10  | Analog input or output | Source pin 7. Can be an input or output.                                                                                                                                                                                                                            |
| S8   | 9   | Analog input or output | Source pin 8. Can be an input or output.                                                                                                                                                                                                                            |
| VDD  | 13  | Power supply           | 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 VDD and GND.                                                                     |
| VSS  | 3   | Power supply           | 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 VSS and GND. |

**MUX509: PW and D Packages  
16-Pin TSSOP and SOIC  
Top View**



**Pin Functions: MUX509**

| PIN  |     | TYPE                   | DESCRIPTION                                                                                                                                                                                                                                                         |
|------|-----|------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NAME | NO. |                        |                                                                                                                                                                                                                                                                     |
| A0   | 1   | Digital input          | Address line 0                                                                                                                                                                                                                                                      |
| A1   | 16  | Digital input          | Address line 1                                                                                                                                                                                                                                                      |
| DA   | 8   | Analog input or output | Drain pin A. Can be an input or output.                                                                                                                                                                                                                             |
| DB   | 9   | Analog input or output | Drain pin B. Can be an input or output.                                                                                                                                                                                                                             |
| EN   | 2   | Digital input          | Active high digital input. When this pin is low, all switches are turned off. When this pin is high, the A[1:0] logic inputs determine which pair of switches is turned on.                                                                                         |
| GND  | 15  | Power supply           | Ground (0 V) reference                                                                                                                                                                                                                                              |
| S1A  | 4   | Analog input or output | Source pin 1A. Can be an input or output.                                                                                                                                                                                                                           |
| S2A  | 5   | Analog input or output | Source pin 2A. Can be an input or output.                                                                                                                                                                                                                           |
| S3A  | 6   | Analog input or output | Source pin 3A. Can be an input or output.                                                                                                                                                                                                                           |
| S4A  | 7   | Analog input or output | Source pin 4A. Can be an input or output.                                                                                                                                                                                                                           |
| S1B  | 13  | Analog input or output | Source pin 1B. Can be an input or output.                                                                                                                                                                                                                           |
| S2B  | 12  | Analog input or output | Source pin 2B. Can be an input or output.                                                                                                                                                                                                                           |
| S3B  | 11  | Analog input or output | Source pin 3B. Can be an input or output.                                                                                                                                                                                                                           |
| S4B  | 10  | Analog input or output | Source pin 4B. Can be an input or output.                                                                                                                                                                                                                           |
| VDD  | 14  | Power supply           | 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 VDD and GND.                                                                     |
| VSS  | 3   | Power supply           | 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 VSS and GND. |

## 7 Specifications

### 7.1 Absolute Maximum Ratings

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

|                                   |                     |         | MIN            | MAX            | UNIT |
|-----------------------------------|---------------------|---------|----------------|----------------|------|
| Supply voltage                    | $V_{DD}$            |         | –0.3           | 40             | V    |
|                                   | $V_{SS}$            |         | –40            | 0.3            |      |
|                                   | $V_{DD} - V_{SS}$   |         |                | 40             |      |
| Digital input pins <sup>(2)</sup> | EN, A0, A1, A2 pins | Voltage | $V_{SS} - 0.3$ | $V_{DD} + 0.3$ | V    |
|                                   |                     | Current | –30            | 30             | mA   |
| Analog input pins <sup>(2)</sup>  | Sx, SxA, SxB pins   | Voltage | $V_{SS} - 2$   | $V_{DD} + 2$   | V    |
|                                   |                     | Current | –30            | 30             | mA   |
| Analog output pins <sup>(2)</sup> | D, DA, DB pins      | Voltage | $V_{SS} - 2$   | $V_{DD} + 2$   | V    |
|                                   |                     | Current | –30            | 30             | mA   |
| Temperature                       | Operating, $T_A$    |         | –55            | 150            | °C   |
|                                   | Junction, $T_J$     |         |                | 150            |      |
|                                   | Storage, $T_{stg}$  |         | –65            | 150            |      |

(1) Stresses beyond those listed under *Absolute Maximum Ratings* 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 Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

(2) Only one pin at a time

### 7.2 ESD Ratings

|                                     |                                                                                |  | VALUE | UNIT |
|-------------------------------------|--------------------------------------------------------------------------------|--|-------|------|
| $V_{(ESD)}$ Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>              |  | 2000  | V    |
|                                     | Charged-device model (CDM), per JEDEC specification JESD22-C101 <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.

### 7.3 Recommended Operating Conditions

|                                                                     |               |  | MIN      | NOM | MAX      | UNIT |
|---------------------------------------------------------------------|---------------|--|----------|-----|----------|------|
| $V_{DD}$ <sup>(1)</sup> Positive power-supply voltage               | Dual supply   |  | 5        |     | 18       | V    |
|                                                                     | Single supply |  | 10       |     | 36       |      |
| $V_{SS}$ <sup>(2)</sup> Negative power-supply voltage (dual supply) |               |  | –5       |     | –18      | V    |
| $V_{DD} - V_{SS}$ Supply voltage                                    |               |  | 10       |     | 36       | V    |
| $V_S$ Source pins voltage <sup>(3)</sup>                            |               |  | $V_{SS}$ |     | $V_{DD}$ | V    |
| $V_D$ Drain pins voltage                                            |               |  | $V_{SS}$ |     | $V_{DD}$ | V    |
| $V_{EN}$ Enable pin voltage                                         |               |  | $V_{SS}$ |     | $V_{DD}$ | V    |
| $V_A$ Address pins voltage                                          |               |  | $V_{SS}$ |     | $V_{DD}$ | V    |
| $I_{CH}$ Channel current ( $T_A = 25^\circ\text{C}$ )               |               |  | –25      |     | 25       | mA   |
| $T_A$ Operating temperature                                         |               |  | –40      |     | 125      | °C   |

(1) When  $V_{SS} = 0$  V,  $V_{DD}$  can range from 10 V to 36 V.

(2)  $V_{DD}$  and  $V_{SS}$  can be any value as long as  $10\text{ V} \leq (V_{DD} - V_{SS}) \leq 36\text{ V}$ , and  $V_{DD} \geq 5\text{ V}$ .

(3)  $V_S$  is the voltage on all the S pins.

## 7.4 Thermal Information

| THERMAL METRIC <sup>(1)</sup> |                                              | MUX50x     |          | UNIT |
|-------------------------------|----------------------------------------------|------------|----------|------|
|                               |                                              | PW (TSSOP) | D (SOIC) |      |
|                               |                                              | 16 PINS    | 16 PINS  |      |
| $R_{\theta JA}$               | Junction-to-ambient thermal resistance       | 103.8      | 78.3     | °C/W |
| $R_{\theta JC(top)}$          | Junction-to-case (top) thermal resistance    | 36.8       | 37.2     | °C/W |
| $R_{\theta JB}$               | Junction-to-board thermal resistance         | 49.8       | 35.7     | °C/W |
| $\psi_{JT}$                   | Junction-to-top characterization parameter   | 2.7        | 8.2      | °C/W |
| $\psi_{JB}$                   | Junction-to-board characterization parameter | 49.1       | 35.4     | °C/W |
| $R_{\theta JC(bot)}$          | Junction-to-case (bottom) thermal resistance | n/a        | n/a      | °C/W |

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

## 7.5 Electrical Characteristics: Dual Supply

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 |
|---------------------|-----------------------------------------|---------------------------------------------------------------------------------------|----------------------------------|-----------------|------|-----------------|------|
| ANALOG SWITCH       |                                         |                                                                                       |                                  |                 |      |                 |      |
| Analog signal range |                                         | T <sub>A</sub> = −40°C to +125°C                                                      |                                  | V <sub>SS</sub> |      | V <sub>DD</sub> | V    |
| R <sub>ON</sub>     | On-resistance                           | V <sub>S</sub> = 0 V, I <sub>CH</sub> = 1 mA                                          |                                  | 125             | 170  | Ω               |      |
|                     |                                         |                                                                                       |                                  | 145             | 200  |                 |      |
|                     |                                         | V <sub>S</sub> = ±10 V, I <sub>CH</sub> = 1 mA                                        | T <sub>A</sub> = −40°C to +85°C  |                 | 230  |                 |      |
|                     |                                         |                                                                                       | T <sub>A</sub> = −40°C to +125°C |                 | 250  |                 |      |
| ΔR <sub>ON</sub>    | On-resistance mismatch between channels | V <sub>S</sub> = ±10 V, I <sub>CH</sub> = 1 mA                                        |                                  | 2.4             | 6    | Ω               |      |
|                     |                                         |                                                                                       | T <sub>A</sub> = −40°C to +85°C  |                 | 9    |                 |      |
|                     |                                         |                                                                                       | T <sub>A</sub> = −40°C to +125°C |                 | 11   |                 |      |
| R <sub>FLAT</sub>   | On-resistance flatness                  | V <sub>S</sub> = 10 V, 0 V, −10 V                                                     |                                  | 22              | 45   | Ω               |      |
|                     |                                         |                                                                                       | T <sub>A</sub> = −40°C to +85°C  |                 | 53   |                 |      |
|                     |                                         |                                                                                       | T <sub>A</sub> = −40°C to +125°C |                 | 58   |                 |      |
| On-resistance drift |                                         | V <sub>S</sub> = 0 V                                                                  |                                  | 0.52            |      | %°C             |      |
| I <sub>S(OFF)</sub> | Input leakage current                   | Switch state is off,<br>V <sub>S</sub> = ±10 V, V <sub>D</sub> = ±10 V <sup>(1)</sup> |                                  | −1              | 0.01 | 1               | nA   |
|                     |                                         |                                                                                       | T <sub>A</sub> = −40°C to +85°C  | −10             |      | 10              |      |
|                     |                                         |                                                                                       | T <sub>A</sub> = −40°C to +125°C | −25             |      | 25              |      |
| I <sub>D(OFF)</sub> | Output off leakage current              | Switch state is off,<br>V <sub>S</sub> = ±10 V, V <sub>D</sub> = ±10 V <sup>(1)</sup> |                                  | −1              | 0.01 | 1               | nA   |
|                     |                                         |                                                                                       | T <sub>A</sub> = −40°C to +85°C  | −10             |      | 10              |      |
|                     |                                         |                                                                                       | T <sub>A</sub> = −40°C to +125°C | −50             |      | 50              |      |
| I <sub>D(ON)</sub>  | Output on leakage current               | Switch state is on,<br>V <sub>D</sub> = ±10 V, V <sub>S</sub> = floating              |                                  | −1              | 0.01 | 1               | nA   |
|                     |                                         |                                                                                       | T <sub>A</sub> = −40°C to +85°C  | −10             |      | 10              |      |
|                     |                                         |                                                                                       | T <sub>A</sub> = −40°C to +125°C | −50             |      | 50              |      |
| LOGIC INPUT         |                                         |                                                                                       |                                  |                 |      |                 |      |
| V <sub>IH</sub>     | High-level input voltage                |                                                                                       |                                  | 2.0             |      | V               |      |
| V <sub>IL</sub>     | Low-level input voltage                 |                                                                                       |                                  |                 |      | 0.8             | V    |
| I <sub>D</sub>      | Input current                           |                                                                                       |                                  |                 |      | 0.15            | μA   |

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

**MUX508, MUX509**

SBAS758C –JANUARY 2016–REVISED SEPTEMBER 2016

[www.ti.com](http://www.ti.com)
**Electrical Characteristics: Dual Supply (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                                                                                         |                                  | MIN  | TYP  | MAX | UNIT |
|--------------------------------|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|----------------------------------|------|------|-----|------|
| SWITCH DYNAMICS <sup>(2)</sup> |                                                                                      |                                                                                                         |                                  |      |      |     |      |
| t <sub>ON</sub>                | Enable turn-on time                                                                  | V <sub>S</sub> = ±10 V, R <sub>L</sub> = 300 Ω,<br>C <sub>L</sub> = 35 pF                               |                                  | 88   | 136  | ns  |      |
|                                |                                                                                      |                                                                                                         | T <sub>A</sub> = −40°C to +85°C  |      | 144  |     |      |
|                                |                                                                                      |                                                                                                         | T <sub>A</sub> = −40°C to +125°C |      | 151  |     |      |
| t <sub>OFF</sub>               | Enable turn-off time                                                                 | V <sub>S</sub> = ±10 V, R <sub>L</sub> = 300 Ω,<br>C <sub>L</sub> = 35 pF                               |                                  | 63   | 75   | ns  |      |
|                                |                                                                                      |                                                                                                         | T <sub>A</sub> = −40°C to +85°C  |      | 83   |     |      |
|                                |                                                                                      |                                                                                                         | T <sub>A</sub> = −40°C to +125°C |      | 90   |     |      |
| t <sub>t</sub>                 | Transition time                                                                      | V <sub>S</sub> = 10 V, R <sub>L</sub> = 300 Ω,<br>C <sub>L</sub> = 35 pF,                               |                                  | 92   | 143  | ns  |      |
|                                |                                                                                      |                                                                                                         | T <sub>A</sub> = −40°C to +85°C  |      | 151  |     |      |
|                                |                                                                                      |                                                                                                         | T <sub>A</sub> = −40°C to +125°C |      | 157  |     |      |
| t <sub>BBM</sub>               | Break-before-make time delay                                                         | V <sub>S</sub> = 10 V, R <sub>L</sub> = 300 Ω, C <sub>L</sub> = 35 pF, T <sub>A</sub> = −40°C to +125°C | 30                               | 54   |      | ns  |      |
| Q <sub>J</sub>                 | Charge injection                                                                     | C <sub>L</sub> = 1 nF, R <sub>S</sub> = 0 Ω                                                             | V <sub>S</sub> = 0 V             | 0.3  |      | pC  |      |
|                                |                                                                                      |                                                                                                         | V <sub>S</sub> = −15 V to +15 V  | ±0.6 |      |     |      |
|                                | Off-isolation                                                                        | R <sub>L</sub> = 50 Ω, V <sub>S</sub> = 1 V <sub>RMS</sub> ,<br>f = 1 MHz                               | Nonadjacent channel to D, DA, DB | −96  |      | dB  |      |
|                                |                                                                                      |                                                                                                         | Adjacent channel to D, DA, DB    | −85  |      |     |      |
|                                | Channel-to-channel crosstalk                                                         | R <sub>L</sub> = 50 Ω, V <sub>S</sub> = 1 V <sub>RMS</sub> ,<br>f = 1 MHz                               | Nonadjacent channels             | −96  |      | dB  |      |
|                                |                                                                                      |                                                                                                         | Adjacent channels                | −88  |      |     |      |
| C <sub>S(OFF)</sub>            | Input off-capacitance                                                                | f = 1 MHz, V <sub>S</sub> = 0 V                                                                         |                                  | 2.4  | 2.9  | pF  |      |
| C <sub>D(OFF)</sub>            | Output off-capacitance                                                               | f = 1 MHz, V <sub>S</sub> = 0 V                                                                         | MUX508                           | 7.5  | 8.4  | pF  |      |
|                                |                                                                                      |                                                                                                         | MUX509                           | 4.3  | 5    |     |      |
| C <sub>D(ON)</sub>             | Input/Output on-capacitance                                                          | f = 1 MHz, V <sub>S</sub> = 0 V                                                                         | MUX508                           | 9.4  | 10.6 | pF  |      |
|                                |                                                                                      |                                                                                                         | MUX509                           | 6.7  | 7.7  |     |      |
| POWER SUPPLY                   |                                                                                      |                                                                                                         |                                  |      |      |     |      |
| V <sub>DD</sub> supply current | All V <sub>A</sub> = 0 V or 3.3 V,<br>V <sub>S</sub> = 0 V, V <sub>EN</sub> = 3.3 V, |                                                                                                         |                                  | 45   | 59   | μA  |      |
|                                |                                                                                      |                                                                                                         | T <sub>A</sub> = −40°C to +85°C  |      | 62   |     |      |
|                                |                                                                                      |                                                                                                         | T <sub>A</sub> = −40°C to +125°C |      | 83   |     |      |
| V <sub>SS</sub> supply current | All V <sub>A</sub> = 0 V or 3.3 V,<br>V <sub>S</sub> = 0 V, V <sub>EN</sub> = 3.3 V, |                                                                                                         |                                  | 25   | 34   | μA  |      |
|                                |                                                                                      |                                                                                                         | T <sub>A</sub> = −40°C to +85°C  |      | 37   |     |      |
|                                |                                                                                      |                                                                                                         | T <sub>A</sub> = −40°C to +125°C |      | 57   |     |      |

(2) Specified by design, not production tested.



