

## TS5A3166 0.9-Ω SPST Analog Switch

### 1 Features

- Low ON-State Resistance (0.9 Ω)
- Control Inputs Are 5.5-V Tolerant
- Low Charge Injection
- Low Total Harmonic Distortion (THD)
- 1.65-V to 5.5-V Single-Supply Operation
- Latch-Up Performance Exceeds 100 mA Per JESD 78, Class II
- ESD Performance Tested Per JESD 22
  - 2000-V Human-Body Model (A114-B, Class II)
  - 1000-V Charged-Device Model (C101)

### 2 Applications

- Cell Phones
- PDAs
- Portable Instrumentation
- Audio and Video Signal Routing
- Low-Voltage Data-Acquisition Systems
- Communication Circuits
- Modems
- Hard Drives
- Computer Peripherals
- Wireless Terminals and Peripherals
- Microphone Switching – Notebook Docking

### 3 Description

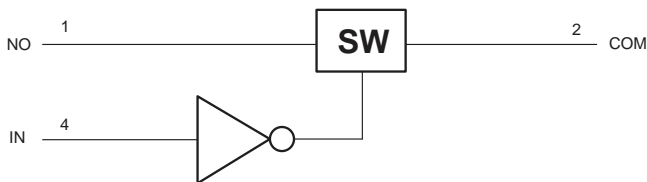
The TS5A3166 device is a single-pole single-throw (SPST) analog switch that is designed to operate from 1.65 V to 5.5 V. The device offers a low ON-state resistance. The device has excellent total harmonic distortion (THD) performance and consumes very low power. These features make this device suitable for portable audio applications.

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

| PART NUMBER | PACKAGE    | BODY SIZE (NOM)     |
|-------------|------------|---------------------|
| TS5A3166    | SOT-23 (5) | 2.90 mm × 1.60 mm   |
|             | SC70 (5)   | 2.00 mm × 1.25 mm   |
|             | DSBGA (5)  | 1.388 mm × 0.888 mm |

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

#### Simplified Schematic



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## Table of Contents

|                                                       |           |                                                                  |           |
|-------------------------------------------------------|-----------|------------------------------------------------------------------|-----------|
| <b>1 Features</b> .....                               | <b>1</b>  | 8.2 Functional Block Diagram .....                               | <b>16</b> |
| <b>2 Applications</b> .....                           | <b>1</b>  | 8.3 Feature Description .....                                    | <b>16</b> |
| <b>3 Description</b> .....                            | <b>1</b>  | 8.4 Device Functional Modes .....                                | <b>16</b> |
| <b>4 Revision History</b> .....                       | <b>2</b>  | <b>9 Application and Implementation</b> .....                    | <b>17</b> |
| <b>5 Pin Configuration and Functions</b> .....        | <b>3</b>  | 9.1 Application Information .....                                | <b>17</b> |
| <b>6 Specifications</b> .....                         | <b>3</b>  | 9.2 Typical Application .....                                    | <b>18</b> |
| 6.1 Absolute Maximum Ratings .....                    | <b>3</b>  | <b>10 Power Supply Recommendations</b> .....                     | <b>19</b> |
| 6.2 ESD Ratings .....                                 | <b>4</b>  | <b>11 Layout</b> .....                                           | <b>20</b> |
| 6.3 Recommended Operating Conditions .....            | <b>4</b>  | 11.1 Layout Guidelines .....                                     | <b>20</b> |
| 6.4 Thermal Information .....                         | <b>4</b>  | 11.2 Layout Example .....                                        | <b>20</b> |
| 6.5 Electrical Characteristics for 5-V Supply .....   | <b>4</b>  | <b>12 Device and Documentation Support</b> .....                 | <b>21</b> |
| 6.6 Electrical Characteristics for 3.3-V Supply ..... | <b>6</b>  | 12.1 Device Support .....                                        | <b>21</b> |
| 6.7 Electrical Characteristics for 2.5-V Supply ..... | <b>7</b>  | 12.2 Community Resources .....                                   | <b>22</b> |
| 6.8 Electrical Characteristics for 1.8-V Supply ..... | <b>9</b>  | 12.3 Trademarks .....                                            | <b>22</b> |
| 6.9 Typical Characteristics .....                     | <b>11</b> | 12.4 Electrostatic Discharge Caution .....                       | <b>22</b> |
| <b>7 Parameter Measurement Information</b> .....      | <b>13</b> | 12.5 Glossary .....                                              | <b>22</b> |
| <b>8 Detailed Description</b> .....                   | <b>16</b> | <b>13 Mechanical, Packaging, and Orderable Information</b> ..... | <b>22</b> |
| 8.1 Overview .....                                    | <b>16</b> |                                                                  |           |

## 4 Revision History

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

| <b>Changes from Revision D (February 2016) to Revision E</b> | <b>Page</b> |
|--------------------------------------------------------------|-------------|
| • Changed the YZP package pin numbers .....                  | <b>3</b>    |

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| <b>Changes from Revision C (May 2015) to Revision D</b>                      | <b>Page</b> |
|------------------------------------------------------------------------------|-------------|
| • Added "port" to COM description in <i>Pin Functions</i> table .....        | <b>3</b>    |
| • Deleted "digital" from GND description in <i>Pin Functions</i> table ..... | <b>3</b>    |

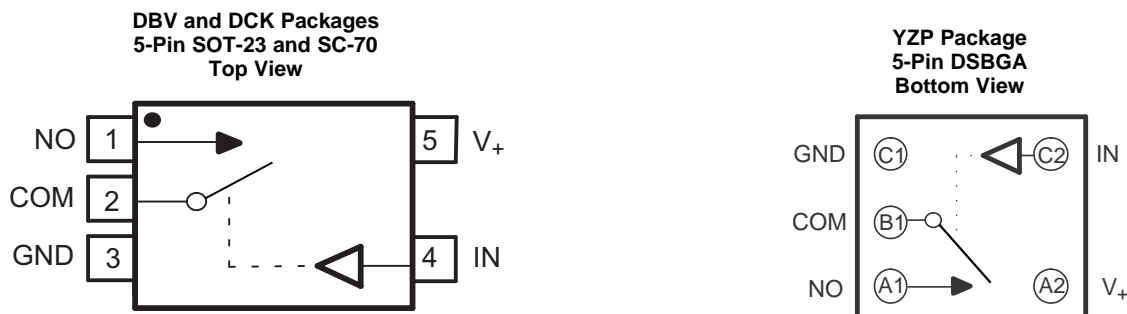
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| <b>Changes from Revision B (September 2013) to Revision C</b>                                                                                                                                                                                                                                                                                                                                                                                                                                              | <b>Page</b> |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|
| • Added <i>Applications</i> , <i>Device Information</i> table, <i>Pin Functions</i> table, <i>ESD Ratings</i> table, <i>Thermal Information</i> table, <i>Typical Characteristics</i> , <i>Feature Description</i> section, <i>Device Functional Modes</i> , <i>Application and Implementation</i> section, <i>Power Supply Recommendations</i> section, <i>Layout</i> section, <i>Device and Documentation Support</i> section, and <i>Mechanical, Packaging, and Orderable Information</i> section. .... | <b>1</b>    |
| • Deleted <i>Ordering Information</i> table. ....                                                                                                                                                                                                                                                                                                                                                                                                                                                          | <b>1</b>    |

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| <b>Changes from Revision A (October 2012) to Revision B</b>                             | <b>Page</b> |
|-----------------------------------------------------------------------------------------|-------------|
| • Removed 'Isolation in Powered-Off Mode, $V_+ = 0$ ' bullet from <i>Features</i> ..... | <b>1</b>    |
| • Changed pin name from NC to NO throughout the datasheet. ....                         | <b>1</b>    |

## 5 Pin Configuration and Functions


**Pin Functions**

| PIN          |         | NAME           | TYPE  | DESCRIPTION                              |
|--------------|---------|----------------|-------|------------------------------------------|
| DBC, DCK NO. | YZP NO. |                |       |                                          |
| 1            | A1      | NO             | I/O   | Normally opened port                     |
| 2            | B1      | COM            | I/O   | Common port                              |
| 3            | C1      | GND            | GND   | Ground                                   |
| 4            | C2      | IN             | I     | Digital control pin to connect COM to NO |
| 5            | A2      | V <sub>+</sub> | Power | Power Supply                             |

## 6 Specifications

### 6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)<sup>(1)(2)</sup>

|                                     |                                                                        | MIN                                                      | MAX                  | UNIT       |
|-------------------------------------|------------------------------------------------------------------------|----------------------------------------------------------|----------------------|------------|
| V <sub>+</sub>                      | Supply voltage <sup>(3)</sup>                                          | -0.5                                                     | 6.5                  | V          |
| V <sub>NO</sub><br>V <sub>COM</sub> | Analog voltage <sup>(3)(4)(5)</sup>                                    | -0.5                                                     | V <sub>+</sub> + 0.5 | V          |
| I <sub>K</sub>                      | Analog port diode current                                              | V <sub>NO</sub> , V <sub>COM</sub> < 0                   |                      | mA         |
| I <sub>NO</sub><br>I <sub>COM</sub> | ON-state switch current<br>ON-state peak switch current <sup>(6)</sup> | V <sub>NO</sub> , V <sub>COM</sub> = 0 to V <sub>+</sub> |                      | mA         |
| V <sub>I</sub>                      | Digital input voltage <sup>(3)(4)</sup>                                | -0.5                                                     | 6.5                  | V          |
| I <sub>IK</sub>                     | Digital clamp current                                                  | V <sub>I</sub> < 0                                       |                      | mA         |
| I <sub>+</sub>                      | Continuous current through V <sub>+</sub>                              |                                                          |                      | 100<br>mA  |
| I <sub>GND</sub>                    | Continuous current through GND                                         |                                                          |                      | -100<br>mA |
| T <sub>stg</sub>                    | Storage temperature                                                    | -65                                                      | 150                  | °C         |
| T <sub>j</sub>                      | Junction temperature                                                   |                                                          |                      | 150<br>°C  |

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) The algebraic convention, whereby the most negative value is a minimum and the most positive value is a maximum
- (3) All voltages are with respect to ground, unless otherwise specified.
- (4) The input and output voltage ratings may be exceeded if the input and output clamp-current ratings are observed.
- (5) This value is limited to 5.5 V maximum.
- (6) Pulse at 1-ms duration < 10% duty cycle.

## 6.2 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> | ±1000 |      |

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

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

## 6.3 Recommended Operating Conditions

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

|           |                                | MIN  | MAX   | UNIT |
|-----------|--------------------------------|------|-------|------|
| $V_{I/O}$ | Input/output voltage           | 0    | $V_+$ | V    |
| $V_+$     | Supply voltage                 | 1.65 | 5.5   | V    |
| $V_I$     | Control Input Voltage          | 0    | 5.5   | V    |
| $T_A$     | Operating free-air temperature | −40  | 85    | °C   |

## 6.4 Thermal Information

| THERMAL METRIC <sup>(1)</sup>                          | TS5A3166  |             |             | UNIT |
|--------------------------------------------------------|-----------|-------------|-------------|------|
|                                                        | DBV (SOT) | DCK (SC-70) | YZP (DSBGA) |      |
|                                                        | 5 PINS    | 5 PINS      | 5 PINS      |      |
| $R_{\theta JA}$ Junction-to-ambient thermal resistance | 206       | 252         | 132         | °C/W |

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, [SPRA953](#).