## 7.6 Electrical Characteristics: Single Supply

at  $T_A = 25^\circ\text{C}$ ,  $V_{DD} = 12\text{ V}$ , and  $V_{SS} = 0\text{ V}$  (unless otherwise noted)<sup>(1)</sup>

| PARAMETER                      |                              | TEST CONDITIONS                                                                                                                             |                                  | MIN             | TYP  | MAX             | UNIT |
|--------------------------------|------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|-----------------|------|-----------------|------|
| ANALOG SWITCH                  |                              |                                                                                                                                             |                                  |                 |      |                 |      |
| Analog signal range            |                              | T <sub>A</sub> = −40°C to +125°C                                                                                                            |                                  | V <sub>SS</sub> |      | V <sub>DD</sub> | V    |
| R <sub>ON</sub>                | On-resistance                | V <sub>S</sub> = 10 V, I <sub>CH</sub> = 1 mA                                                                                               |                                  | 235             |      | 340             | Ω    |
|                                |                              |                                                                                                                                             | T <sub>A</sub> = −40°C to +85°C  |                 |      | 390             |      |
|                                |                              |                                                                                                                                             | T <sub>A</sub> = −40°C to +125°C |                 |      | 430             |      |
| ΔR <sub>ON</sub>               | On-resistance match          | V <sub>S</sub> = 10 V, I <sub>CH</sub> = 1 mA                                                                                               |                                  | 3.1             |      | 12              | Ω    |
|                                |                              |                                                                                                                                             | T <sub>A</sub> = −40°C to +85°C  |                 |      | 19              |      |
|                                |                              |                                                                                                                                             | T <sub>A</sub> = −40°C to +125°C |                 |      | 23              |      |
| On-resistance drift            |                              | V <sub>S</sub> = 10 V                                                                                                                       |                                  | 0.47            |      |                 | %/°C |
| I <sub>S(OFF)</sub>            | Input leakage current        | Switch state is off,<br>V <sub>S</sub> = 1 V and V <sub>D</sub> = 10 V,<br>or V <sub>S</sub> = 10 V and V <sub>D</sub> = 1 V <sup>(2)</sup> |                                  | −1              | 0.01 | 1               | nA   |
|                                |                              |                                                                                                                                             | T <sub>A</sub> = −40°C to +85°C  | −10             |      | 10              |      |
|                                |                              |                                                                                                                                             | T <sub>A</sub> = −40°C to +125°C | −25             |      | 25              |      |
| I <sub>D(OFF)</sub>            | Output off leakage current   | Switch state is off,<br>V <sub>S</sub> = 1 V and V <sub>D</sub> = 10 V,<br>or V <sub>S</sub> = 10 V and V <sub>D</sub> = 1 V <sup>(2)</sup> |                                  | −1              | 0.01 | 1               | nA   |
|                                |                              |                                                                                                                                             | T <sub>A</sub> = −40°C to +85°C  | −10             |      | 10              |      |
|                                |                              |                                                                                                                                             | T <sub>A</sub> = −40°C to +125°C | −50             |      | 50              |      |
| I <sub>D(ON)</sub>             | Output on leakage current    | Switch state is on,<br>V <sub>D</sub> = 1 V and 10 V,<br>V <sub>S</sub> = floating                                                          |                                  | −1              | 0.01 | 1               | nA   |
|                                |                              |                                                                                                                                             | T <sub>A</sub> = −40°C to +85°C  | −10             |      | 10              |      |
|                                |                              |                                                                                                                                             | T <sub>A</sub> = −40°C to +125°C | −50             |      | 50              |      |
| LOGIC INPUT                    |                              |                                                                                                                                             |                                  |                 |      |                 |      |
| V <sub>IH</sub>                | High-level input voltage     |                                                                                                                                             |                                  | 2.0             |      |                 | V    |
| V <sub>IL</sub>                | Low-level input voltage      |                                                                                                                                             |                                  |                 |      | 0.8             | V    |
| I <sub>D</sub>                 | Input current                |                                                                                                                                             |                                  |                 |      | 0.15            | μA   |
| SWITCH DYNAMIC CHARACTERISTICS |                              |                                                                                                                                             |                                  |                 |      |                 |      |
| t <sub>ON</sub>                | Enable turn-on time          | V <sub>S</sub> = 8 V, R <sub>L</sub> = 300 Ω,<br>C <sub>L</sub> = 35 pF                                                                     |                                  | 85              |      | 140             | ns   |
|                                |                              |                                                                                                                                             | T <sub>A</sub> = −40°C to +85°C  |                 |      | 145             |      |
|                                |                              |                                                                                                                                             | T <sub>A</sub> = −40°C to +125°C |                 |      | 149             |      |
| t <sub>OFF</sub>               | Enable turn-off time         | V <sub>S</sub> = 8 V, R <sub>L</sub> = 300 Ω,<br>C <sub>L</sub> = 35 pF                                                                     |                                  | 48              |      | 83              | ns   |
|                                |                              |                                                                                                                                             | T <sub>A</sub> = −40°C to +85°C  |                 |      | 94              |      |
|                                |                              |                                                                                                                                             | T <sub>A</sub> = −40°C to +125°C |                 |      | 102             |      |
| t <sub>t</sub>                 | Transition time              | V <sub>S</sub> = 8 V, C <sub>L</sub> = 35 pF                                                                                                |                                  | 87              |      | 147             | ns   |
|                                |                              | V <sub>S</sub> = 8 V, R <sub>L</sub> = 300 Ω,<br>C <sub>L</sub> = 35 pF,                                                                    | T <sub>A</sub> = −40°C to +85°C  |                 |      | 153             |      |
|                                |                              | V <sub>S</sub> = 8 V, R <sub>L</sub> = 300 Ω,<br>C <sub>L</sub> = 35 pF,                                                                    | T <sub>A</sub> = −40°C to +125°C |                 |      | 155             |      |
| t <sub>BBM</sub>               | Break-before-make time delay | V <sub>S</sub> = 8 V, R <sub>L</sub> = 300 Ω, C <sub>L</sub> = 35 pF, T <sub>A</sub> = −40°C to +125°C                                      |                                  | 30              | 54   |                 | ns   |
| Q <sub>J</sub>                 | Charge injection             | C <sub>L</sub> = 1 nF, R <sub>S</sub> = 0 Ω                                                                                                 | V <sub>S</sub> = 6 V             | 0.15            |      |                 | pC   |
|                                |                              |                                                                                                                                             | V <sub>S</sub> = 0 V to 12 V,    | ±0.4            |      |                 |      |
|                                | Off-isolation                | R <sub>L</sub> = 50 Ω, V <sub>S</sub> = 1 V <sub>RMS</sub> ,<br>f = 1 MHz                                                                   | Nonadjacent channel to D, DA, DB | −96             |      |                 | dB   |
|                                |                              |                                                                                                                                             | Adjacent channel to D, DA, DB    | −85             |      |                 |      |
|                                | Channel-to-channel crosstalk | R <sub>L</sub> = 50 Ω, V <sub>S</sub> = 1 V <sub>RMS</sub> ,<br>f = 1 MHz                                                                   | Nonadjacent channels             | −96             |      |                 | dB   |
|                                |                              |                                                                                                                                             | Adjacent channels                | −88             |      |                 |      |
| C <sub>S(OFF)</sub>            | Input off-capacitance        | f = 1 MHz, V <sub>S</sub> = 6 V                                                                                                             |                                  | 2.7             |      | 3.2             | pF   |
| C <sub>D(OFF)</sub>            | Output off-capacitance       | f = 1 MHz, V <sub>S</sub> = 6 V                                                                                                             | MUX508                           | 9.1             |      | 10              | pF   |
|                                |                              |                                                                                                                                             | MUX509                           | 5               |      | 5.7             |      |
| C <sub>D(ON)</sub>             | Input/Output on-capacitance  | f = 1 MHz, V <sub>S</sub> = 6 V                                                                                                             | MUX508                           | 10.8            |      | 12              | pF   |
|                                |                              |                                                                                                                                             | MUX509                           | 6.9             |      | 8               |      |

(1) Specified by design, not production tested.

(2) When  $V_S$  is 1 V,  $V_D$  is 10 V, and vice versa.

**MUX508, MUX509**

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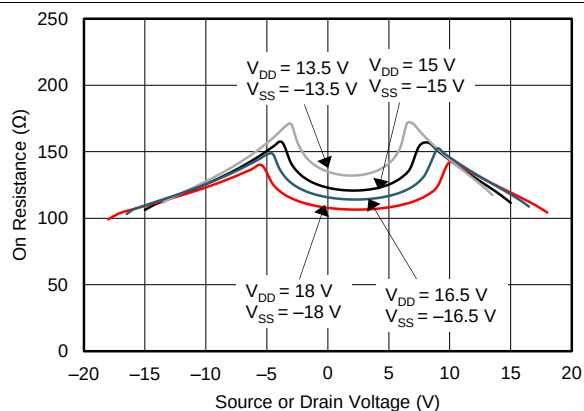
[www.ti.com](http://www.ti.com)
**Electrical Characteristics: Single Supply (continued)**

 at  $T_A = 25^\circ\text{C}$ ,  $V_{DD} = 12\text{ V}$ , and  $V_{SS} = 0\text{ V}$  (unless otherwise noted)<sup>(1)</sup>

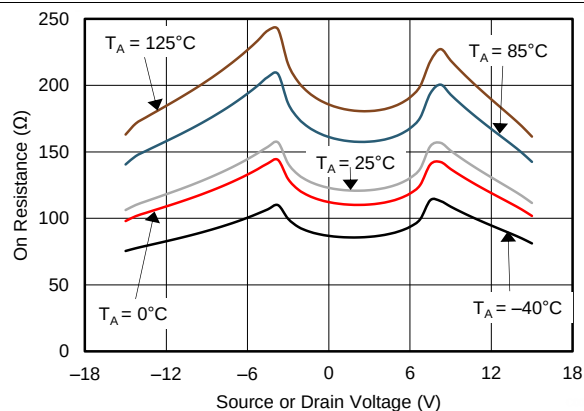
| PARAMETER               | TEST CONDITIONS                                                                            | MIN                                               | TYP | MAX | UNIT          |
|-------------------------|--------------------------------------------------------------------------------------------|---------------------------------------------------|-----|-----|---------------|
| <b>POWER SUPPLY</b>     |                                                                                            |                                                   |     |     |               |
| $V_{DD}$ supply current | All $V_A = 0\text{ V}$ or $3.3\text{ V}$ ,<br>$V_S = 0\text{ V}$ , $V_{EN} = 3.3\text{ V}$ |                                                   | 42  | 53  | $\mu\text{A}$ |
|                         |                                                                                            | $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$  |     | 56  |               |
|                         |                                                                                            | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$ |     | 77  |               |
| $V_{SS}$ supply current | All $V_A = 0\text{ V}$ or $3.3\text{ V}$ ,<br>$V_S = 0\text{ V}$ , $V_{EN} = 3.3\text{ V}$ |                                                   | 23  | 38  | $\mu\text{A}$ |
|                         |                                                                                            | $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$  |     | 31  |               |
|                         |                                                                                            | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$ |     | 51  |               |