## 6.5 Electrical Characteristics for 5-V Supply

$V_+ = 4.5\text{ V to }5.5\text{ V}$ ,  $T_A = -40^\circ\text{C to }85^\circ\text{C}$  (unless otherwise noted)<sup>(1)</sup>

| PARAMETER            | TEST CONDITIONS              | $T_A$                                                                                                              | $V_+$                                        | MIN  | TYP   | MAX   | UNIT |          |               |
|----------------------|------------------------------|--------------------------------------------------------------------------------------------------------------------|----------------------------------------------|------|-------|-------|------|----------|---------------|
| <b>Analog Switch</b> |                              |                                                                                                                    |                                              |      |       |       |      |          |               |
| $V_{COM}, V_{NO}$    | Analog signal range          |                                                                                                                    |                                              | 0    |       | $V_+$ | V    |          |               |
| $r_{peak}$           | Peak ON resistance           | $0 \leq V_{NO} \leq V_+$ ,<br>$I_{COM} = -100\text{ mA}$                                                           | Switch ON,<br>see <a href="#">Figure 13</a>  | 25°C | 4.5 V | 0.8   | 1.1  | $\Omega$ |               |
|                      |                              |                                                                                                                    |                                              | Full |       | 1.2   |      |          |               |
| $r_{on}$             | ON-state resistance          | $V_{NO} = 2.5\text{ V}$ ,<br>$I_{COM} = -100\text{ mA}$                                                            | Switch ON,<br>see <a href="#">Figure 13</a>  | 25°C | 4.5 V | 0.7   | 0.9  | $\Omega$ |               |
|                      |                              |                                                                                                                    |                                              | Full |       | 1     |      |          |               |
| $r_{on(flat)}$       | ON-state resistance flatness | $0 \leq V_{NO} \leq V_+$ ,<br>$I_{COM} = -100\text{ mA}$                                                           | Switch ON,<br>see <a href="#">Figure 13</a>  | 25°C | 4.5 V | 0.15  |      | $\Omega$ |               |
|                      |                              |                                                                                                                    |                                              | 25°C |       | 0.09  | 0.15 |          |               |
|                      |                              |                                                                                                                    |                                              | Full |       | 0.15  |      |          |               |
| $I_{NO(OFF)}$        | NO OFF leakage current       | $V_{NO} = 1\text{ V}$ ,<br>$V_{COM} = 4.5\text{ V}$ ,<br>or<br>$V_{NO} = 4.5\text{ V}$ ,<br>$V_{COM} = 1\text{ V}$ | Switch OFF,<br>see <a href="#">Figure 14</a> | 25°C | 5.5 V | −20   | 4    | 20       | nA            |
|                      |                              |                                                                                                                    |                                              | Full |       | −100  | 100  |          |               |
| $I_{NO(PWROFF)}$     |                              | $V_{NO} = 0\text{ to }5.5\text{ V}$ ,<br>$V_{COM} = 5.5\text{ V to }0$                                             |                                              | 25°C | 0 V   | −5    | 0.4  | 5        | $\mu\text{A}$ |
|                      |                              |                                                                                                                    |                                              | Full |       | −15   | 15   |          |               |
| $I_{COM(OFF)}$       | COM OFF leakage current      | $V_{COM} = 1\text{ V}$ ,<br>$V_{NO} = 4.5\text{ V}$ ,<br>or<br>$V_{COM} = 4.5\text{ V}$ ,<br>$V_{NO} = 1\text{ V}$ | Switch OFF,<br>see <a href="#">Figure 14</a> | 25°C | 5.5 V | −20   | 4    | 20       | nA            |
|                      |                              |                                                                                                                    |                                              | Full |       | −100  | 100  |          |               |
| $I_{COM(PWROFF)}$    |                              | $V_{COM} = 5.5\text{ V to }0$ ,<br>$V_{NO} = 0\text{ to }5.5\text{ V}$                                             |                                              | 25°C | 0 V   | −5    | 0.4  | 5        | $\mu\text{A}$ |
|                      |                              |                                                                                                                    |                                              | Full |       | −15   | 15   |          |               |

(1) The algebraic convention, whereby the most negative value is a minimum and the most positive value is a maximum.

**Electrical Characteristics for 5-V Supply (continued)**
 $V_+ = 4.5\text{ V to }5.5\text{ V}$ ,  $T_A = -40^\circ\text{C to }85^\circ\text{C}$  (unless otherwise noted)<sup>(1)</sup>

| PARAMETER                          |                           | TEST CONDITIONS                                                                                                      |                                                                        | $T_A$ | $V_+$          | MIN | TYP    | MAX  | UNIT          |
|------------------------------------|---------------------------|----------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|-------|----------------|-----|--------|------|---------------|
| $I_{NO(ON)}$                       | NO ON leakage current     | $V_{NO} = 1\text{ V}$ ,<br>$V_{COM} = \text{Open}$ ,<br>or<br>$V_{NO} = 4.5\text{ V}$ ,<br>$V_{COM} = \text{Open}$ , | Switch ON,<br>see <a href="#">Figure 15</a>                            | 25°C  | 5.5 V          | -2  | 0.3    | 2    | nA            |
|                                    |                           |                                                                                                                      |                                                                        | Full  |                | -20 | 20     |      |               |
| $I_{COM(ON)}$                      | COM ON leakage current    | $V_{COM} = 1\text{ V}$ ,<br>$V_{NO} = \text{Open}$ ,<br>or<br>$V_{COM} = 4.5\text{ V}$ ,<br>$V_{NO} = \text{Open}$ , | Switch ON,<br>see <a href="#">Figure 15</a>                            | 25°C  | 5.5 V          | -2  | 0.3    | 2    | nA            |
|                                    |                           |                                                                                                                      |                                                                        | Full  |                | -20 | 20     |      |               |
| <b>Digital Control Inputs (IN)</b> |                           |                                                                                                                      |                                                                        |       |                |     |        |      |               |
| $V_{IH}$                           | Input logic high          |                                                                                                                      |                                                                        | Full  |                | 2.4 |        | 5.5  | V             |
| $V_{IL}$                           | Input logic low           |                                                                                                                      |                                                                        | Full  |                | 0   |        | 0.8  | V             |
| $I_{IH}, I_{IL}$                   | Input leakage current     | $V_I = 5.5\text{ V or }0$                                                                                            |                                                                        | 25°C  | 5.5 V          | -2  | 0.3    | 2    | nA            |
|                                    |                           |                                                                                                                      |                                                                        | Full  |                | -20 | 20     |      |               |
| <b>Dynamic</b>                     |                           |                                                                                                                      |                                                                        |       |                |     |        |      |               |
| $t_{ON}$                           | Turnon time               | $V_{COM} = V_+$ ,<br>$R_L = 50\ \Omega$ ,                                                                            | $C_L = 35\text{ pF}$ ,<br>see <a href="#">Figure 17</a>                | 25°C  | 5 V            | 2.5 | 4.5    | 7    | ns            |
|                                    |                           |                                                                                                                      |                                                                        | Full  | 4.5 V to 5.5 V | 1.5 |        | 7.5  |               |
| $t_{OFF}$                          | Turnoff time              | $V_{COM} = V_+$ ,<br>$R_L = 50\ \Omega$ ,                                                                            | $C_L = 35\text{ pF}$ ,<br>see <a href="#">Figure 17</a>                | 25°C  | 5 V            | 6   | 9      | 11.5 | ns            |
|                                    |                           |                                                                                                                      |                                                                        | Full  | 4.5 V to 5.5 V | 4   |        | 12.5 |               |
| $Q_C$                              | Charge injection          | $V_{GEN} = 0$ ,<br>$R_{GEN} = 0$ ,                                                                                   | $C_L = 1\text{ nF}$ ,<br>see <a href="#">Figure 20</a>                 | 25°C  | 5 V            |     | 1      |      | pC            |
| $C_{NO(OFF)}$                      | NO OFF capacitance        | $V_{NO} = V_+$ or GND,<br>Switch OFF,                                                                                | See <a href="#">Figure 16</a>                                          | 25°C  | 5 V            |     | 19     |      | pF            |
| $C_{COM(OFF)}$                     | COM OFF capacitance       | $V_{COM} = V_+$ or GND,<br>Switch OFF,                                                                               | See <a href="#">Figure 16</a>                                          | 25°C  | 5 V            |     | 18     |      | pF            |
| $C_{NO(ON)}$                       | NO ON capacitance         | $V_{NO} = V_+$ or GND,<br>Switch ON,                                                                                 | See <a href="#">Figure 16</a>                                          | 25°C  | 5 V            |     | 35.5   |      | pF            |
| $C_{COM(ON)}$                      | COM ON capacitance        | $V_{COM} = V_+$ or GND,<br>Switch ON,                                                                                | See <a href="#">Figure 16</a>                                          | 25°C  | 5 V            |     | 35.5   |      | pF            |
| $C_I$                              | Digital input capacitance | $V_I = V_+$ or GND,                                                                                                  | See <a href="#">Figure 16</a>                                          | 25°C  | 5 V            |     | 2      |      | pF            |
| BW                                 | Bandwidth                 | $R_L = 50\ \Omega$ ,<br>Switch ON,                                                                                   | See <a href="#">Figure 18</a>                                          | 25°C  | 5 V            |     | 200    |      | MHz           |
| $O_{ISO}$                          | OFF isolation             | $R_L = 50\ \Omega$ ,<br>$f = 1\text{ MHz}$ ,                                                                         | Switch OFF,<br>see <a href="#">Figure 19</a>                           | 25°C  | 5 V            |     | -64    |      | dB            |
| THD                                | Total harmonic distortion | $R_L = 600\ \Omega$ ,<br>$C_L = 50\text{ pF}$ ,                                                                      | $f = 20\text{ Hz to }20\text{ kHz}$ ,<br>see <a href="#">Figure 21</a> | 25°C  | 5 V            |     | 0.005% |      |               |
| <b>Supply</b>                      |                           |                                                                                                                      |                                                                        |       |                |     |        |      |               |
| $I_+$                              | Positive supply current   | $V_I = V_+$ or GND,                                                                                                  | Switch ON or OFF                                                       | 25°C  | 5.5 V          |     | 0.01   | 0.1  | $\mu\text{A}$ |
|                                    |                           |                                                                                                                      |                                                                        | Full  |                |     | 0.5    |      |               |

## 6.6 Electrical Characteristics for 3.3-V Supply

 $V_+ = 3\text{ V to }3.6\text{ V}$ ,  $T_A = -40^\circ\text{C to }85^\circ\text{C}$  (unless otherwise noted)<sup>(1)</sup>