## 7.7 Typical Characteristics

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

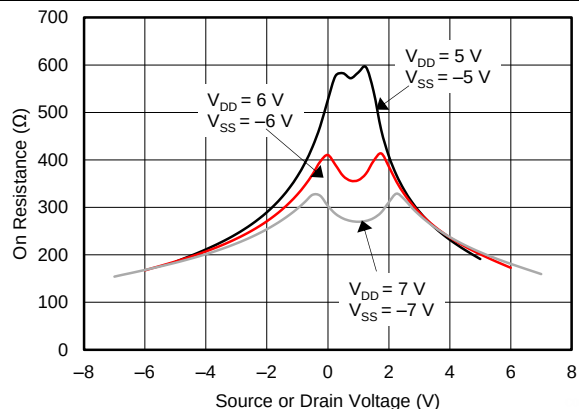


**Figure 1. On-Resistance vs Source or Drain Voltage**

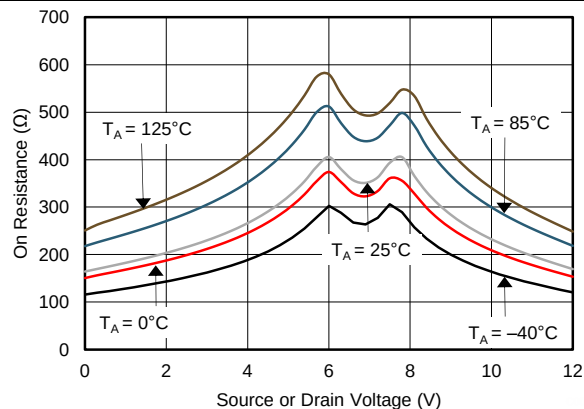


$V_{DD} = 15\text{ V}$ ,  $V_{SS} = -15\text{ V}$

**Figure 2. On-Resistance vs Source or Drain Voltage**

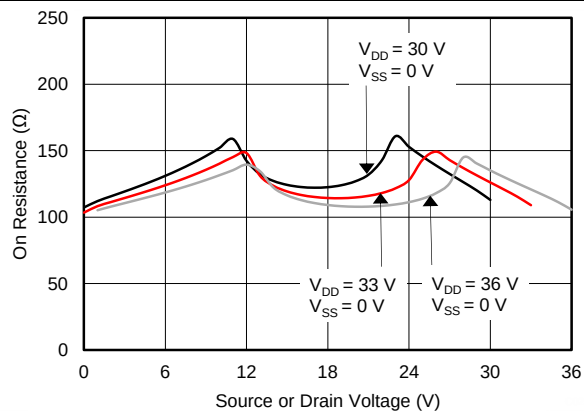


**Figure 3. On-Resistance vs Source or Drain Voltage**

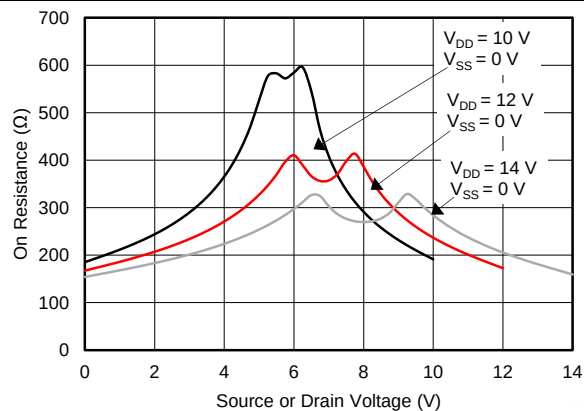


$V_{DD} = 12\text{ V}$ ,  $V_{SS} = 0\text{ V}$

**Figure 4. On-Resistance vs Source or Drain Voltage**



**Figure 5. On-Resistance vs Source or Drain Voltage**



**Figure 6. On-Resistance vs Source or Drain Voltage**

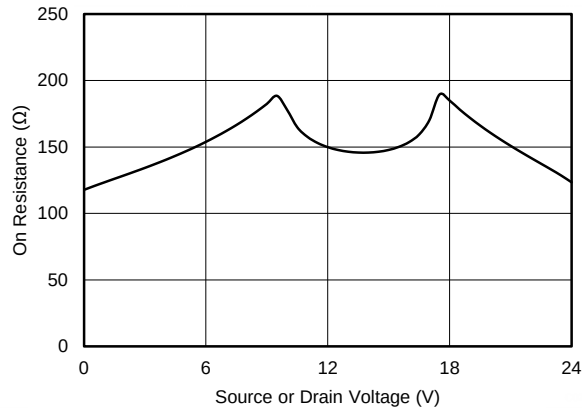
## MUX508, MUX509

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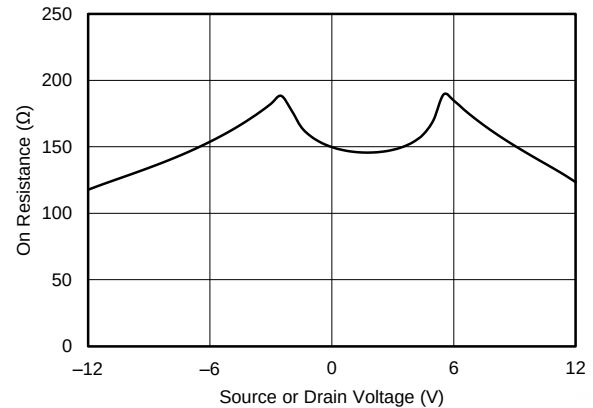
### Typical Characteristics (continued)

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



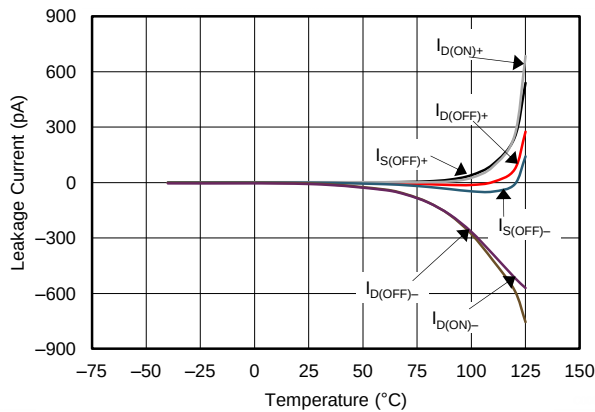
$V_{DD} = 24\text{ V}$ ,  $V_{SS} = 0\text{ V}$

**Figure 7. On-Resistance vs Source or Drain Voltage**



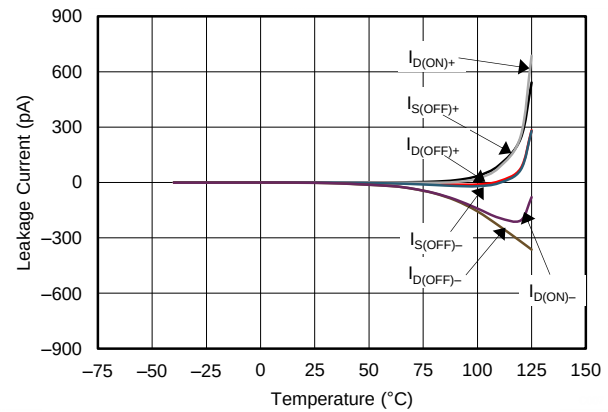
$V_{DD} = 12\text{ V}$ ,  $V_{SS} = -12\text{ V}$

**Figure 8. On-Resistance vs Source or Drain Voltage**



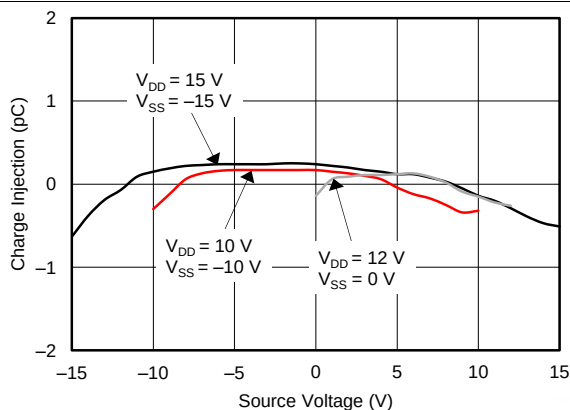
$V_{DD} = 15\text{ V}$ ,  $V_{SS} = -15\text{ V}$

**Figure 9. Leakage Current vs Temperature**



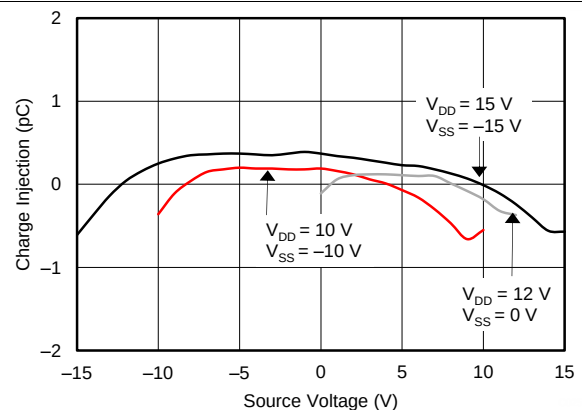
$V_{DD} = 12\text{ V}$ ,  $V_{SS} = 0\text{ V}$

**Figure 10. Leakage Current vs Temperature**



MUX508, source-to-drain

**Figure 11. Charge Injection vs Source Voltage**

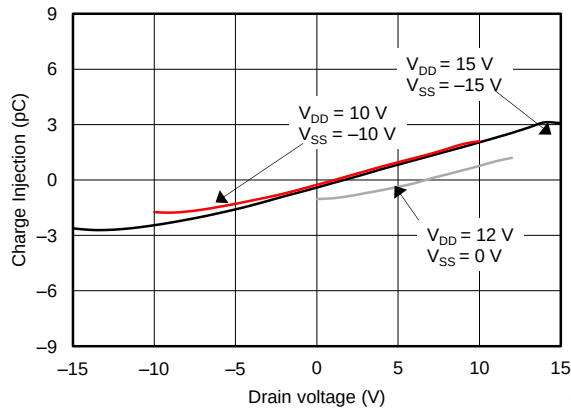


MUX509, source-to-drain

**Figure 12. Charge Injection vs Source Voltage**

## Typical Characteristics (continued)

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



Drain-to-source

Figure 13. Charge Injection vs Source or Drain Voltage

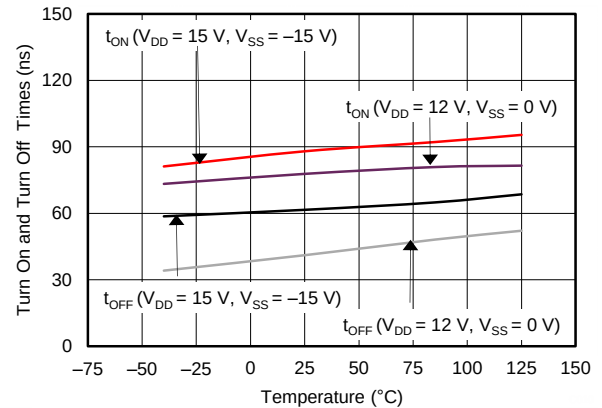


Figure 14. Turn-On and Turn-Off Times vs Temperature

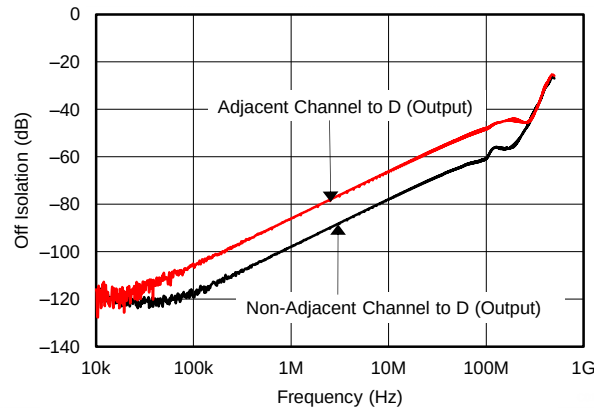


Figure 15. Off Isolation vs Frequency

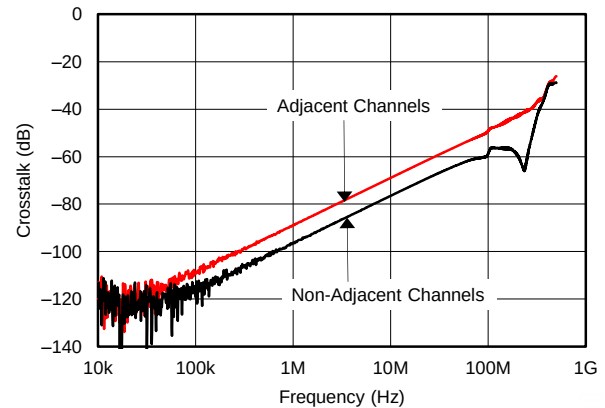


Figure 16. Crosstalk vs Frequency

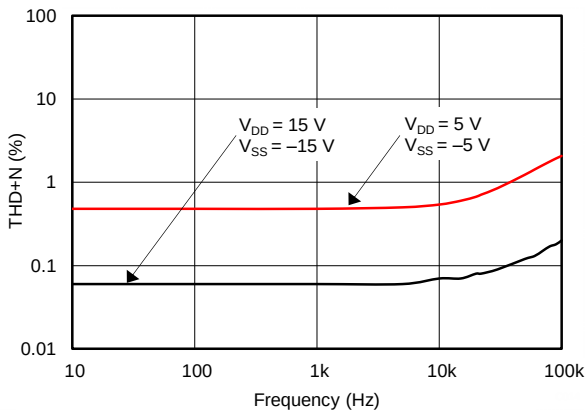


Figure 17. THD+N vs Frequency

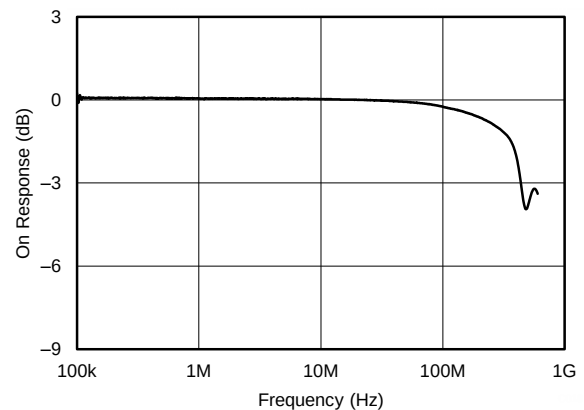


Figure 18. On Response vs Frequency

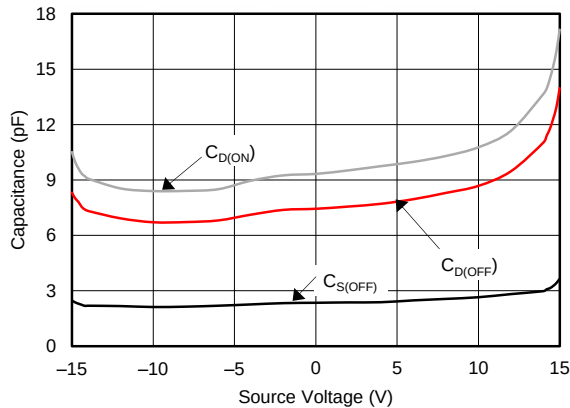
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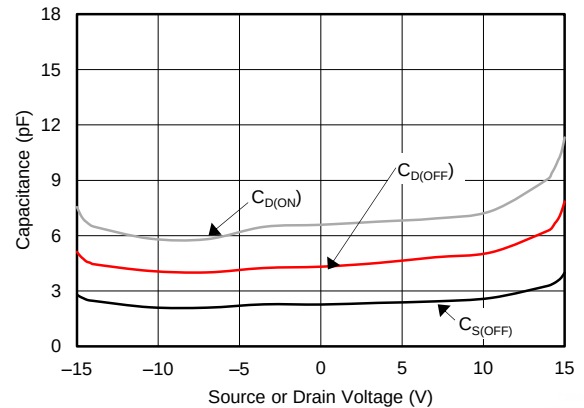
## Typical Characteristics (continued)