| PARAMETER                          |                              | TEST CONDITIONS                                                                                                    |                                                         | $T_A$ | $V_+$        | MIN | TYP  | MAX   | UNIT     |               |
|------------------------------------|------------------------------|--------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------|-------|--------------|-----|------|-------|----------|---------------|
| <b>Analog Switch</b>               |                              |                                                                                                                    |                                                         |       |              |     |      |       |          |               |
| $V_{COM}, V_{NO}$                  | Analog signal range          |                                                                                                                    |                                                         |       |              | 0   |      | $V_+$ | V        |               |
| $r_{peak}$                         | Peak ON resistance           | $0 \leq V_{NO} \leq V_+$ ,<br>$I_{COM} = -100\text{ mA}$ ,                                                         | Switch ON,<br>see <a href="#">Figure 13</a>             | 25°C  | 3 V          |     | 1.1  | 1.5   | $\Omega$ |               |
|                                    |                              |                                                                                                                    |                                                         | Full  |              |     | 1.7  |       |          |               |
| $r_{on}$                           | ON-state resistance          | $V_{NO} = 2\text{ V}$ ,<br>$I_{COM} = -100\text{ mA}$ ,                                                            | Switch ON,<br>see <a href="#">Figure 13</a>             | 25°C  | 3 V          |     | 1    | 1.4   | $\Omega$ |               |
|                                    |                              |                                                                                                                    |                                                         | Full  |              |     | 1.5  |       |          |               |
| $r_{on(Flat)}$                     | ON-state resistance flatness | $0 \leq V_{NO} \leq V_+$ ,<br>$I_{COM} = -100\text{ mA}$ ,                                                         | Switch ON,<br>see <a href="#">Figure 13</a>             | 25°C  | 3 V          |     | 0.3  |       | $\Omega$ |               |
|                                    |                              |                                                                                                                    |                                                         | 25°C  |              |     | 0.09 | 0.15  |          |               |
|                                    |                              |                                                                                                                    |                                                         | Full  |              |     | 0.15 |       |          |               |
| $I_{NO(OFF)}$                      | NO OFF leakage current       | $V_{NO} = 1\text{ V}$ ,<br>$V_{COM} = 3\text{ V}$ ,<br>or<br>$V_{NO} = 3\text{ V}$ ,<br>$V_{COM} = 1\text{ V}$ ,   | Switch OFF,<br>see <a href="#">Figure 14</a>            | 25°C  | 3.6 V        |     | -2   | 0.5   | 2        | nA            |
|                                    |                              |                                                                                                                    |                                                         | Full  |              |     | -20  | 20    |          |               |
| $I_{NO(PWROFF)}$                   |                              | $V_{NO} = 0\text{ to }3.6\text{ V}$ ,<br>$V_{COM} = 3.6\text{ V to }0$ ,                                           |                                                         | 25°C  | 0 V          |     | -1   | 0.1   | 1        | $\mu\text{A}$ |
|                                    |                              |                                                                                                                    |                                                         | Full  |              |     | -5   | 5     |          |               |
| $I_{COM(OFF)}$                     | COM OFF leakage current      | $V_{COM} = 1\text{ V}$ ,<br>$V_{NO} = 3\text{ V}$ ,<br>or<br>$V_{COM} = 3\text{ V}$ ,<br>$V_{NO} = 1\text{ V}$ ,   | Switch OFF,<br>see <a href="#">Figure 14</a>            | 25°C  | 3.6 V        |     | -2   | 0.5   | 2        | nA            |
|                                    |                              |                                                                                                                    |                                                         | Full  |              |     | -20  | 20    |          |               |
| $I_{COM(PWROFF)}$                  |                              | $V_{COM} = 3.6\text{ V to }0$ ,<br>$V_{NO} = 0\text{ to }3.6\text{ V}$ ,                                           |                                                         | 25°C  | 0 V          |     | -1   | 0.1   | 1        | $\mu\text{A}$ |
|                                    |                              |                                                                                                                    |                                                         | Full  |              |     | -5   | 5     |          |               |
| $I_{NO(ON)}$                       | NO ON leakage current        | $V_{NO} = 1\text{ V}$ ,<br>$V_{COM} = \text{Open}$ ,<br>or<br>$V_{NO} = 3\text{ V}$ ,<br>$V_{COM} = \text{Open}$ , | Switch ON,<br>see <a href="#">Figure 15</a>             | 25°C  | 3.6 V        |     | -2   | 0.2   | 2        | nA            |
|                                    |                              |                                                                                                                    |                                                         | Full  |              |     | -20  | 20    |          |               |
| $I_{COM(ON)}$                      | COM ON leakage current       | $V_{COM} = 1\text{ V}$ ,<br>$V_{NO} = \text{Open}$ ,<br>or<br>$V_{COM} = 3\text{ V}$ ,<br>$V_{NO} = \text{Open}$ , | Switch ON,<br>see <a href="#">Figure 15</a>             | 25°C  | 3.6 V        |     | -2   | 0.2   | 2        | nA            |
|                                    |                              |                                                                                                                    |                                                         | Full  |              |     | -20  | 20    |          |               |
| <b>Digital Control Inputs (IN)</b> |                              |                                                                                                                    |                                                         |       |              |     |      |       |          |               |
| $V_{IH}$                           | Input logic high             |                                                                                                                    |                                                         | Full  |              | 2   |      | 5.5   | V        |               |
| $V_{IL}$                           | Input logic low              |                                                                                                                    |                                                         | Full  |              | 0   |      | 0.8   | V        |               |
| $I_{IH}, I_{IL}$                   | Input leakage current        | $V_I = 5.5\text{ V or }0$                                                                                          |                                                         | 25°C  | 3.6 V        |     | -2   | 0.3   | 2        | nA            |
|                                    |                              |                                                                                                                    |                                                         | Full  |              |     | -20  | 20    |          |               |
| <b>Dynamic</b>                     |                              |                                                                                                                    |                                                         |       |              |     |      |       |          |               |
| $t_{ON}$                           | Turnon time                  | $V_{COM} = V_+$ ,<br>$R_L = 50\ \Omega$ ,                                                                          | $C_L = 35\text{ pF}$ ,<br>see <a href="#">Figure 17</a> | 25°C  | 3.3 V        | 2   | 5    | 10    | ns       |               |
|                                    |                              |                                                                                                                    |                                                         | Full  | 3 V to 3.6 V | 1.5 |      | 11    |          |               |
| $t_{OFF}$                          | Turnoff time                 | $V_{COM} = V_+$ ,<br>$R_L = 50\ \Omega$ ,                                                                          | $C_L = 35\text{ pF}$ ,<br>see <a href="#">Figure 17</a> | 25°C  | 3.3 V        | 6.5 | 9    | 12    | ns       |               |
|                                    |                              |                                                                                                                    |                                                         | Full  | 3 V to 3.6 V | 4   |      | 13    |          |               |
| $Q_C$                              | Charge injection             | $V_{GEN} = 0$ ,<br>$R_{GEN} = 0$ ,                                                                                 | $C_L = 1\text{ nF}$ ,<br>see <a href="#">Figure 21</a>  | 25°C  | 3.3 V        |     | 1    |       | pC       |               |
| $C_{NO(OFF)}$                      | NO OFF capacitance           | $V_{NO} = V_+$ or GND,<br>Switch OFF,                                                                              | See <a href="#">Figure 16</a>                           | 25°C  | 3.3 V        |     | 19   |       | pF       |               |
| $C_{COM(OFF)}$                     | COM OFF capacitance          | $V_{COM} = V_+$ or GND,<br>Switch OFF,                                                                             | See <a href="#">Figure 16</a>                           | 25°C  | 3.3 V        |     | 18   |       | pF       |               |
| $C_{NO(ON)}$                       | NO ON capacitance            | $V_{NO} = V_+$ or GND,<br>Switch ON,                                                                               | See <a href="#">Figure 16</a>                           | 25°C  | 3.3 V        |     | 36   |       | pF       |               |
| $C_{COM(ON)}$                      | COM ON capacitance           | $V_{COM} = V_+$ or GND,<br>Switch ON,                                                                              | See <a href="#">Figure 16</a>                           | 25°C  | 3.3 V        |     | 36   |       | pF       |               |

(1) The algebraic convention, whereby the most negative value is a minimum and the most positive value is a maximum.

## Electrical Characteristics for 3.3-V Supply (continued)

 $V_+ = 3\text{ V to }3.6\text{ V}$ ,  $T_A = -40^\circ\text{C to }85^\circ\text{C}$  (unless otherwise noted)<sup>(1)</sup>

| PARAMETER     |                           | TEST CONDITIONS                                 |                                                        | $T_A$ | $V_+$ | MIN | TYP   | MAX | UNIT          |
|---------------|---------------------------|-------------------------------------------------|--------------------------------------------------------|-------|-------|-----|-------|-----|---------------|
| $C_I$         | Digital input capacitance | $V_I = V_+$ or GND,                             | See Figure 16                                          | 25°C  | 3.3 V |     | 2     |     | pF            |
| BW            | Bandwidth                 | $R_L = 50\ \Omega$ ,<br>Switch ON,              | See Figure 18                                          | 25°C  | 3.3 V |     | 200   |     | MHz           |
| $O_{ISO}$     | OFF isolation             | $R_L = 50\ \Omega$ ,<br>$f = 1\text{ MHz}$ ,    | Switch OFF,<br>see Figure 19                           | 25°C  | 3.3 V |     | -64   |     | dB            |
| THD           | Total harmonic distortion | $R_L = 600\ \Omega$ ,<br>$C_L = 50\text{ pF}$ , | $f = 20\text{ Hz to }20\text{ kHz}$ ,<br>see Figure 21 | 25°C  | 3.3 V |     | 0.01% |     |               |
| <b>Supply</b> |                           |                                                 |                                                        |       |       |     |       |     |               |
| $I_+$         | Positive supply current   | $V_I = V_+$ or GND,                             | Switch ON or OFF                                       | 25°C  | 3.6 V |     | 0.01  | 0.1 | $\mu\text{A}$ |
|               |                           |                                                 |                                                        | Full  |       |     | 0.25  |     |               |

## 6.7 Electrical Characteristics for 2.5-V Supply

 $V_+ = 2.3\text{ V to }2.7\text{ V}$ ,  $T_A = -40^\circ\text{C to }85^\circ\text{C}$  (unless otherwise noted)<sup>(1)</sup>

| PARAMETER                                |                              | TEST CONDITIONS                                                                                                                     |                              | $T_A$ | $V_+$ | MIN | TYP  | MAX   | UNIT          |
|------------------------------------------|------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|------------------------------|-------|-------|-----|------|-------|---------------|
| <b>Analog Switch</b>                     |                              |                                                                                                                                     |                              |       |       |     |      |       |               |
| $V_{COM}$ ,<br>$V_{NO}$                  | Analog signal range          |                                                                                                                                     |                              |       | 2.3 V | 0   |      | $V_+$ | V             |
| $r_{peak}$                               | Peak ON resistance           | $0 \leq V_{NO} \leq V_+$ ,<br>$I_{COM} = -100\text{ mA}$ ,                                                                          | Switch ON,<br>see Figure 13  | 25°C  | 2.3 V |     | 1.8  | 2.4   | $\Omega$      |
|                                          |                              |                                                                                                                                     |                              | Full  |       |     |      | 2.6   |               |
| $r_{on}$                                 | ON-state resistance          | $V_{NO} = 2\text{ V}$ ,<br>$I_{COM} = -100\text{ mA}$ ,                                                                             | Switch ON,<br>see Figure 13  | 25°C  | 2.3 V |     | 1.2  | 2.1   | $\Omega$      |
|                                          |                              |                                                                                                                                     |                              | Full  |       |     |      | 2.4   |               |
| $r_{on(Flat)}$                           | ON-state resistance flatness | $0 \leq V_{NO} \leq V_+$ ,<br>$I_{COM} = -100\text{ mA}$ ,<br>$V_{NO} = 2\text{ V}, 0.8\text{ V}$ ,<br>$I_{COM} = -100\text{ mA}$ , | Switch ON,<br>see Figure 13  | 25°C  | 2.3 V |     | 0.7  |       | $\Omega$      |
|                                          |                              |                                                                                                                                     |                              | 25°C  |       |     | 0.4  | 0.6   |               |
|                                          |                              |                                                                                                                                     |                              | Full  |       |     |      | 0.6   |               |
| $I_{NO(OFF)}$                            | NO OFF leakage current       | $V_{NO} = 1\text{ V}$ ,<br>$V_{COM} = 3\text{ V}$ ,<br>or<br>$V_{NO} = 3\text{ V}$ ,<br>$V_{COM} = 1\text{ V}$ ,                    | Switch OFF,<br>see Figure 14 | 25°C  | 2.7 V | -5  | 0.3  | 5     | nA            |
|                                          |                              |                                                                                                                                     |                              | Full  |       |     | -50  |       |               |
| $I_{NO(PWROFF)}$                         |                              | $V_{NO} = 0\text{ to }3.6\text{ V}$ ,<br>$V_{COM} = 3.6\text{ V to }0$ ,                                                            |                              | 25°C  | 0 V   | -2  | 0.05 | 2     | $\mu\text{A}$ |
|                                          |                              |                                                                                                                                     |                              | Full  |       |     | -15  |       |               |
| $I_{COM(OFF)}$                           | COM OFF leakage current      | $V_{COM} = 1\text{ V}$ ,<br>$V_{NO} = 3\text{ V}$ ,<br>or<br>$V_{COM} = 3\text{ V}$ ,<br>$V_{NO} = 1\text{ V}$ ,                    | Switch OFF,<br>see Figure 14 | 25°C  | 2.7 V | -5  | 0.3  | 5     | nA            |
|                                          |                              |                                                                                                                                     |                              | Full  |       |     | -50  |       |               |
| $I_{COM(PWROFF)}$                        |                              | $V_{COM} = 3.6\text{ V to }0$ ,<br>$V_{NO} = 0\text{ to }3.6\text{ V}$ ,                                                            |                              | 25°C  | 0 V   | -2  | 0.05 | 2     | $\mu\text{A}$ |
|                                          |                              |                                                                                                                                     |                              | Full  |       |     | -15  |       |               |
| $I_{NO(ON)}$                             | NO ON leakage current        | $V_{NO} = 1\text{ V}$ ,<br>$V_{COM} = \text{Open}$ ,<br>or<br>$V_{NO} = 3\text{ V}$ ,<br>$V_{COM} = \text{Open}$ ,                  | Switch ON,<br>see Figure 15  | 25°C  | 2.7 V | -2  | 0.3  | 2     | nA            |
|                                          |                              |                                                                                                                                     |                              | Full  |       |     | -20  |       |               |
| $I_{COM(ON)}$                            | COM ON leakage current       | $V_{COM} = 1\text{ V}$ ,<br>$V_{NO} = \text{Open}$ ,<br>or<br>$V_{COM} = 3\text{ V}$ ,<br>$V_{NO} = \text{Open}$ ,                  | Switch ON,<br>see Figure 15  | 25°C  | 2.7 V | -2  | 0.3  | 2     | nA            |
|                                          |                              |                                                                                                                                     |                              | Full  |       |     | -20  |       |               |
| <b>Digital Control Inputs (IN1, IN2)</b> |                              |                                                                                                                                     |                              |       |       |     |      |       |               |
| $V_{IH}$                                 | Input logic high             |                                                                                                                                     |                              | Full  |       | 1.8 |      | 5.5   | V             |
| $V_{IL}$                                 | Input logic low              |                                                                                                                                     |                              | Full  |       | 0   |      | 0.6   | V             |

(1) The algebraic convention, whereby the most negative value is a minimum and the most positive value is a maximum.