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



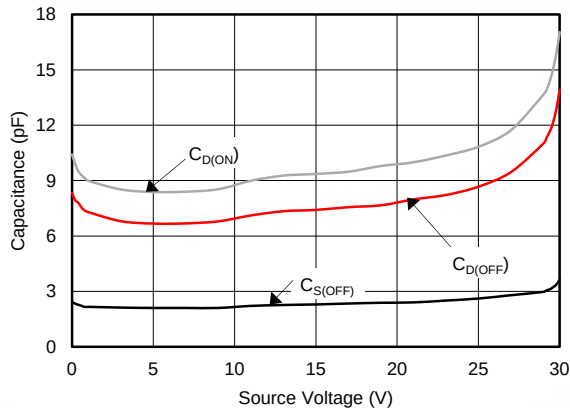
MUX508,  $V_{DD} = 15\text{ V}$ ,  $V_{SS} = -15\text{ V}$

Figure 19. Capacitance vs Source Voltage



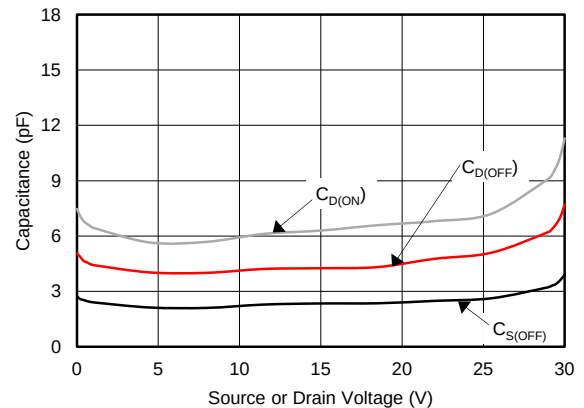
MUX509,  $V_{DD} = 15\text{ V}$ ,  $V_{SS} = -15\text{ V}$

Figure 20. Capacitance vs Source Voltage



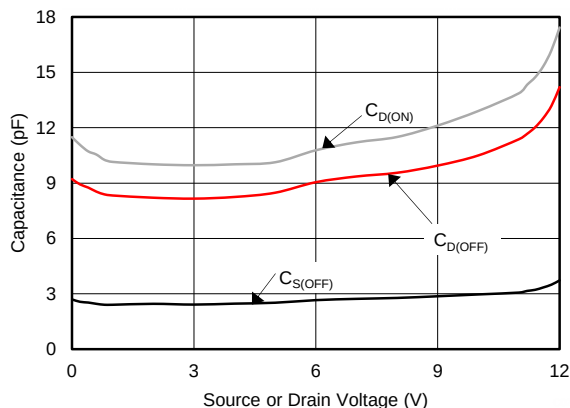
MUX508,  $V_{DD} = 30\text{ V}$ ,  $V_{SS} = 0\text{ V}$

Figure 21. Capacitance vs Source Voltage



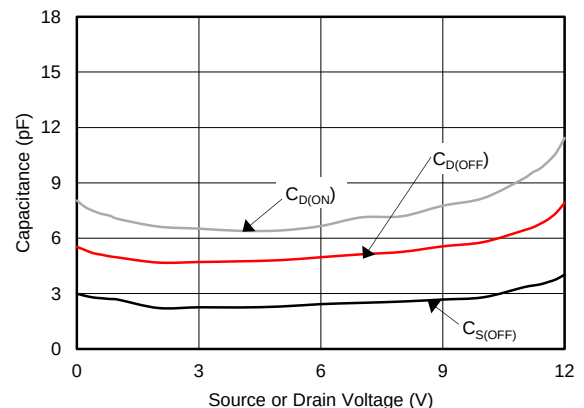
MUX509,  $V_{DD} = 30\text{ V}$ ,  $V_{SS} = 0\text{ V}$

Figure 22. Capacitance vs Source Voltage



MUX508,  $V_{DD} = 12\text{ V}$ ,  $V_{SS} = 0\text{ V}$

Figure 23. Capacitance vs Source Voltage



MUX509,  $V_{DD} = 12\text{ V}$ ,  $V_{SS} = 0\text{ V}$

Figure 24. Capacitance vs Source Voltage

## Typical Characteristics (continued)

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

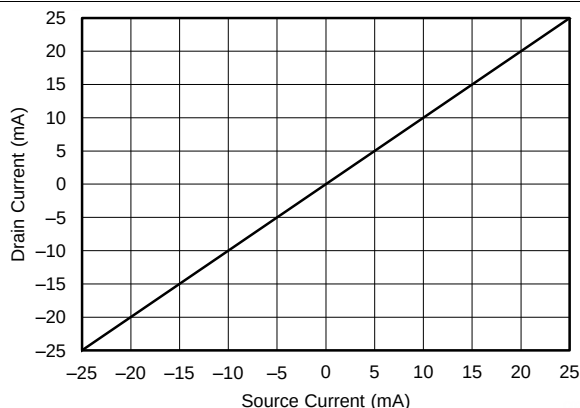


Figure 25. Source Current vs Drain Current

## 8 Parameter Measurement Information

### 8.1 Truth Tables

Table 1 and Table 2 show the truth tables for the MUX508 and MUX509, respectively.

Table 1. MUX508 Truth Table

| EN | A2               | A1               | A0               | STATE                |
|----|------------------|------------------|------------------|----------------------|
| 0  | X <sup>(1)</sup> | X <sup>(1)</sup> | X <sup>(1)</sup> | All channels are off |
| 1  | 0                | 0                | 0                | Channel 1 on         |
| 1  | 0                | 0                | 1                | Channel 2 on         |
| 1  | 0                | 1                | 0                | Channel 3 on         |
| 1  | 0                | 1                | 1                | Channel 4 on         |
| 1  | 1                | 0                | 0                | Channel 5 on         |
| 1  | 1                | 0                | 1                | Channel 6 on         |
| 1  | 1                | 1                | 0                | Channel 7 on         |
| 1  | 1                | 1                | 1                | Channel 8 on         |

(1) X denotes *don't care*..

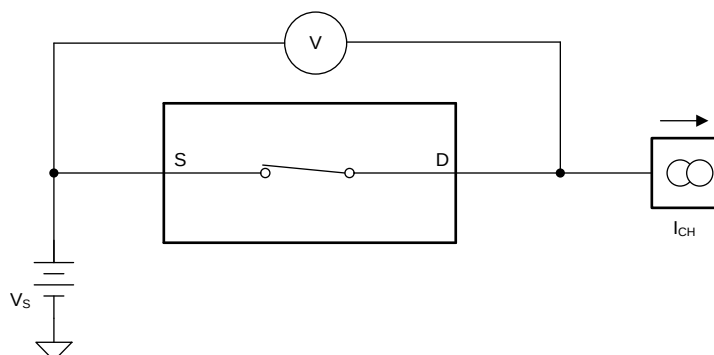
Table 2. MUX509 Truth Table

| EN | A1               | A0               | STATE                 |
|----|------------------|------------------|-----------------------|
| 0  | X <sup>(1)</sup> | X <sup>(1)</sup> | All channels are off  |
| 1  | 0                | 0                | Channels 1A and 1B on |
| 1  | 0                | 1                | Channels 2A and 2B on |
| 1  | 1                | 0                | Channels 3A and 3B on |
| 1  | 1                | 1                | Channels 4A and 4B on |

(1) X denotes *don't care*.

## 8.2 On-Resistance

The on-resistance of the MUX50x is the ohmic resistance across the source (Sx, SxA, or SxB) and drain (D, DA, or DB) 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 26. Voltage (V) and current ( $I_{CH}$ ) are measured using this setup, and  $R_{ON}$  is computed as shown in Equation 1.



**Figure 26. On-Resistance Measurement Setup**

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

## 8.3 Off-Leakage Current

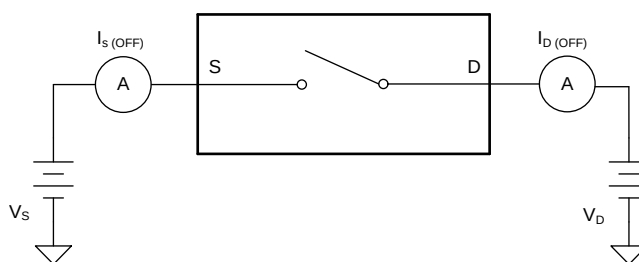
There are two types of leakage currents associated with a switch during the off state:

1. Source off-leakage current
2. Drain off-leakage current

Source off-leakage current is defined as the leakage current flowing into or out of the source pin when the switch is off. This current is denoted by the symbol  $I_{S(OFF)}$ .

Drain off-leakage current is defined as the leakage current flowing into or out of the drain pin when the switch is off. This current is denoted by the symbol  $I_{D(OFF)}$ .

The setup used to measure both types of off-leakage currents is shown in Figure 27.



**Figure 27. Off-Leakage Measurement Setup**



## 8.4 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 28 shows the circuit used for measuring the on-leakage current, denoted by  $I_{D(ON)}$ .

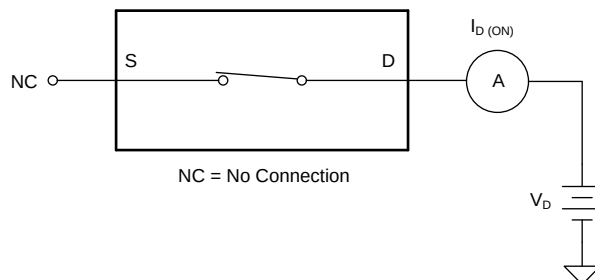
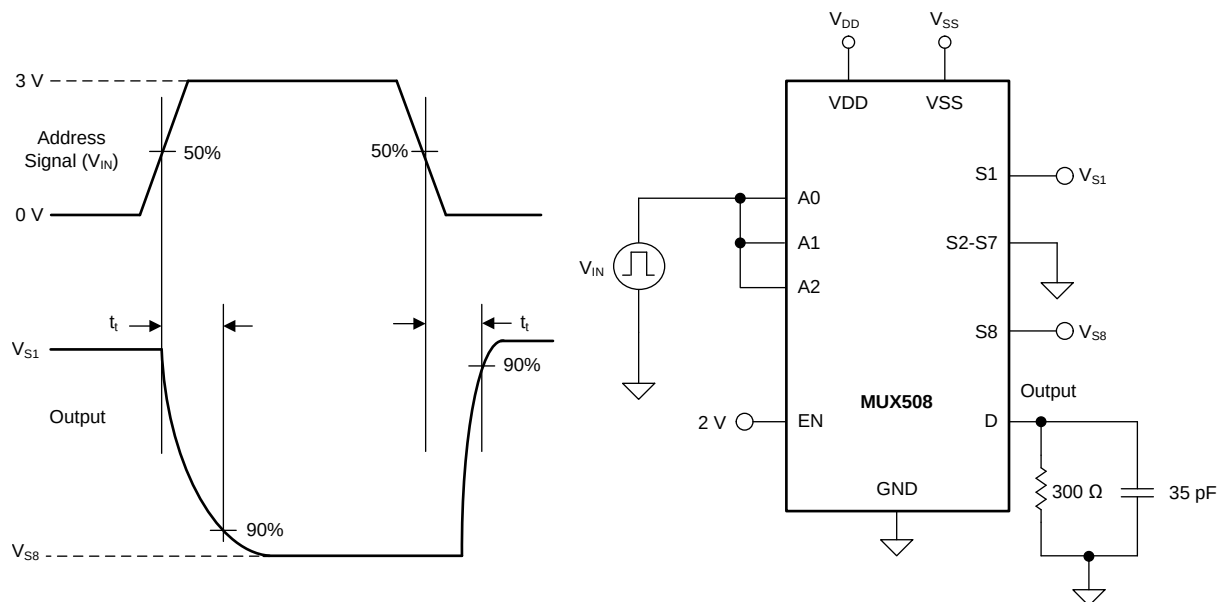


Figure 28. On-Leakage Measurement Setup

## 8.5 Transition Time

Transition time is defined as the time taken by the output of the MUX50x to rise or fall to 90% of the transition after the digital address signal has fallen or risen to the 50% of the transition. Figure 29 shows the setup used to measure transition time, denoted by the symbol  $t_t$ .

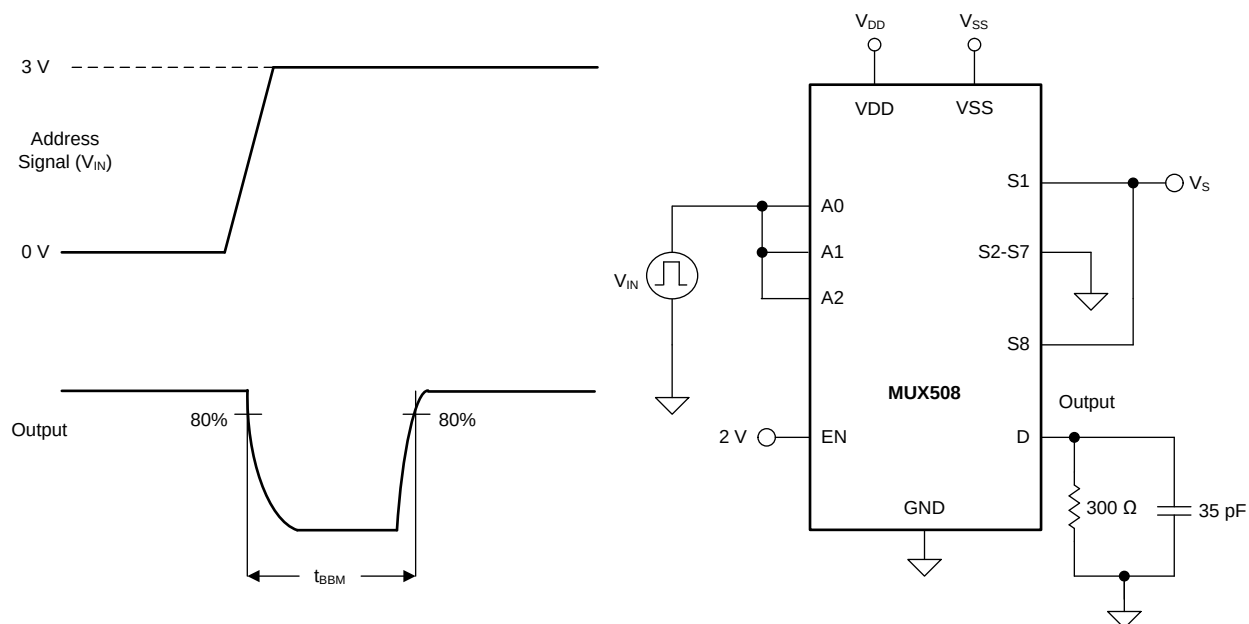


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Figure 29. Transition-Time Measurement Setup

## 8.6 Break-Before-Make Delay

Break-before-make delay is a safety feature that prevents two inputs from connecting when the MUX50x is switching. The MUX50x 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 a break-before-make delay. Figure 30 shows the setup used to measure break-before-make delay, denoted by the symbol  $t_{BBM}$ .