**Electrical Characteristics for 2.5-V Supply (continued)**
 $V_+ = 2.3 \text{ V to } 2.7 \text{ V}$ ,  $T_A = -40^\circ\text{C to } 85^\circ\text{C}$  (unless otherwise noted)<sup>(1)</sup>

| PARAMETER           |                           | TEST CONDITIONS                                 |                                                                           | $T_A$ | $V_+$          | MIN | TYP   | MAX  | UNIT          |
|---------------------|---------------------------|-------------------------------------------------|---------------------------------------------------------------------------|-------|----------------|-----|-------|------|---------------|
| $I_{IH}$ , $I_{IL}$ | Input leakage current     | $V_I = 5.5 \text{ V or } 0$                     |                                                                           | 25°C  | 2.7 V          | -2  | 0.3   | 2    | nA            |
|                     |                           |                                                 |                                                                           | Full  |                | -20 |       | 20   |               |
| <b>Dynamic</b>      |                           |                                                 |                                                                           |       |                |     |       |      |               |
| $t_{ON}$            | Turnon time               | $V_{COM} = V_+$ ,<br>$R_L = 50 \Omega$ ,        | $C_L = 35 \text{ pF}$ ,<br>see <a href="#">Figure 17</a>                  | 25°C  | 2.5 V          | 2   | 6     | 10   | ns            |
|                     |                           |                                                 |                                                                           | Full  | 2.3 V to 2.7 V | 1   |       | 12   |               |
| $t_{OFF}$           | Turnoff time              | $V_{COM} = V_+$ ,<br>$R_L = 50 \Omega$ ,        | $C_L = 35 \text{ pF}$ ,<br>see <a href="#">Figure 17</a>                  | 25°C  | 2.5 V          | 4.5 | 8     | 10.5 | ns            |
|                     |                           |                                                 |                                                                           | Full  | 2.3 V to 2.7 V | 3   |       | 15   |               |
| $Q_C$               | Charge injection          | $V_{GEN} = 0$ ,<br>$R_{GEN} = 0$ ,              | $C_L = 1 \text{ nF}$ ,<br>see <a href="#">Figure 21</a>                   | 25°C  | 2.5 V          |     | 4     |      | pC            |
| $C_{NO(OFF)}$       | NO OFF capacitance        | $V_{NO} = V_+$ or GND,<br>Switch OFF,           | See <a href="#">Figure 16</a>                                             | 25°C  | 2.5 V          |     | 19.5  |      | pF            |
| $C_{COM(OFF)}$      | COM OFF capacitance       | $V_{COM} = V_+$ or GND,<br>Switch OFF,          | See <a href="#">Figure 16</a>                                             | 25°C  | 2.5 V          |     | 18.5  |      | pF            |
| $C_{NO(ON)}$        | NO ON capacitance         | $V_{NO} = V_+$ or GND,<br>Switch ON,            | See <a href="#">Figure 16</a>                                             | 25°C  | 2.5 V          |     | 36.5  |      | pF            |
| $C_{COM(ON)}$       | COM ON capacitance        | $V_{COM} = V_+$ or GND,<br>Switch ON,           | See <a href="#">Figure 16</a>                                             | 25°C  | 2.5 V          |     | 36.5  |      | pF            |
| $C_I$               | Digital input capacitance | $V_I = V_+$ or GND,                             | See <a href="#">Figure 16</a>                                             | 25°C  | 2.5 V          |     | 2     |      | pF            |
| BW                  | Bandwidth                 | $R_L = 50 \Omega$ ,<br>Switch ON,               | See <a href="#">Figure 18</a>                                             | 25°C  | 2.5 V          |     | 150   |      | MHz           |
| $O_{ISO}$           | OFF isolation             | $R_L = 50 \Omega$ ,<br>$f = 1 \text{ MHz}$ ,    | Switch OFF,<br>see <a href="#">Figure 19</a>                              | 25°C  | 2.5 V          |     | -62   |      | dB            |
| THD                 | Total harmonic distortion | $R_L = 600 \Omega$ ,<br>$C_L = 50 \text{ pF}$ , | $f = 20 \text{ Hz to } 20 \text{ kHz}$ ,<br>see <a href="#">Figure 21</a> | 25°C  | 2.5 V          |     | 0.02% |      |               |
| <b>Supply</b>       |                           |                                                 |                                                                           |       |                |     |       |      |               |
| $I_+$               | Positive supply current   | $V_I = V_+$ or GND,                             | Switch ON or OFF                                                          | 25°C  | 2.7 V          |     | 0.001 | 0.02 | $\mu\text{A}$ |
|                     |                           |                                                 |                                                                           | Full  |                |     |       | 0.25 |               |



## 6.8 Electrical Characteristics for 1.8-V Supply<sup>(1)</sup>

 $V_+ = 1.65\text{ V to }1.95\text{ V}$ ,  $T_A = -40^\circ\text{C to }85^\circ\text{C}$  (unless otherwise noted)

| PARAMETER                                |                              | TEST CONDITIONS                                                                                                    |                                                         | $T_A$ | $V_+$            | MIN | TYP  | MAX   | UNIT          |
|------------------------------------------|------------------------------|--------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------|-------|------------------|-----|------|-------|---------------|
| <b>Analog Switch</b>                     |                              |                                                                                                                    |                                                         |       |                  |     |      |       |               |
| $V_{COM}, V_{NO}$                        | Analog signal range          |                                                                                                                    |                                                         |       |                  | 0   |      | $V_+$ | V             |
| $r_{peak}$                               | Peak ON resistance           | $0 \leq V_{NO} \leq V_+$ ,<br>$I_{COM} = -100\text{ mA}$ ,                                                         | Switch ON,<br>see <a href="#">Figure 13</a>             | 25°C  | 1.65 V           |     | 4.2  | 25    | $\Omega$      |
|                                          |                              |                                                                                                                    |                                                         | Full  |                  |     | 30   |       |               |
| $r_{on}$                                 | ON-state resistance          | $V_{NO} = 2\text{ V}$ ,<br>$I_{COM} = -100\text{ mA}$ ,                                                            | Switch ON,<br>see <a href="#">Figure 13</a>             | 25°C  | 1.65 V           |     | 1.6  | 3.9   | $\Omega$      |
|                                          |                              |                                                                                                                    |                                                         | Full  |                  |     | 4.0  |       |               |
| $r_{on(Flat)}$                           | ON-state resistance flatness | $0 \leq V_{NO} \leq V_+$ ,<br>$I_{COM} = -100\text{ mA}$ ,                                                         | Switch ON,<br>see <a href="#">Figure 13</a>             | 25°C  | 1.65 V           |     | 2.8  |       | $\Omega$      |
|                                          |                              |                                                                                                                    |                                                         | 25°C  |                  |     | 4.1  | 22    |               |
|                                          |                              |                                                                                                                    |                                                         | Full  |                  |     | 27   |       |               |
| $I_{NO(OFF)}$                            | NO OFF leakage current       | $V_{NO} = 1\text{ V}$ ,<br>$V_{COM} = 3\text{ V}$ ,<br>or<br>$V_{NO} = 3\text{ V}$ ,<br>$V_{COM} = 1\text{ V}$ ,   | Switch OFF,<br>see <a href="#">Figure 14</a>            | 25°C  | 1.95 V           | -5  |      | 5     | nA            |
|                                          |                              |                                                                                                                    |                                                         | Full  |                  |     | -50  | 50    |               |
| $I_{NO(PWROFF)}$                         |                              | $V_{NO} = 0\text{ to }3.6\text{ V}$ ,<br>$V_{COM} = 3.6\text{ V to }0$ ,                                           |                                                         | 25°C  | 0 V              | -2  |      | 2     | $\mu\text{A}$ |
|                                          |                              |                                                                                                                    |                                                         | Full  |                  |     | -10  | 10    |               |
| $I_{COM(OFF)}$                           | COM OFF leakage current      | $V_{COM} = 1\text{ V}$ ,<br>$V_{NO} = 3\text{ V}$ ,<br>or<br>$V_{COM} = 3\text{ V}$ ,<br>$V_{NO} = 1\text{ V}$ ,   | Switch OFF,<br>see <a href="#">Figure 14</a>            | 25°C  | 1.95 V           | -5  |      | 5     | nA            |
|                                          |                              |                                                                                                                    |                                                         | Full  |                  |     | -50  | 50    |               |
| $I_{COM(PWROFF)}$                        |                              | $V_{COM} = 0\text{ to }3.6\text{ V}$ ,<br>$V_{NO} = 3.6\text{ V to }0$ ,                                           |                                                         | 25°C  | 0 V              | -2  |      | 2     | $\mu\text{A}$ |
|                                          |                              |                                                                                                                    |                                                         | Full  |                  |     | -10  | 10    |               |
| $I_{NO(ON)}$                             | NO ON leakage current        | $V_{NO} = 1\text{ V}$ ,<br>$V_{COM} = \text{Open}$ ,<br>or<br>$V_{NO} = 3\text{ V}$ ,<br>$V_{COM} = \text{Open}$ , | Switch ON,<br>see <a href="#">Figure 15</a>             | 25°C  | 1.95 V           | -2  |      | 2     | nA            |
|                                          |                              |                                                                                                                    |                                                         | Full  |                  |     | -20  | 20    |               |
| $I_{COM(ON)}$                            | COM ON leakage current       | $V_{COM} = 1\text{ V}$ ,<br>$V_{NO} = \text{Open}$ ,<br>or<br>$V_{COM} = 3\text{ V}$ ,<br>$V_{NO} = \text{Open}$ , | Switch ON,<br>see <a href="#">Figure 15</a>             | 25°C  | 1.95 V           | -2  |      | 2     | nA            |
|                                          |                              |                                                                                                                    |                                                         | Full  |                  |     | -20  | 20    |               |
| <b>Digital Control Inputs (IN1, IN2)</b> |                              |                                                                                                                    |                                                         |       |                  |     |      |       |               |
| $V_{IH}$                                 | Input logic high             |                                                                                                                    |                                                         | Full  |                  | 1.5 |      | 5.5   | V             |
| $V_{IL}$                                 | Input logic low              |                                                                                                                    |                                                         | Full  |                  | 0   |      | 0.6   | V             |
| $I_{IH}, I_{IL}$                         | Input leakage current        | $V_I = 5.5\text{ V or }0$                                                                                          |                                                         | 25°C  | 1.95 V           | -2  | 0.3  | 2     | nA            |
|                                          |                              |                                                                                                                    |                                                         | Full  |                  |     | -20  | 20    |               |
| <b>Dynamic</b>                           |                              |                                                                                                                    |                                                         |       |                  |     |      |       |               |
| $t_{ON}$                                 | Turnon time                  | $V_{COM} = V_+$ ,<br>$R_L = 50\ \Omega$ ,                                                                          | $C_L = 35\text{ pF}$ ,<br>see <a href="#">Figure 17</a> | 25°C  | 1.8 V            | 3   | 9    | 18    | ns            |
|                                          |                              |                                                                                                                    |                                                         | Full  | 1.65 V to 1.95 V | 1   |      | 20    |               |
| $t_{OFF}$                                | Turnoff time                 | $V_{COM} = V_+$ ,<br>$R_L = 50\ \Omega$ ,                                                                          | $C_L = 35\text{ pF}$ ,<br>see <a href="#">Figure 17</a> | 25°C  | 1.8 V            | 5   | 10   | 15.5  | ns            |
|                                          |                              |                                                                                                                    |                                                         | Full  | 1.65 V to 1.95 V | 4   |      | 18.5  |               |
| $Q_C$                                    | Charge injection             | $V_{GEN} = 0$ ,<br>$R_{GEN} = 0$ ,                                                                                 | $C_L = 1\text{ nF}$ ,<br>see <a href="#">Figure 21</a>  | 25°C  | 1.8 V            |     | 2    |       | pC            |
| $C_{NO(OFF)}$                            | NO OFF capacitance           | $V_{NO} = V_+ \text{ or GND}$ ,<br>Switch OFF,                                                                     | See <a href="#">Figure 16</a>                           | 25°C  | 1.8 V            |     | 19.5 |       | pF            |
| $C_{COM(OFF)}$                           | COM OFF capacitance          | $V_{COM} = V_+ \text{ or GND}$ ,<br>Switch OFF,                                                                    | See <a href="#">Figure 16</a>                           | 25°C  | 1.8 V            |     | 18.5 |       | pF            |

(1) The algebraic convention, whereby the most negative value is a minimum and the most positive value is a maximum.

**Electrical Characteristics for 1.8-V Supply<sup>(1)</sup> (continued)**
 $V_+ = 1.65\text{ V to }1.95\text{ V}$ ,  $T_A = -40^\circ\text{C to }85^\circ\text{C}$  (unless otherwise noted)

| PARAMETER     |                              | TEST CONDITIONS                                 |                                                                      | $T_A$ | $V_+$  | MIN   | TYP        | MAX  | UNIT          |
|---------------|------------------------------|-------------------------------------------------|----------------------------------------------------------------------|-------|--------|-------|------------|------|---------------|
| $C_{NO(ON)}$  | NO<br>ON capacitance         | $V_{NO} = V_+$ or GND,<br>Switch ON,            | See <a href="#">Figure 16</a>                                        | 25°C  | 1.8 V  |       | 36.5       |      | pF            |
| $C_{COM(ON)}$ | COM<br>ON capacitance        | $V_{COM} = V_+$ or GND,<br>Switch ON,           | See <a href="#">Figure 16</a>                                        | 25°C  | 1.8 V  |       | 36.5       |      | pF            |
| $C_I$         | Digital input<br>capacitance | $V_I = V_+$ or GND,                             | See <a href="#">Figure 16</a>                                        | 25°C  | 1.8 V  |       | 2          |      | pF            |
| BW            | Bandwidth                    | $R_L = 50\ \Omega$ ,<br>Switch ON,              | See <a href="#">Figure 18</a>                                        | 25°C  | 1.8 V  |       | 150        |      | MHz           |
| $O_{ISO}$     | OFF isolation                | $R_L = 50\ \Omega$ ,<br>$f = 1\text{ MHz}$ ,    | Switch OFF,<br>see <a href="#">Figure 19</a>                         | 25°C  | 1.8 V  |       | -62        |      | dB            |
| THD           | Total harmonic<br>distortion | $R_L = 600\ \Omega$ ,<br>$C_L = 50\text{ pF}$ , | $f = 20\text{ Hz to }20\text{ kHz}$<br>see <a href="#">Figure 21</a> | 25°C  | 1.8 V  |       | 0.055<br>% |      |               |
| <b>Supply</b> |                              |                                                 |                                                                      |       |        |       |            |      |               |
| $I_+$         | Positive supply<br>current   | $V_I = V_+$ or GND,                             | Switch ON or<br>OFF                                                  | 25°C  | 1.95 V | 0.001 | 0.01       | 0.15 | $\mu\text{A}$ |
|               |                              |                                                 |                                                                      | Full  |        |       |            |      |               |

### 6.9 Typical Characteristics

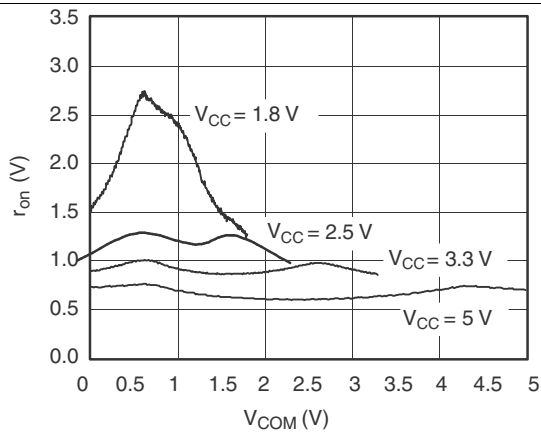


Figure 1.  $r_{on}$  vs  $V_{COM}$

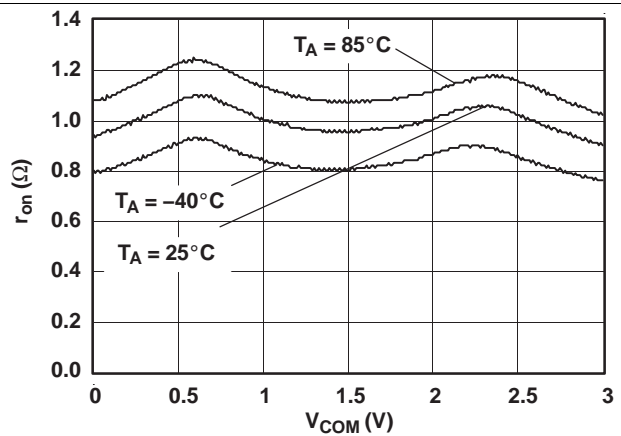


Figure 2.  $r_{on}$  vs  $V_{COM}$  ( $V_+ = 3\text{ V}$ )

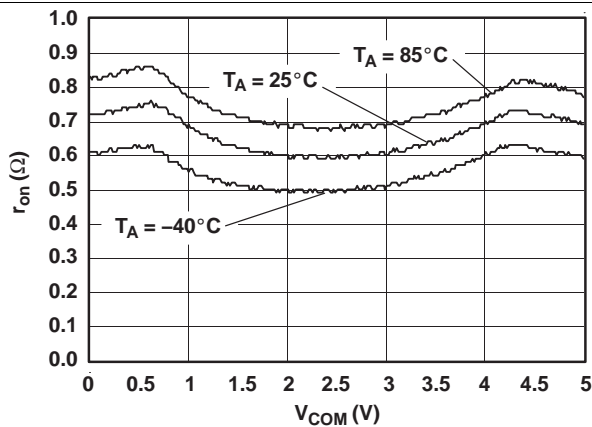


Figure 3.  $r_{on}$  vs  $V_{COM}$  ( $V_+ = 5\text{ V}$ )

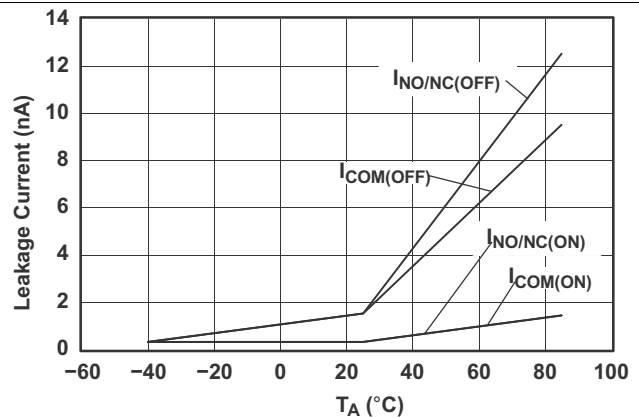


Figure 4. Leakage Current vs Temperature ( $V_+ = 5.5\text{ V}$ )