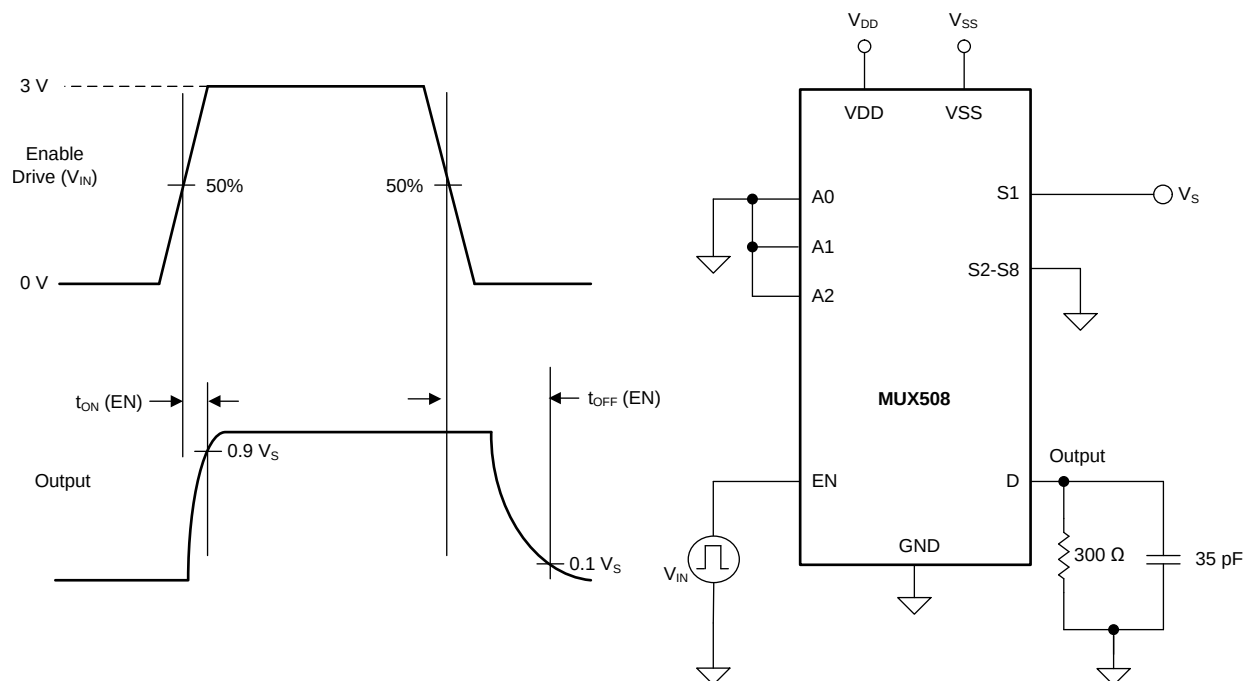
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**Figure 30. Break-Before-Make Delay Measurement Setup**

## 8.7 Turn-On and Turn-Off Time

Turn-on time is defined as the time taken by the output of the MUX50x to rise to a 90% final value after the enable signal has risen to a 50% final value. Figure 31 shows the setup used to measure turn-on time. Turn-on time is denoted by the symbol  $t_{ON}$ .

Turn-off time is defined as the time taken by the output of the MUX50x to fall to a 10% initial value after the enable signal has fallen to a 50% initial value. Figure 31 shows the setup used to measure turn-off time. Turn-off time is denoted by the symbol  $t_{OFF}$ .

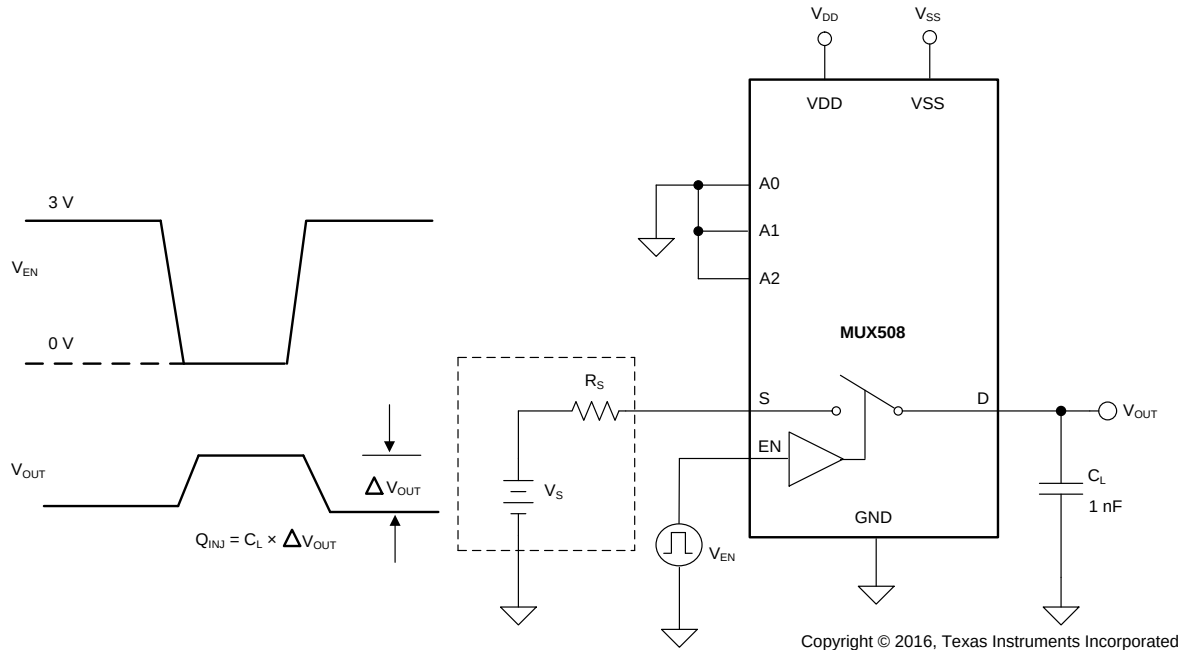


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**Figure 31. Turn-On and Turn-Off Time Measurement Setup**

## 8.8 Charge Injection

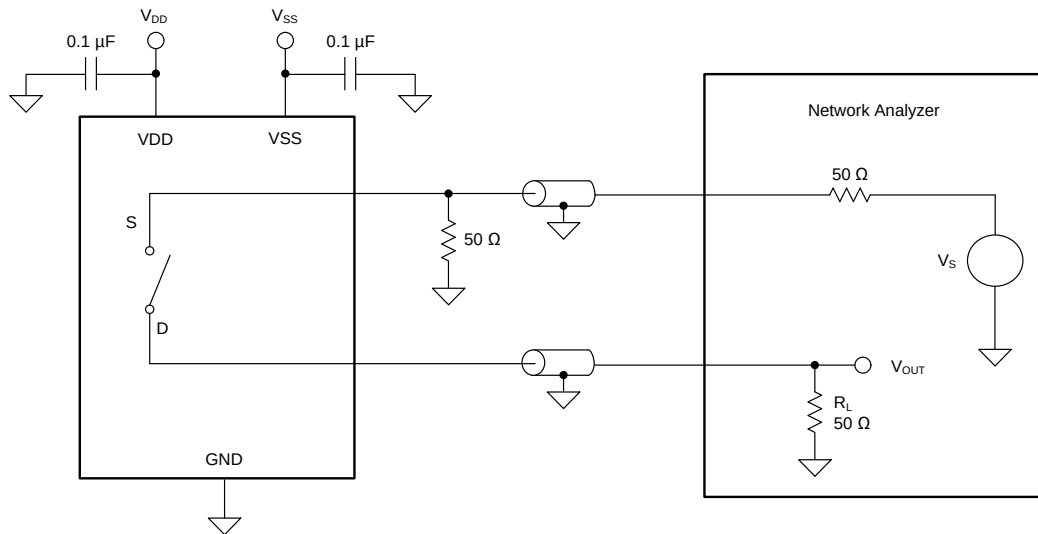
The MUX50x have a simple transmission-gate topology. Any mismatch in capacitance between the NMOS and PMOS transistors results in a charge injected into the drain or source during the falling or rising edge of the gate signal. The amount of charge injected into the source or drain of the device is known as charge injection, and is denoted by the symbol  $Q_{INJ}$ . Figure 32 shows the setup used to measure charge injection.



**Figure 32. Charge-Injection Measurement Setup**

## 8.9 Off Isolation

Off isolation is defined as the voltage at the drain pin (D, DA, or DB) of the MUX50x when a 1- $V_{RMS}$  signal is applied to the source pin (Sx, SxA, or SxB) of an off-channel. Figure 33 shows the setup used to measure off isolation. Use Equation 2 to compute off isolation.

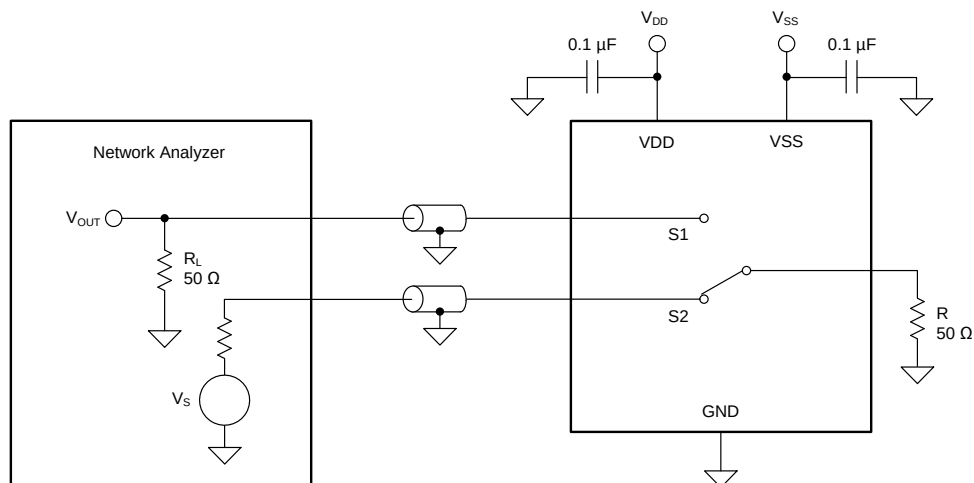


**Figure 33. Off Isolation Measurement Setup**

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

## 8.10 Channel-to-Channel Crosstalk

Channel-to-channel crosstalk is defined as the voltage at the source pin (Sx, SxA, or SxB) of an off-channel, when a 1- $V_{RMS}$  signal is applied at the source pin of an on-channel. Figure 34 shows the setup used to measure, and Equation 3 is the equation used to compute, channel-to-channel crosstalk.

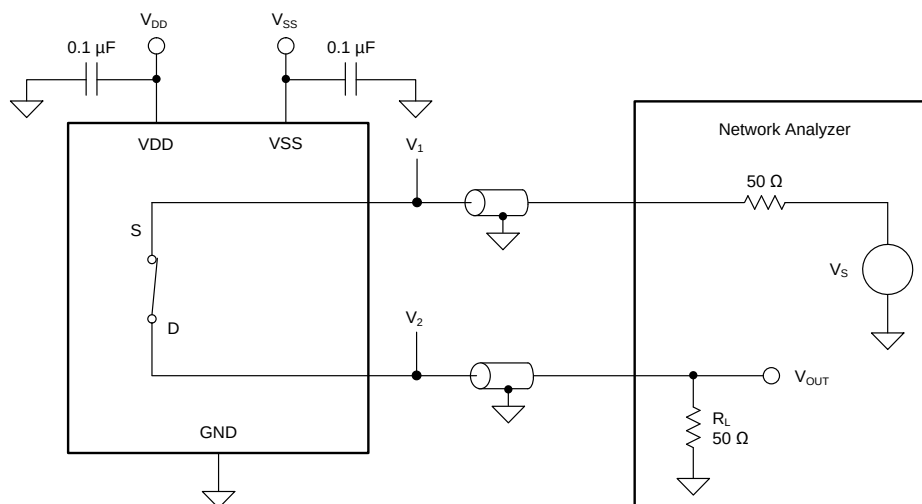


**Figure 34. Channel-to-Channel Crosstalk Measurement Setup**

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

## 8.11 Bandwidth

Bandwidth is defined as the range of frequencies that are attenuated by < 3 dB when the input is applied to the source pin of an on-channel and the output is measured at the drain pin of the MUX50x. [Figure 35](#) shows the setup used to measure bandwidth of the mux. Use [Equation 4](#) to compute the attenuation.

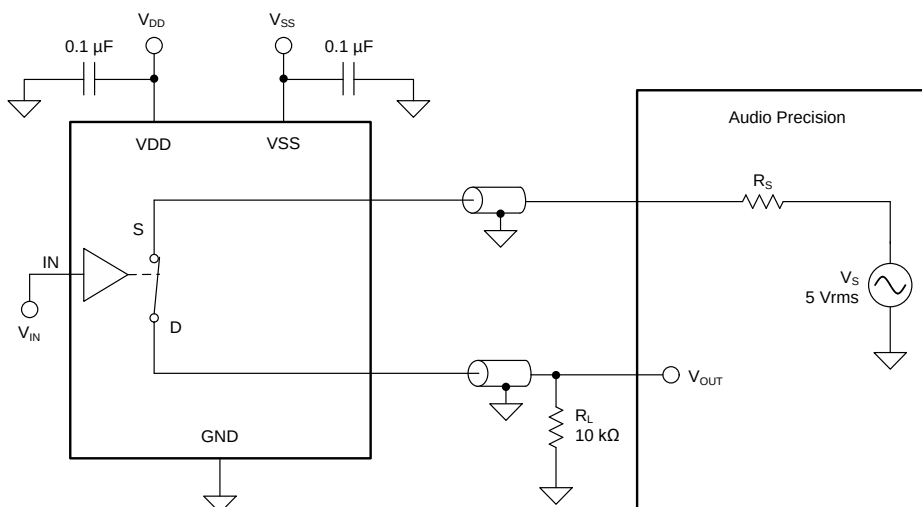


**Figure 35. Bandwidth Measurement Setup**

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

## 8.12 THD + Noise

The total harmonic distortion (THD) of a signal 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 MUX50x 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 36](#) shows the setup used to measure the THD+N of the MUX50x.