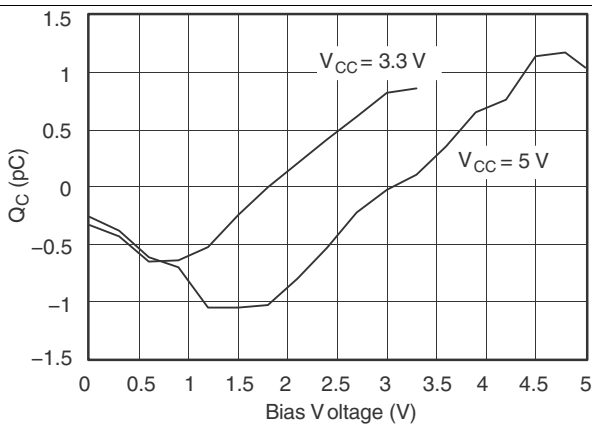


Figure 5. Charge Injection ( $Q_C$ ) vs  $V_{COM}$

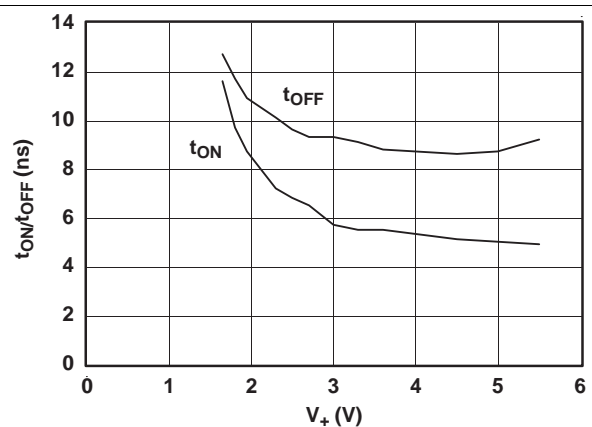
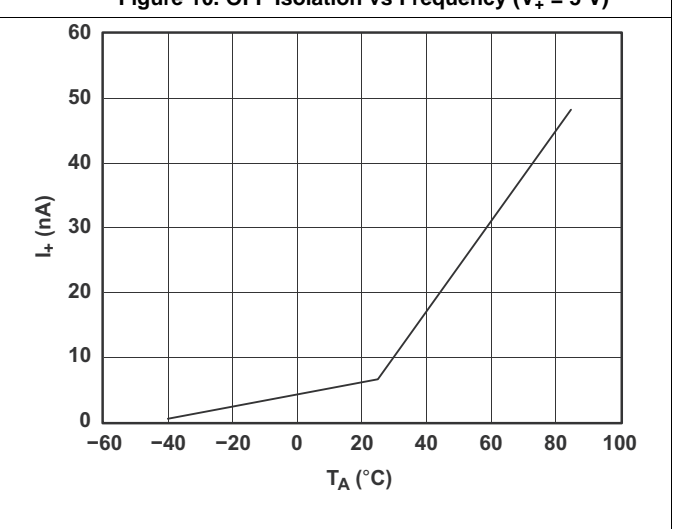
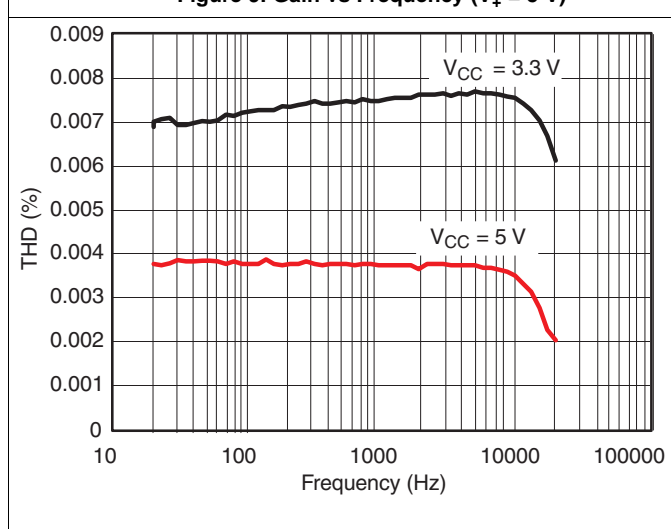
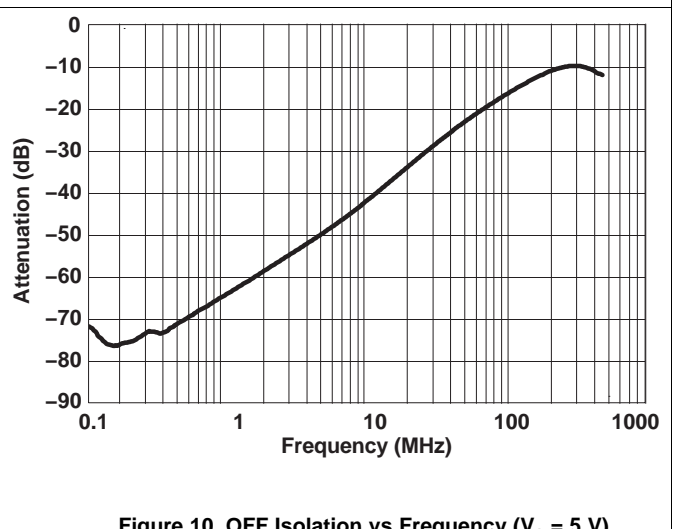
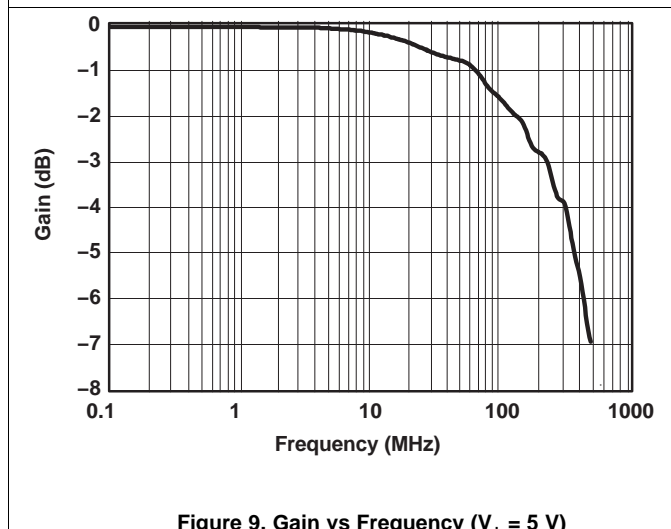
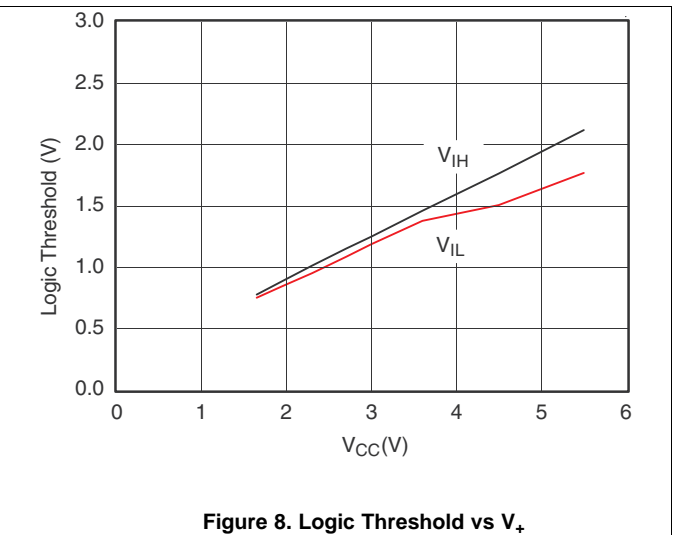
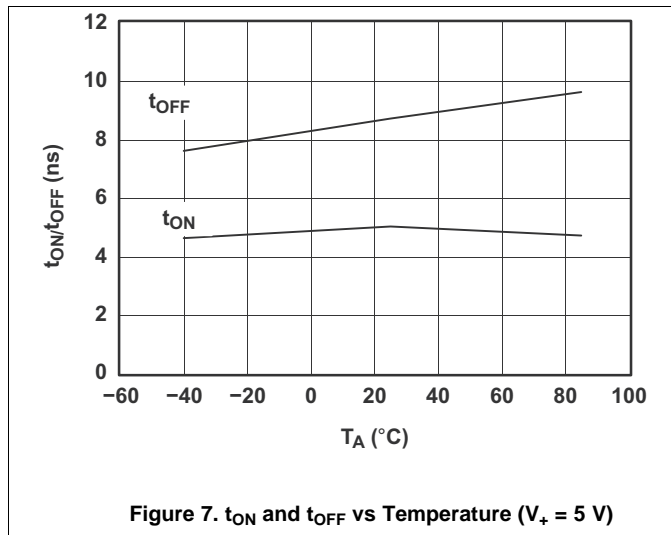


Figure 6.  $t_{ON}$  and  $t_{OFF}$  vs Supply Voltage

**Typical Characteristics (continued)**


## 7 Parameter Measurement Information

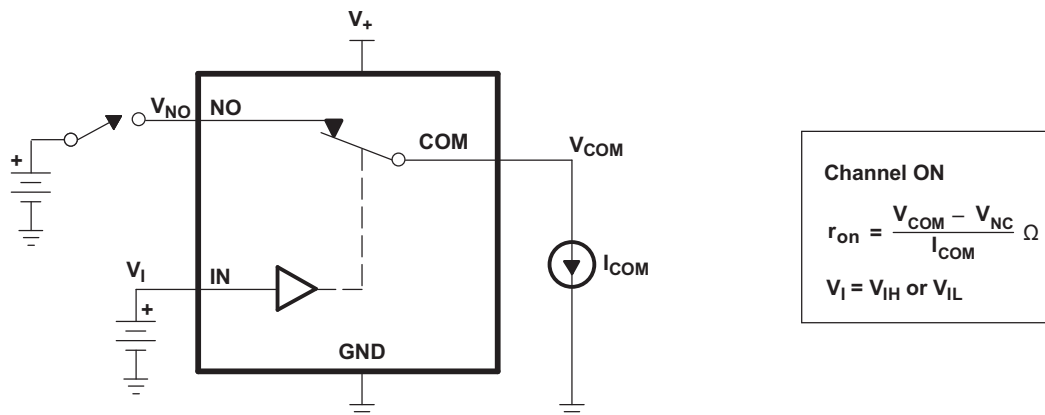


Figure 13. ON-State Resistance ( $r_{on}$ )

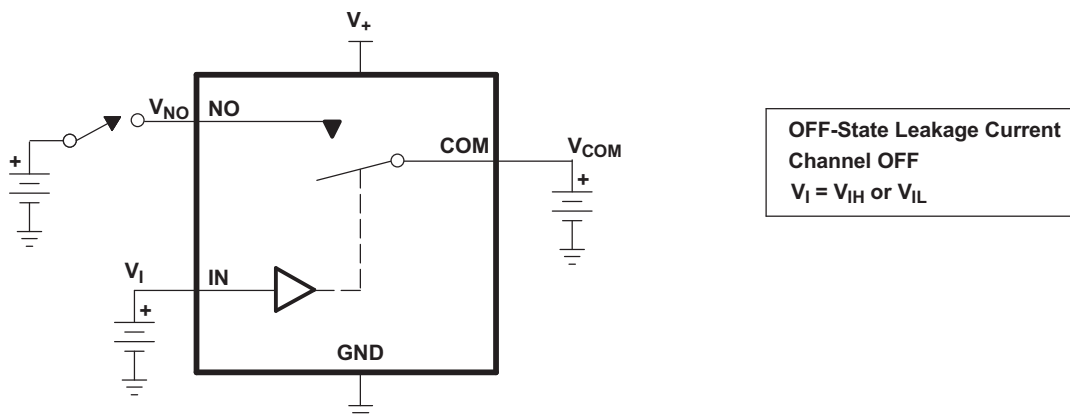


Figure 14. OFF-State Leakage Current ( $I_{COM(OFF)}$ ,  $I_{NO(OFF)}$ ,  $I_{COM(PWROFF)}$ ,  $I_{NO(PWROFF)}$ )

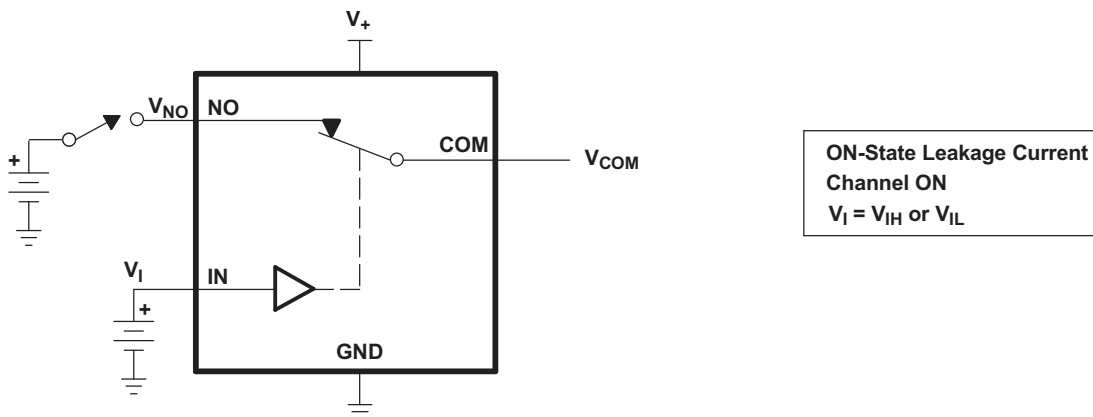


Figure 15. ON-State Leakage Current ( $I_{COM(ON)}$ ,  $I_{NO(ON)}$ )

Parameter Measurement Information (continued)

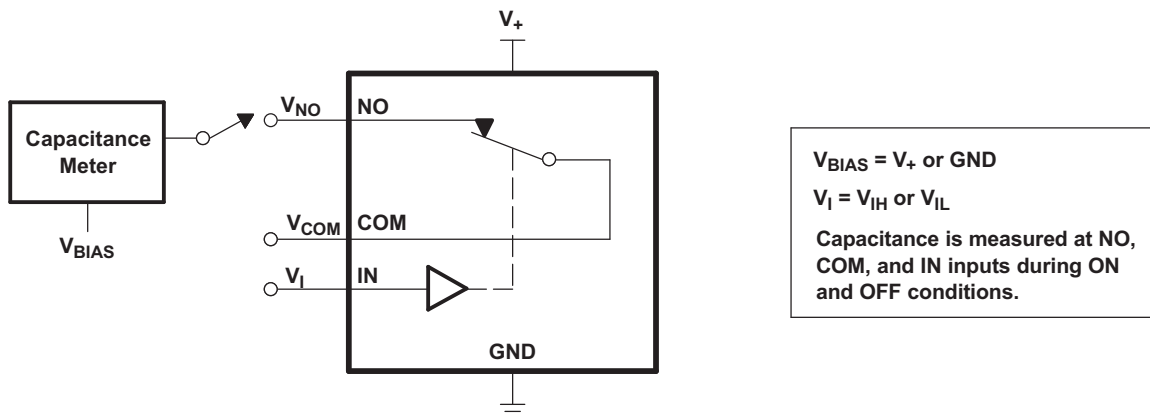
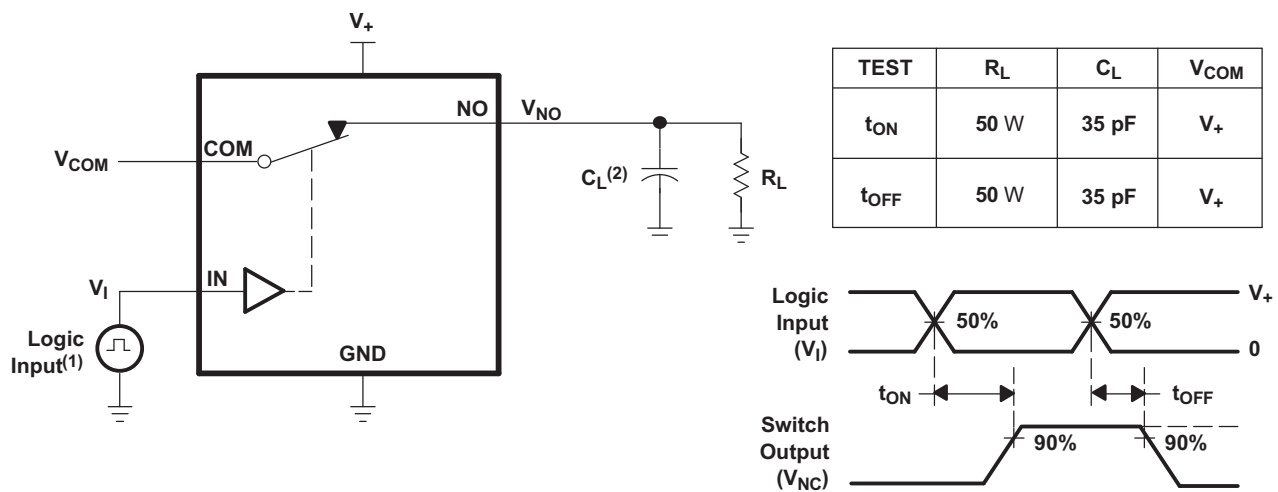


Figure 16. Capacitance ( $C_I$ ,  $C_{COM(OFF)}$ ,  $C_{COM(ON)}$ ,  $C_{NO(OFF)}$ ,  $C_{NO(ON)}$ )



- (1) All input pulses are supplied by generators having the following characteristics: PRR ≤ 10 MHz, Z<sub>O</sub> = 50 Ω, t<sub>r</sub> < 5 ns, t<sub>f</sub> < 5 ns.
- (2) C<sub>L</sub> includes probe and jig capacitance.