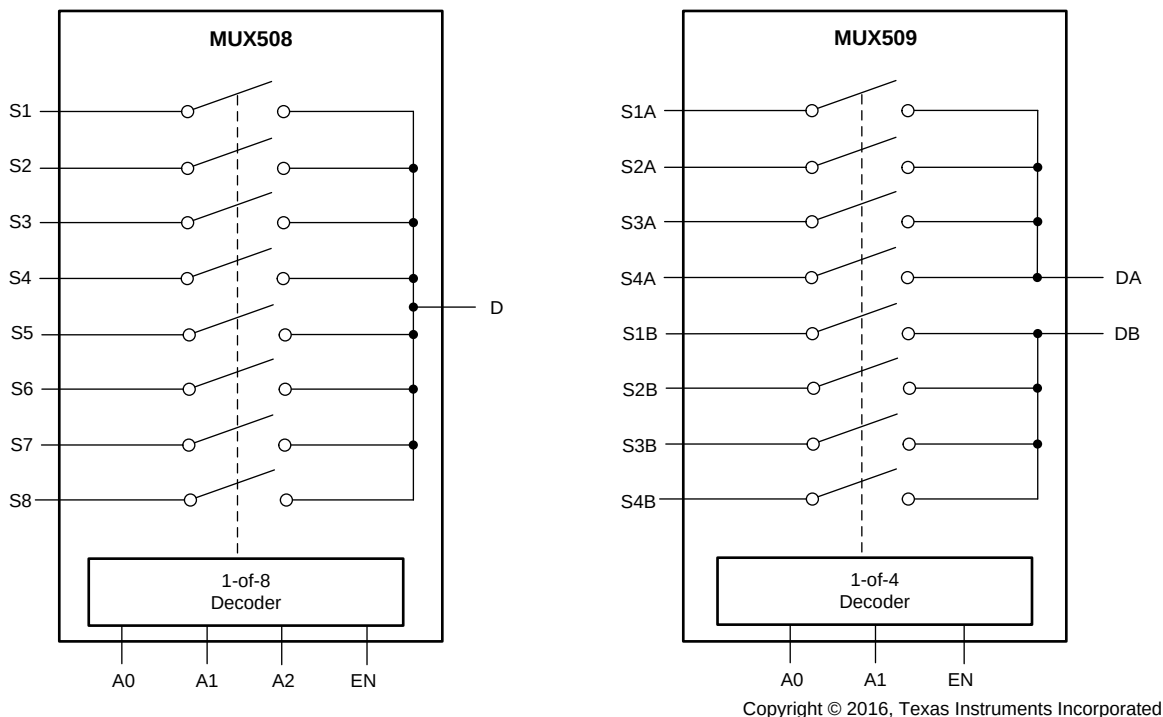
**Figure 36. THD+N Measurement Setup**

## 9 Detailed Description

### 9.1 Overview

The MUX50x are a family of analog multiplexers. The [Functional Block Diagram](#) section provides a top-level block diagram of both the MUX508 and MUX509. The MUX508 is an eight-channel, single-ended, analog mux. The MUX509 is a four-channel, differential or dual 4:1, single-ended, analog mux. Each channel is turned on or turned off based on the state of the address lines and enable pin.

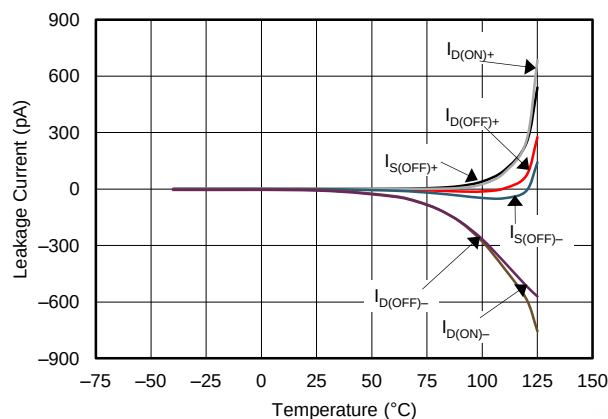
### 9.2 Functional Block Diagram



## 9.3 Feature Description

### 9.3.1 Ultralow Leakage Current

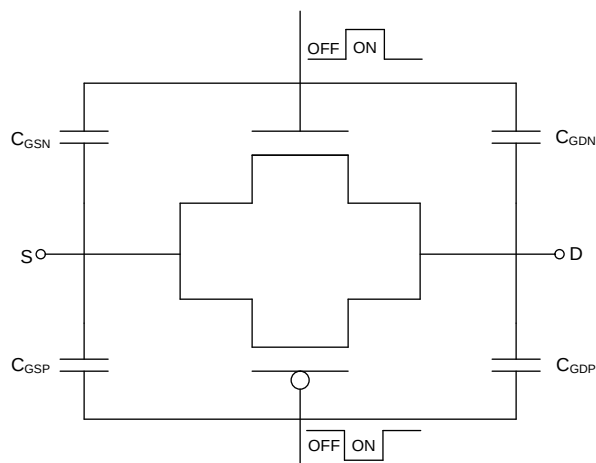
The MUX50x provide extremely low on- and off-leakage currents. The MUX50x are capable of switching signals from high source-impedance inputs into a high input-impedance op amp with minimal offset error because of these ultralow leakage currents. Figure 37 shows typical leakage currents of the MUX50x versus temperature.



**Figure 37. Leakage Current vs Temperature**

### 9.3.2 Ultralow Charge Injection

The MUX50x have a simple transmission gate topology, as shown in Figure 38. Any mismatch in the stray capacitance associated with the NMOS and PMOS transistors creates an output level change whenever the switch is opened or closed.

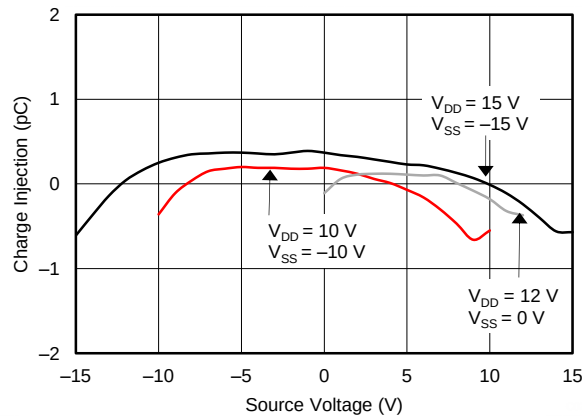


**Figure 38. Transmission Gate Topology**



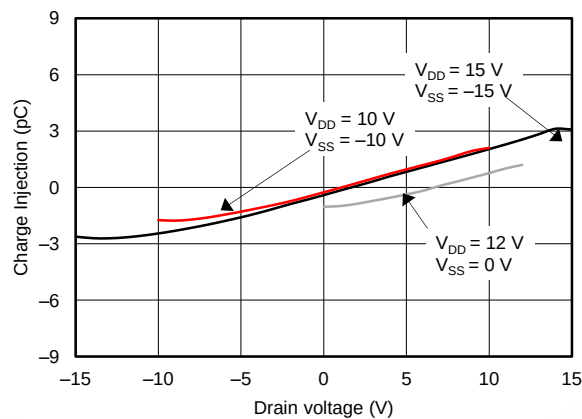
## Feature Description (continued)

The MUX50x have special charge-injection cancellation circuitry that reduces the source-to-drain charge injection to as low as 0.3 pC at  $V_S = 0$  V, and  $\pm 0.6$  pC in the full signal range, as shown in Figure 39.



**Figure 39. Source-to-Drain Charge Injection vs Source or Drain voltage**

The drain-to-source charge injection becomes important when the device is used as a demultiplexer (demux), where D becomes the input and Sx becomes the output. Figure 40 shows the drain-to-source charge injection across the full signal range.



**Figure 40. Drain-to-Source Charge Injection vs Source or Drain voltage**

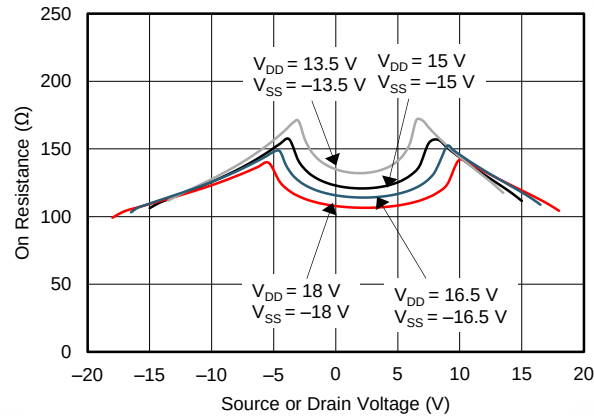
### 9.3.3 Bidirectional Operation

The MUX50x are operable as both a mux or demux. The source (Sx, SxA, SxB) and drain (D, DA, DB) pins of the MUX50x are used either as input or output. Each MUX50x channel has very similar characteristics in both directions.

## Feature Description (continued)

### 9.3.4 Rail-to-Rail Operation

A valid analog signal for the MUX50x ranges from  $V_{SS}$  to  $V_{DD}$ . The input signal to the MUX50x can swing from  $V_{SS}$  to  $V_{DD}$  without any significant degradation in performance. The on-resistance of the MUX50x varies with input signal, as shown in [Figure 41](#).



**Figure 41. On-Resistance vs Source or Drain Voltage**

## 9.4 Device Functional Modes

When the EN pin of the MUX50x is pulled high, one of the switches is closed based on the state of the address lines. When the EN pin is pulled low, all the switches are in an open state irrespective of the state of the address lines. The EN pin can be connected to  $V_{DD}$  (as high as 36 V).

## 10 Applications and Implementation

### NOTE

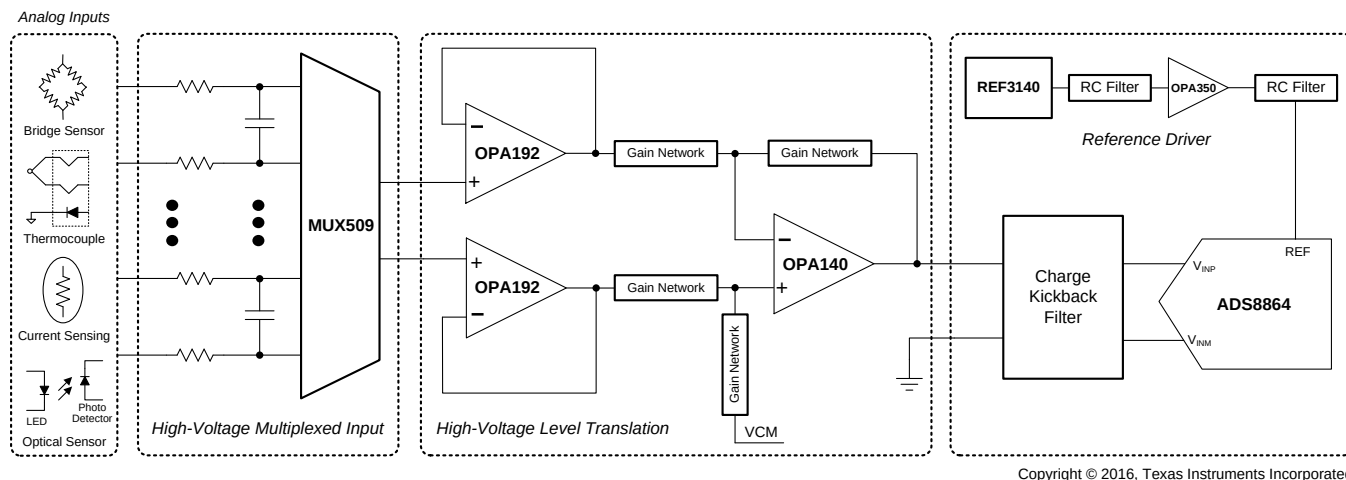
Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation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

### 10.1 Application Information

The MUX50x family offers outstanding input/output leakage currents and ultralow charge injection. These devices operate up to 36 V, and offer true rail-to-rail input and output. The on-capacitance of the MUX50x is very low. These features makes the MUX50x a precision, robust, high-performance analog multiplexer for high-voltage, industrial applications.

### 10.2 Typical Application

Figure 42 shows a 16-bit, differential, four-channel, multiplexed, data-acquisition system. This example is typical in industrial applications that require low distortion and a high-voltage differential input. The circuit uses the ADS8864, a 16-bit, 400-kSPS successive-approximation-resistor (SAR) analog-to-digital converter (ADC), along with a precision, high-voltage, signal-conditioning front end, and a four-channel differential mux. This application example details the process for optimizing a precision, high-voltage, front-end drive circuit using the MUX509, OPA192 and OPA140 to achieve excellent dynamic performance and linearity with the ADS8864.



**Figure 42. 16-Bit Precision Multiplexed Data-Acquisition System for High-Voltage Inputs With Lowest Distortion**

#### 10.2.1 Design Requirements

The primary objective is to design a  $\pm 20$  V, differential, four-channel, multiplexed, data-acquisition system with lowest distortion using the 16-bit ADS8864 at a throughput of 400 kSPS for a 10-kHz, full-scale, pure, sine-wave input. The design requirements for this block design are:

- System supply voltage:  $\pm 15$  V
- ADC supply voltage: 3.3 V
- ADC sampling rate: 400 kSPS
- ADC reference voltage (REFP): 4.096 V
- System input signal: A high-voltage differential input signal with a peak amplitude of 20 V and frequency ( $f_{IN}$ ) of 10 kHz are applied to each differential input of the mux.

## Typical Application (continued)

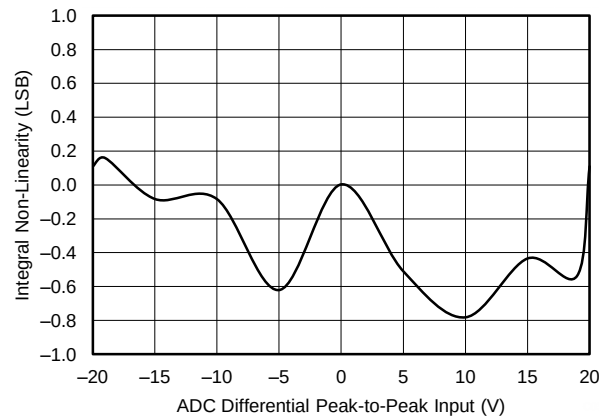
### 10.2.2 Detailed Design Procedure

The purpose of this precision design is to design an optimal, high-voltage, multiplexed, data-acquisition system for highest system linearity and fast settling. The overall system block diagram is illustrated in [Figure 42](#). The circuit is a multichannel, data-acquisition signal chain consisting of an input low-pass filter, mux, mux output buffer, attenuating SAR ADC driver, and the reference driver. The architecture allows fast sampling of multiple channels using a single ADC, providing a low-cost solution. This design systematically approaches each analog circuit block to achieve a 16-bit settling for a full-scale input stage voltage and linearity for a 10-kHz sinusoidal input signal at each input channel.