Figure 17. Turnon (t<sub>ON</sub>) and Turnoff Time (t<sub>OFF</sub>)

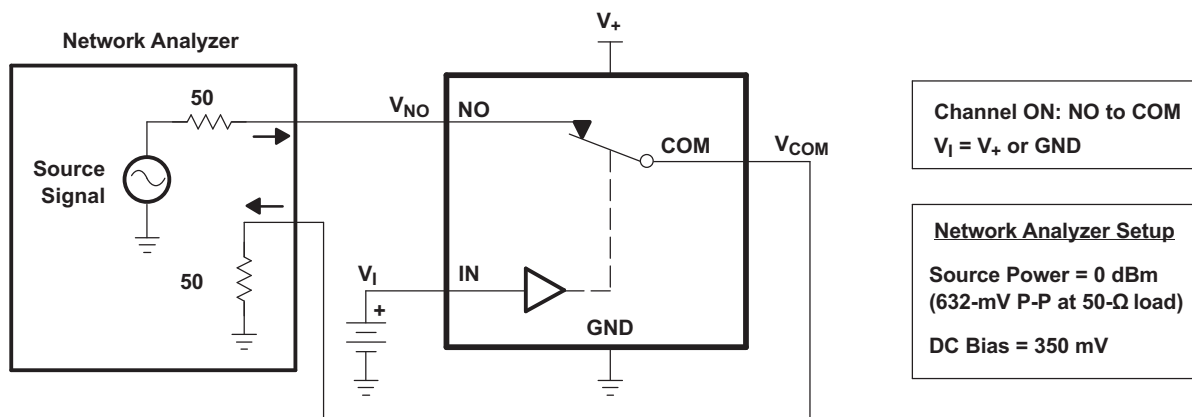


Figure 18. Bandwidth (BW)

Parameter Measurement Information (continued)

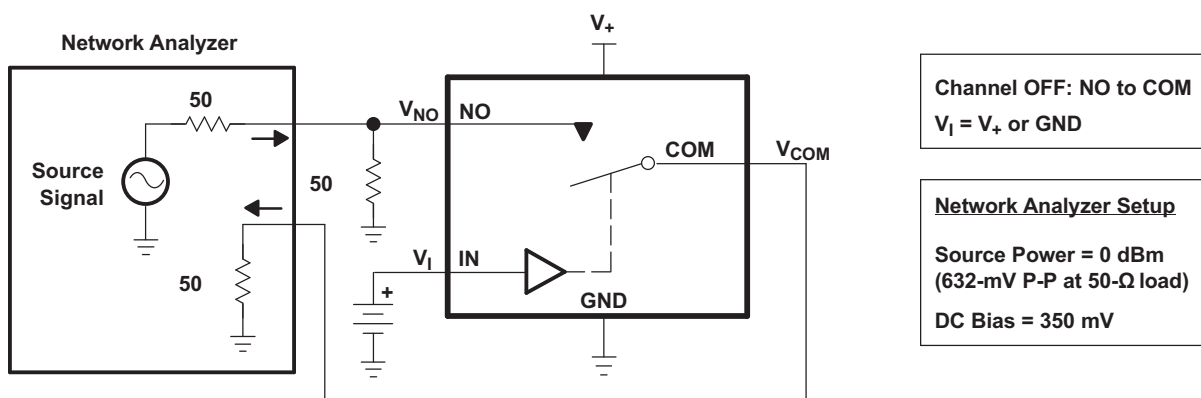
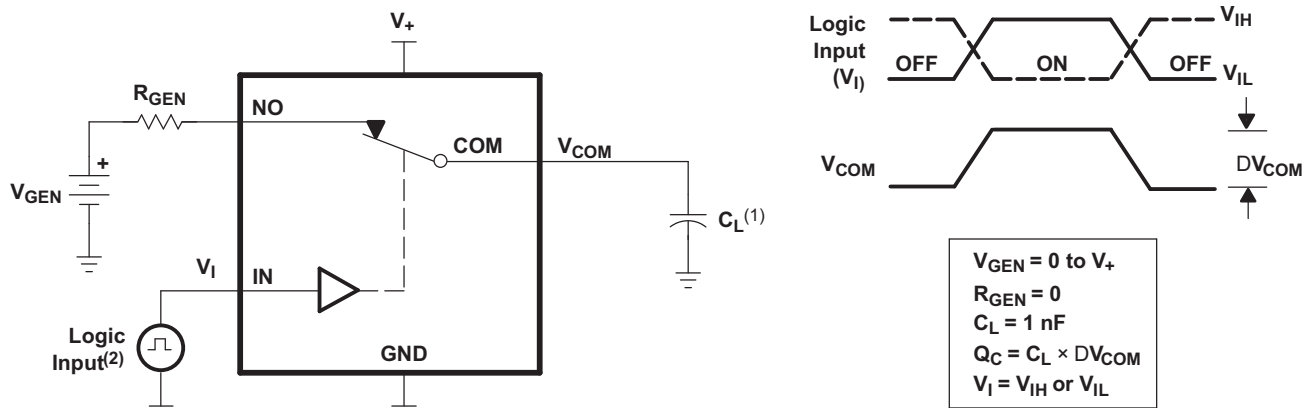
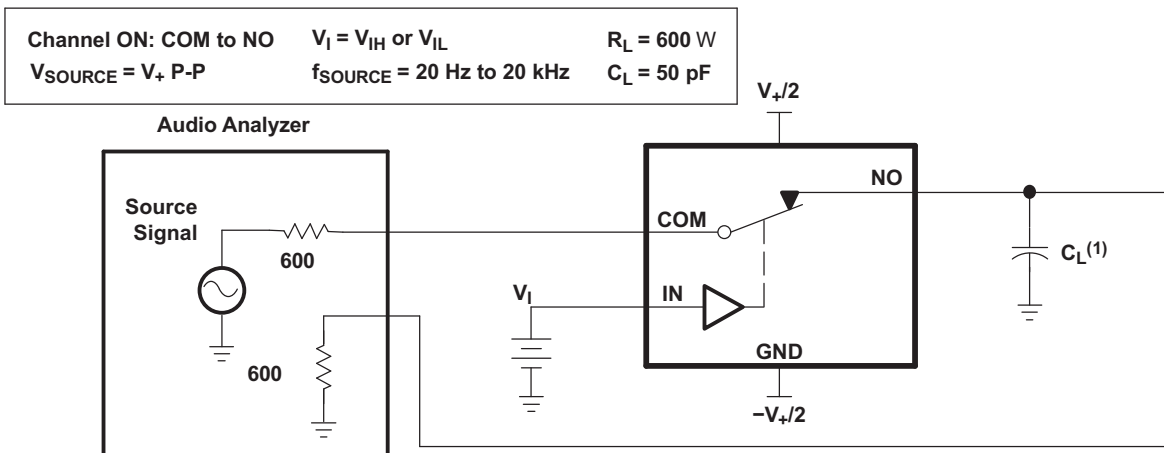


Figure 19. OFF Isolation ( $O_{ISO}$ )



- (1)  $C_L$  includes probe and jig capacitance.
- (2) All input pulses are supplied by generators having the following characteristics:  $PRR \leq 10$  MHz,  $Z_O = 50 \Omega$ ,  $t_r < 5$  ns,  $t_f < 5$  ns.

Figure 20. Charge Injection ( $Q_C$ )



- (1)  $C_L$  includes probe and jig capacitance.

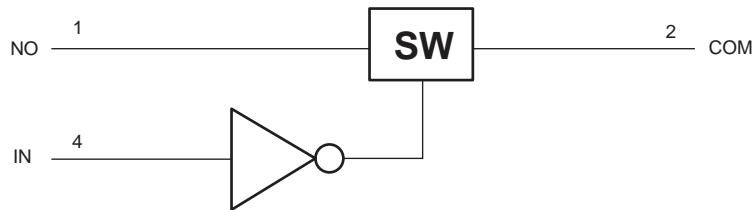
Figure 21. Total Harmonic Distortion (THD)

## 8 Detailed Description

### 8.1 Overview

The TS5A3166 is a single-pole single-throw (SPST) analog switch that is designed to operate from 1.65 V to 5.5 V. The device offers a low ON-state resistance. The device has excellent total harmonic distortion (THD) performance and consumes very low power. These features make this device suitable for portable audio applications.

### 8.2 Functional Block Diagram



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### 8.3 Feature Description

The low ON-state resistance, ON-state resistance matching, and charge injection in the TS5A3166 make this switch an excellent choice for analog signals that require minimal distortion. In addition, the low THD allows audio signals to be preserved more clearly as they pass through the device.

The 1.65-V to 5.5-V operation allows compatibility with more logic levels, and the bidirectional I/Os can pass analog signals from 0 V to  $V_+$  with low distortion.

### 8.4 Device Functional Modes

**Table 1. Function Table**

| IN | NO TO COM,<br>COM TO NO |
|----|-------------------------|
| L  | OFF                     |
| H  | ON                      |



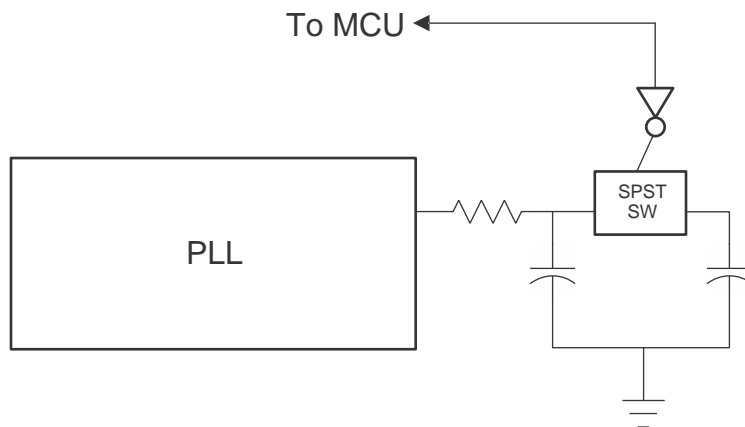
## 9 Application and Implementation

### NOTE

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

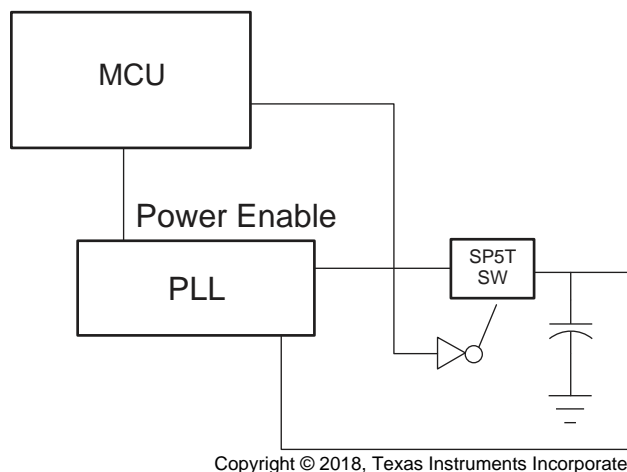
### 9.1 Application Information

SPST analog switch is a basic component that could be used in any electrical system design. [Figure 22](#) and [Figure 23](#) are some basic applications that utilize the TS5A3166.