For step-by-step design procedure, circuit schematics, bill of materials, PCB files, simulation results, and test results, see [TI Precision Design TIPD151, 16-Bit, 400-kSPS, 4-Channel Multiplexed Data-Acquisition System for High-Voltage Inputs with Lowest Distortion](#).

### 10.2.3 Application Curve

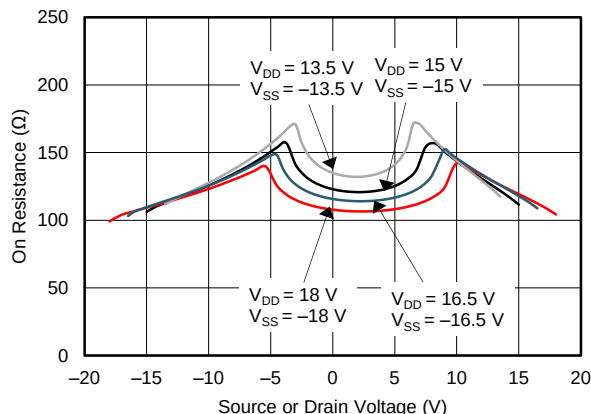


**Figure 43. ADC 16-Bit Linearity Error for the Multiplexed Data-Acquisition Block**

## 11 Power-Supply Recommendations

The MUX50x operates across a wide supply range of  $\pm 5$  V to  $\pm 18$  V (10 V to 36 V in single-supply mode). The MUX508 and MUX509 operate equally well with either dual supplies ( $\pm 5$  V to  $\pm 18$  V), or a single supply (10 V to 36 V). They also perform well with unsymmetric supplies such as  $V_{DD} = 12$  V and  $V_{SS} = -5$  V. For reliable operation, use a supply decoupling capacitor with a capacitance between 0.1  $\mu$ F to 10  $\mu$ F at both the VDD and VSS pins to ground.

The on-resistance of the MUX50x varies with supply voltage, as shown in [Figure 44](#).



**Figure 44. On-Resistance Variation With Supply and Input Voltage**

## 12 Layout

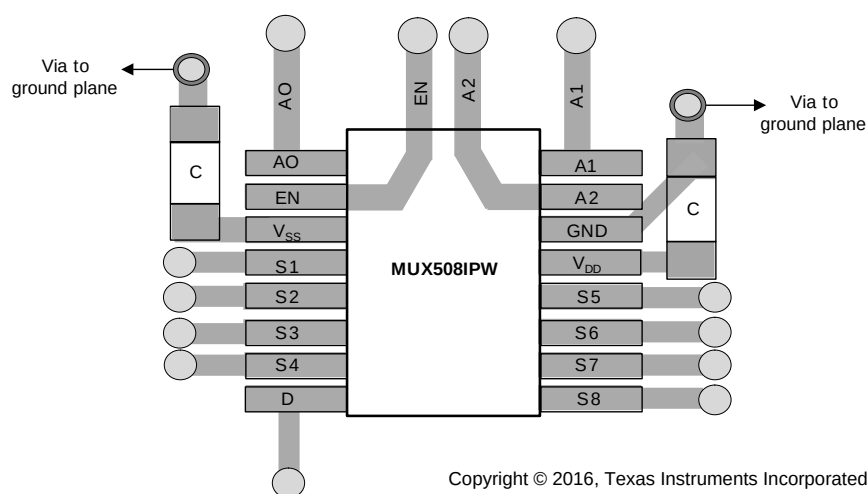
### 12.1 Layout Guidelines

Figure 45 shows an example of a PCB layout with the MUX508IPW, and Figure 46 shows an example of a PCB layout with MUX509IPW. The guidelines provided in this section are also applicable to the SOIC MUX508ID and MUX509ID package variants as well.

Some key considerations are:

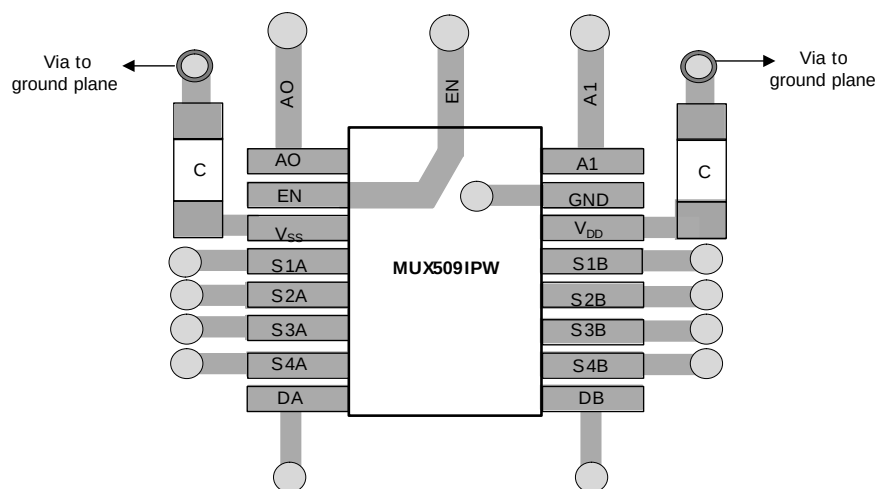
1. Decouple the VDD and VSS pins with a 0.1- $\mu$ F capacitor, placed as close to the pin as possible. Make sure that the capacitor voltage rating is sufficient for the  $V_{DD}$  and  $V_{SS}$  supplies.
2. Keep the input lines as small as possible. For the MUX509 differential signals, make sure the A inputs and B inputs are as symmetric 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.

### 12.2 Layout Example



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**Figure 45. MUX508IPW Layout Example**



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**Figure 46. MUX509IPW Layout Example**

## 13 Device and Documentation Support

### 13.1 Documentation Support

#### 13.1.1 Related Documentation

- [ADS866x 12-Bit, 500-kSPS, 4- and 8-Channel, Single-Supply, SAR ADCs with Bipolar Input Ranges](#) (SBAS492)
- [OPAx140 High-Precision, Low-Noise, Rail-to-Rail Output, 11-MHz JFET Op Amp](#) (SBOS498)
- [OPAx192 36-V, Precision, Rail-to-Rail Input/Output, Low Offset Voltage, Low Input Bias Current Op Amp with e-trim™](#) (SBOS620)

### 13.2 Related Links

[Table 3](#) lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

**Table 3. Related Links**

| PARTS  | PRODUCT FOLDER             | SAMPLE & BUY               | TECHNICAL DOCUMENTS        | TOOLS & SOFTWARE           | SUPPORT & COMMUNITY        |
|--------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| MUX508 | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |
| MUX509 | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |

### 13.3 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.

### 13.4 Community Resources

The following links connect to TI community resources. Linked contents are 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](#).

**TI E2E™ Online Community** *TI's Engineer-to-Engineer (E2E) Community*. Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

**Design Support** *TI's Design Support* Quickly find helpful E2E forums along with design support tools and contact information for technical support.

### 13.5 Trademarks

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All other trademarks are the property of their respective owners.

### 13.6 Electrostatic Discharge Caution



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

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

### 13.7 Glossary

[SLYZ022](#) — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

## 14 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<br>(1) | Material type<br>(2) | Package   Pins  | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|----------------------------|---------------|----------------------|-----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">MUX508ID</a>   | Active        | Production           | SOIC (D)   16   | 40   TUBE             | Yes         | NIPDAU   SN                          | Level-2-260C-1 YEAR               | -40 to 125   | M36508D             |
| MUX508ID.B                 | Active        | Production           | SOIC (D)   16   | 40   TUBE             | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | M36508D             |
| <a href="#">MUX508IDR</a>  | Active        | Production           | SOIC (D)   16   | 2500   LARGE T&R      | Yes         | NIPDAU   SN                          | Level-2-260C-1 YEAR               | -40 to 125   | M36508D             |
| MUX508IDR.B                | Active        | Production           | SOIC (D)   16   | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | M36508D             |
| <a href="#">MUX508IPW</a>  | Active        | Production           | TSSOP (PW)   16 | 90   TUBE             | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | MUX508B             |
| MUX508IPW.B                | Active        | Production           | TSSOP (PW)   16 | 90   TUBE             | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | MUX508B             |
| <a href="#">MUX508IPWR</a> | Active        | Production           | TSSOP (PW)   16 | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | MUX508B             |
| MUX508IPWR.B               | Active        | Production           | TSSOP (PW)   16 | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | MUX508B             |
| MUX508IPWRG4               | Active        | Production           | TSSOP (PW)   16 | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | MUX508B             |
| MUX508IPWRG4.B             | Active        | Production           | TSSOP (PW)   16 | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | MUX508B             |
| <a href="#">MUX509ID</a>   | Active        | Production           | SOIC (D)   16   | 40   TUBE             | Yes         | NIPDAU   SN                          | Level-2-260C-1 YEAR               | -40 to 125   | M36509D             |
| MUX509ID.B                 | Active        | Production           | SOIC (D)   16   | 40   TUBE             | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | M36509D             |
| <a href="#">MUX509IDR</a>  | Active        | Production           | SOIC (D)   16   | 2500   LARGE T&R      | Yes         | NIPDAU   SN                          | Level-2-260C-1 YEAR               | -40 to 125   | M36509D             |
| MUX509IDR.B                | Active        | Production           | SOIC (D)   16   | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | M36509D             |
| <a href="#">MUX509IPW</a>  | Active        | Production           | TSSOP (PW)   16 | 90   TUBE             | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | MUX509C             |
| MUX509IPW.B                | Active        | Production           | TSSOP (PW)   16 | 90   TUBE             | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | MUX509C             |
| <a href="#">MUX509IPWR</a> | Active        | Production           | TSSOP (PW)   16 | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | MUX509C             |
| MUX509IPWR.B               | Active        | Production           | TSSOP (PW)   16 | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | MUX509C             |
| MUX509IPWRG4               | Active        | Production           | TSSOP (PW)   16 | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | MUX509C             |
| MUX509IPWRG4.B             | Active        | Production           | TSSOP (PW)   16 | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | MUX509C             |

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

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

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

(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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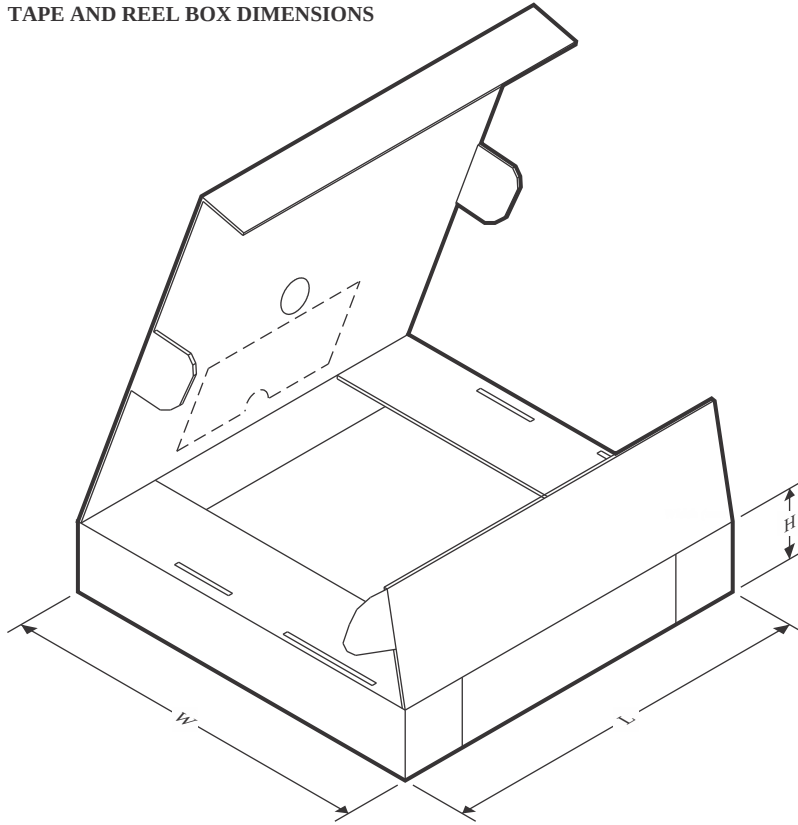
## TAPE AND REEL INFORMATION



\*All dimensions are nominal

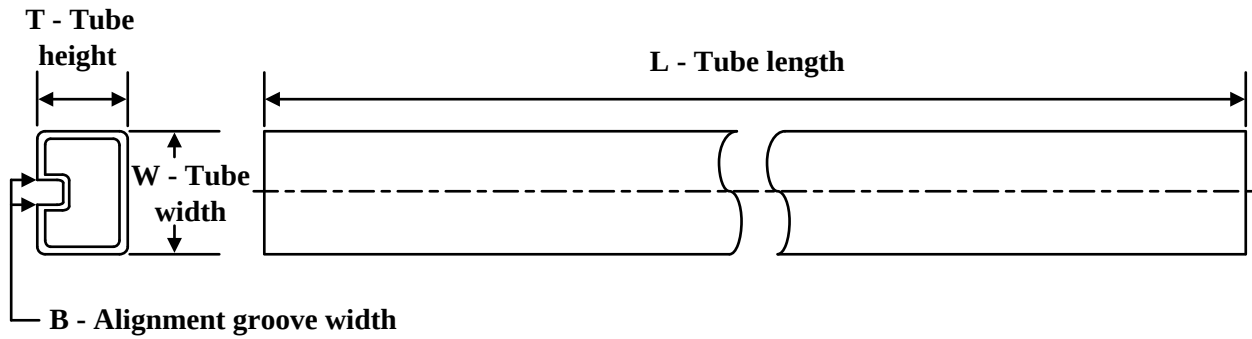
| Device       | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|--------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| MUX508IPWR   | TSSOP        | PW              | 16   | 2000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |
| MUX508IPWRG4 | TSSOP        | PW              | 16   | 2000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |
| MUX509IPWR   | TSSOP        | PW              | 16   | 2000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |
| MUX509IPWRG4 | 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) |
|--------------|--------------|-----------------|------|------|-------------|------------|-------------|
| MUX508IPWR   | TSSOP        | PW              | 16   | 2000 | 353.0       | 353.0      | 32.0        |
| MUX508IPWRG4 | TSSOP        | PW              | 16   | 2000 | 353.0       | 353.0      | 32.0        |
| MUX509IPWR   | TSSOP        | PW              | 16   | 2000 | 353.0       | 353.0      | 32.0        |
| MUX509IPWRG4 | TSSOP        | PW              | 16   | 2000 | 353.0       | 353.0      | 32.0        |

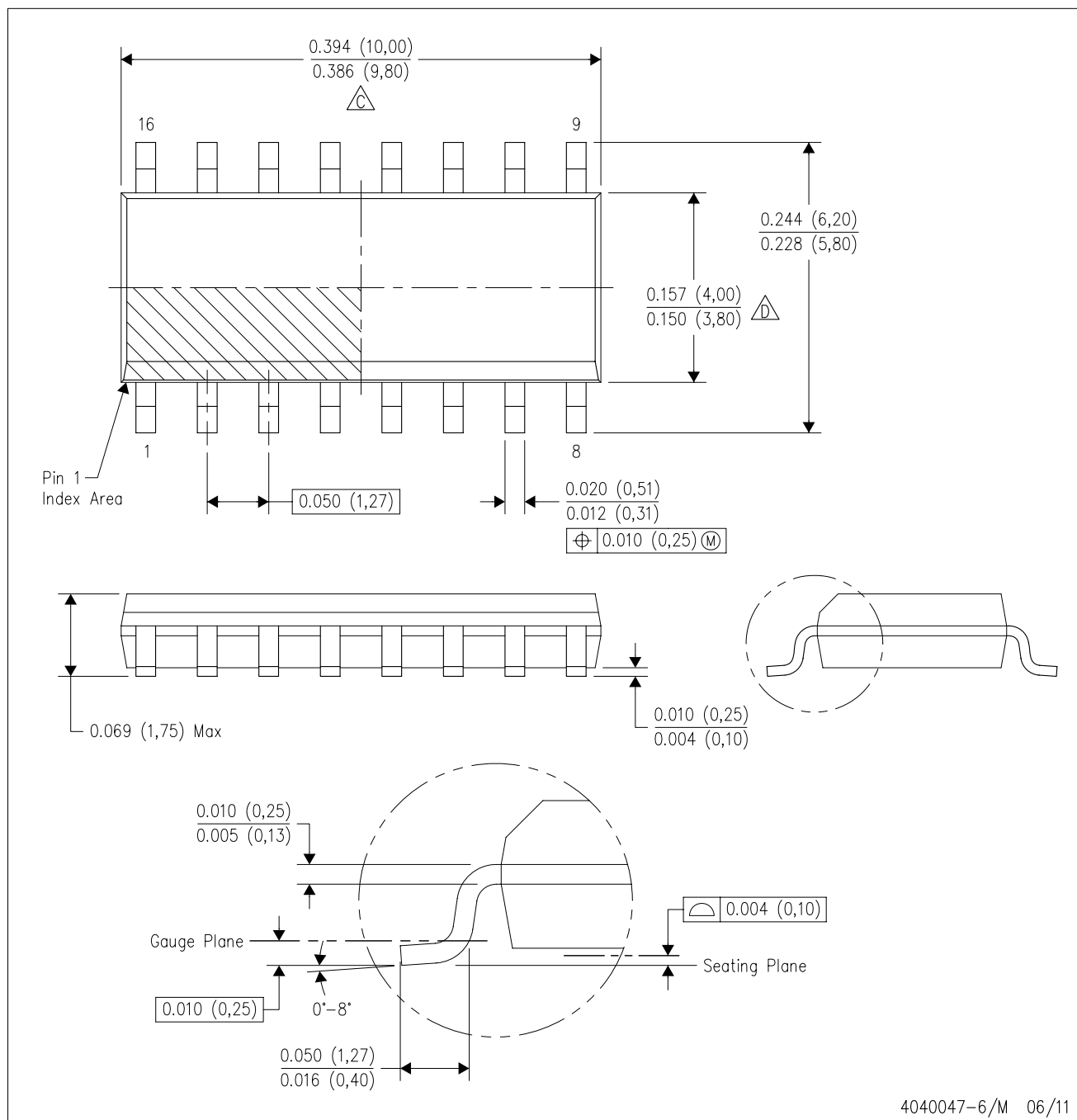
**TUBE**


\*All dimensions are nominal

| Device      | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (μm) | B (mm) |
|-------------|--------------|--------------|------|-----|--------|--------|--------|--------|
| MUX508ID    | D            | SOIC         | 16   | 40  | 517    | 7.87   | 635    | 4.25   |
| MUX508ID    | D            | SOIC         | 16   | 40  | 507    | 8      | 3940   | 4.32   |
| MUX508ID.B  | D            | SOIC         | 16   | 40  | 517    | 7.87   | 635    | 4.25   |
| MUX508ID.B  | D            | SOIC         | 16   | 40  | 507    | 8      | 3940   | 4.32   |
| MUX508IPW   | PW           | TSSOP        | 16   | 90  | 530    | 10.2   | 3600   | 3.5    |
| MUX508IPW.B | PW           | TSSOP        | 16   | 90  | 530    | 10.2   | 3600   | 3.5    |
| MUX509ID    | D            | SOIC         | 16   | 40  | 507    | 8      | 3940   | 4.32   |
| MUX509ID    | D            | SOIC         | 16   | 40  | 517    | 7.87   | 635    | 4.25   |
| MUX509ID.B  | D            | SOIC         | 16   | 40  | 517    | 7.87   | 635    | 4.25   |
| MUX509ID.B  | D            | SOIC         | 16   | 40  | 507    | 8      | 3940   | 4.32   |
| MUX509IPW   | PW           | TSSOP        | 16   | 90  | 530    | 10.2   | 3600   | 3.5    |
| MUX509IPW.B | PW           | TSSOP        | 16   | 90  | 530    | 10.2   | 3600   | 3.5    |

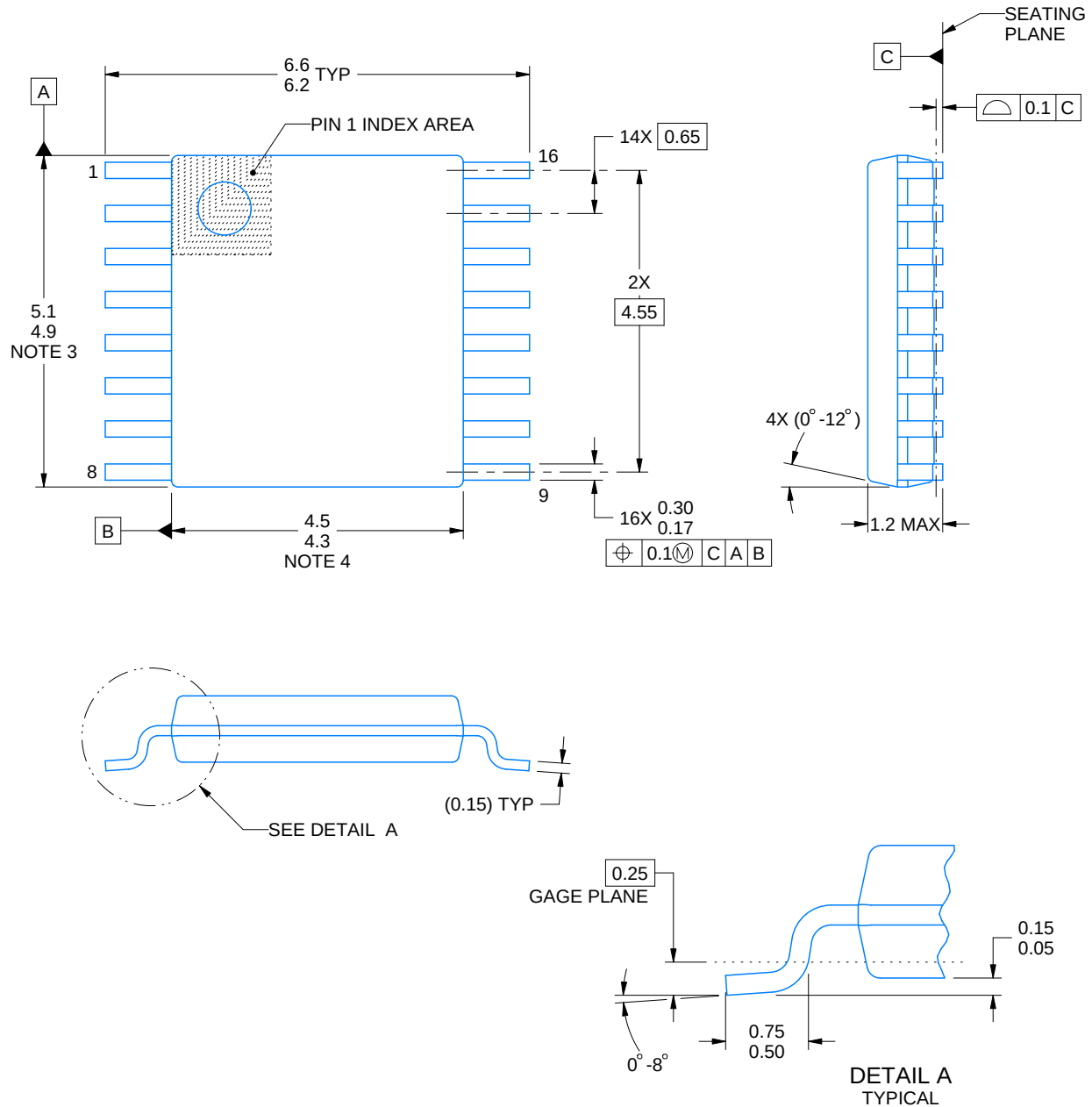
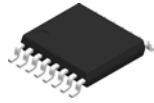
D (R-PDSO-G16)

PLASTIC SMALL OUTLINE



NOTES:

- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- $\triangle C$  Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
- $\triangle D$  Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
- E. Reference JEDEC MS-012 variation AC.



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## NOTES:

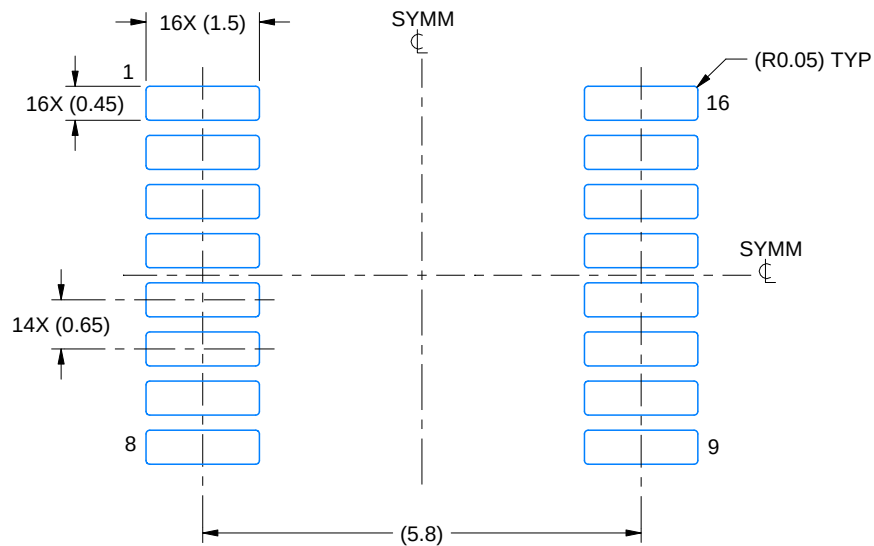
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or 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

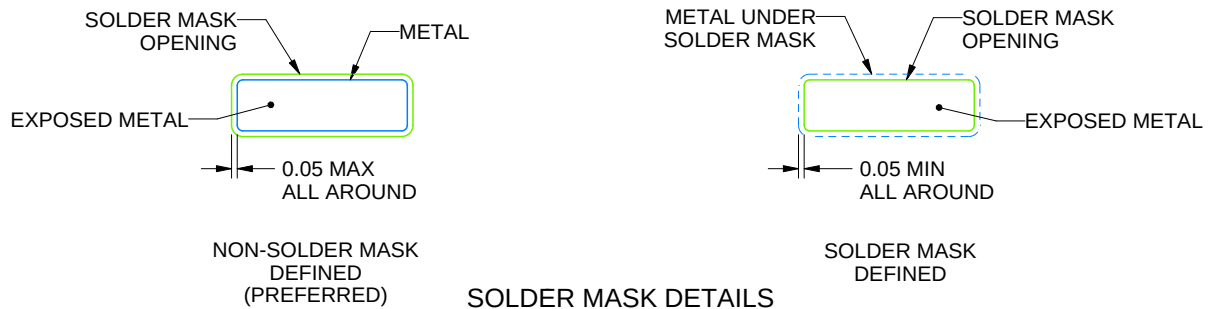
PW0016A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 10X



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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.

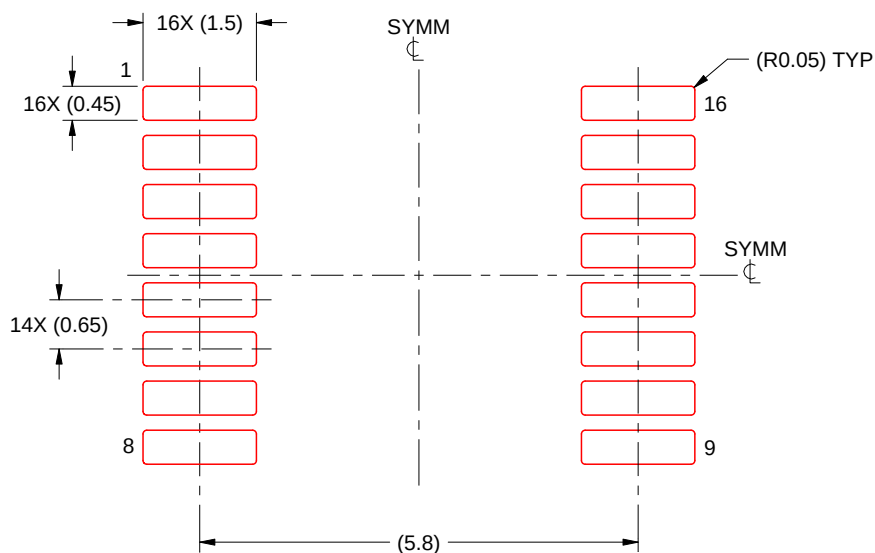


# EXAMPLE STENCIL DESIGN

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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