Copyright © 2018, Texas Instruments Incorporated

**Figure 22. Improved Lock Time Circuit Simplified Block Diagram**



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**Figure 23. PLL Improved Power Consumption Simplified Block Diagram**

## 9.2 Typical Application

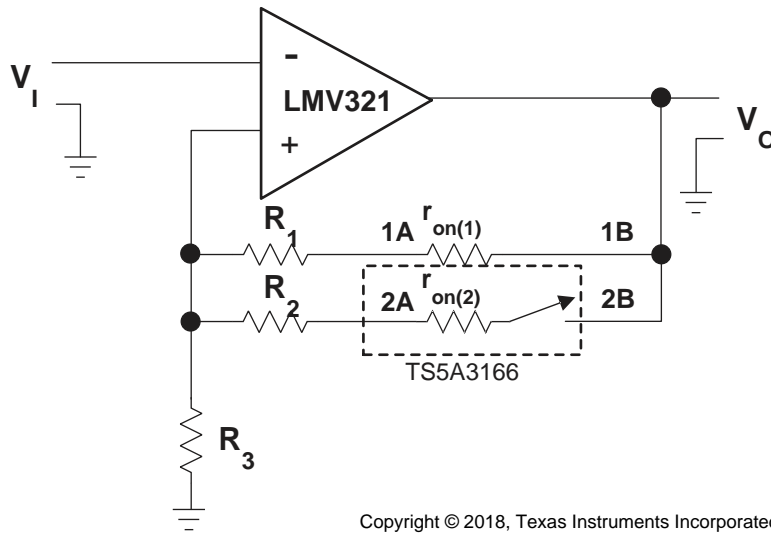


Figure 24. Gain-Control Circuit for Operational Amplifier

### 9.2.1 Design Requirements

By choosing values of R1 and R2, such that  $R_x \gg r_{on(x)}$ ,  $r_{on}$  of TS5A3166 can be ignored. The gain of operational amplifier can be calculated as follow:

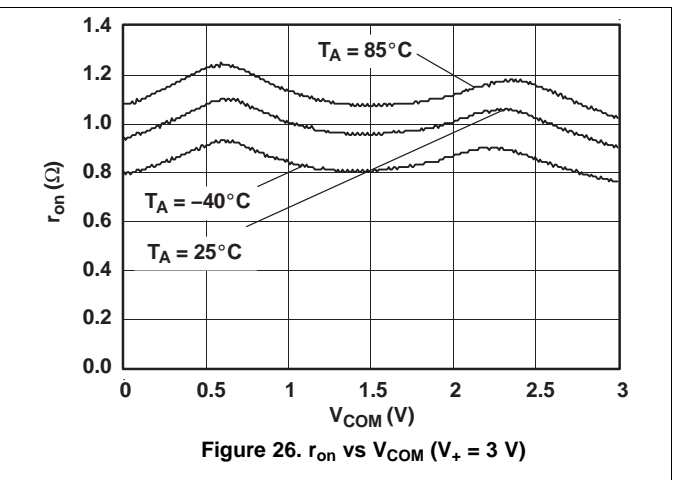
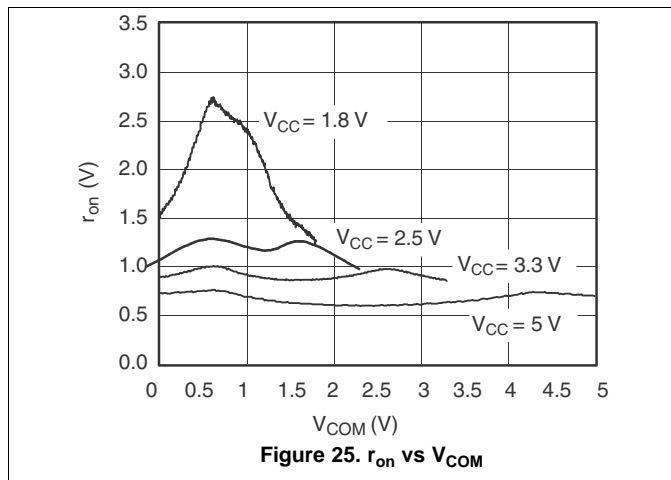
$$V_o / V_i = 1 + R_{||} / R_3 \tag{1}$$

$$R_{||} = (R_1 + r_{on(1)}) || (R_2 + r_{on(2)}) \tag{2}$$

### 9.2.2 Detailed Design Procedure

Place a switch in series with the input of the operational amplifier. Since the operational amplifier input impedance is very large, a switch on  $r_{on(1)}$  is irrelevant.

### 9.2.3 Application Curves



Typical Application (continued)

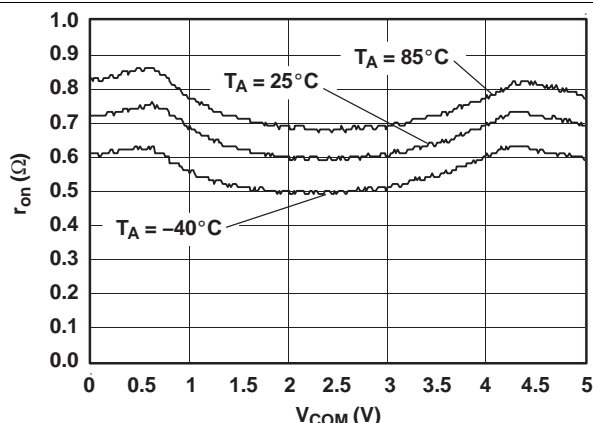


Figure 27. r<sub>on</sub> vs V<sub>COM</sub> (V<sub>+</sub> = 5 V)

10 Power Supply Recommendations

The power supply can be any voltage between the minimum and maximum supply voltage rating located in the [Recommended Operating Conditions](#).

Each V<sub>CC</sub> terminal should have a good bypass capacitor to prevent power disturbance. For devices with a single supply, a 0.1-μF bypass capacitor is recommended. If there are multiple pins labeled V<sub>CC</sub>, then a 0.01-μF or 0.022-μF capacitor is recommended for each V<sub>CC</sub> because the V<sub>CC</sub> pins will be tied together internally. For devices with dual supply pins operating at different voltages, for example V<sub>CC</sub> and V<sub>DD</sub>, a 0.1-μF bypass capacitor is recommended for each supply pin. It is acceptable to parallel multiple bypass capacitors to reject different frequencies of noise. 0.1-μF and 1-μF capacitors are commonly used in parallel. The bypass capacitor should be installed as close to the power terminal as possible for best results.

## 11 Layout

### 11.1 Layout Guidelines

Reflections and matching are closely related to loop antenna theory, but different enough to warrant their own discussion. When a PCB trace turns a corner at a 90° angle, a reflection can occur. This is primarily due to the change of width of the trace. At the apex of the turn, the trace width is increased to 1.414 times its width. This upsets the transmission line characteristics, especially the distributed capacitance and self-inductance of the trace — resulting in the reflection. It is a given that not all PCB traces can be straight, and so they will have to turn corners. [Figure 28](#) shows progressively better techniques of rounding corners. Only the last example maintains constant trace width and minimizes reflections.

### 11.2 Layout Example

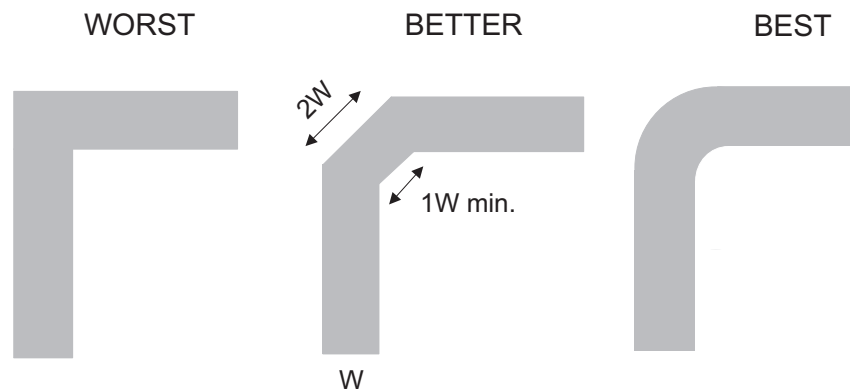


Figure 28. Trace Example

## 12 Device and Documentation Support

### 12.1 Device Support

#### 12.1.1 Device Nomenclature

**Table 2. Parameter Description**

| SYMBOL            | DESCRIPTION                                                                                                                                                                                                                                                                                                                                                                                   |
|-------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $V_{COM}$         | Voltage at COM                                                                                                                                                                                                                                                                                                                                                                                |
| $V_{NO}$          | Voltage at NO                                                                                                                                                                                                                                                                                                                                                                                 |
| $r_{on}$          | Resistance between COM and NO ports when the channel is ON                                                                                                                                                                                                                                                                                                                                    |
| $r_{peak}$        | Peak ON-state resistance over a specified voltage range                                                                                                                                                                                                                                                                                                                                       |
| $r_{on(Flat)}$    | Difference between the maximum and minimum value of $r_{on}$ in a channel over the specified range of conditions                                                                                                                                                                                                                                                                              |
| $I_{NO(OFF)}$     | Leakage current measured at the NO port, with the corresponding channel (NO to COM) in the OFF state under worst-case input and output conditions                                                                                                                                                                                                                                             |
| $I_{NO(PWROFF)}$  | Leakage current measured at the NO port during the power-down condition, $V_+ = 0$                                                                                                                                                                                                                                                                                                            |
| $I_{COM(OFF)}$    | Leakage current measured at the COM port, with the corresponding channel (COM to NO) in the OFF state under worst-case input and output conditions                                                                                                                                                                                                                                            |
| $I_{COM(PWROFF)}$ | Leakage current measured at the COM port during the power-down condition, $V_+ = 0$                                                                                                                                                                                                                                                                                                           |
| $I_{NO(ON)}$      | Leakage current measured at the NO port, with the corresponding channel (NO to COM) in the ON state and the output (COM) open                                                                                                                                                                                                                                                                 |
| $I_{COM(ON)}$     | Leakage current measured at the COM port, with the corresponding channel (COM to NO) in the ON state and the output (NO) open                                                                                                                                                                                                                                                                 |
| $V_{IH}$          | Minimum input voltage for logic high for the control input (IN)                                                                                                                                                                                                                                                                                                                               |
| $V_{IL}$          | Maximum input voltage for logic low for the control input (IN)                                                                                                                                                                                                                                                                                                                                |
| $V_I$             | Voltage at the control input (IN)                                                                                                                                                                                                                                                                                                                                                             |
| $I_{IH}, I_{IL}$  | Leakage current measured at the control input (IN)                                                                                                                                                                                                                                                                                                                                            |
| $t_{ON}$          | Turnon time for the switch. This parameter is measured under the specified range of conditions and by the propagation delay between the digital control (IN) signal and analog output (COM or NO) signal when the switch is turning ON.                                                                                                                                                       |
| $t_{OFF}$         | Turnoff time for the switch. This parameter is measured under the specified range of conditions and by the propagation delay between the digital control (IN) signal and analog output (COM or NO) signal when the switch is turning OFF.                                                                                                                                                     |
| $Q_C$             | Charge injection is a measurement of unwanted signal coupling from the control (IN) input to the analog (NO or COM) output. This is measured in coulomb (C) and measured by the total charge induced due to switching of the control input. Charge injection, $Q_C = C_L \times \Delta V_{COM}$ . $C_L$ is the load capacitance, and $\Delta V_{COM}$ is the change in analog output voltage. |
| $C_{NO(OFF)}$     | Capacitance at the NO port when the corresponding channel (NO to COM) is OFF                                                                                                                                                                                                                                                                                                                  |
| $C_{COM(OFF)}$    | Capacitance at the COM port when the corresponding channel (COM to NO) is OFF                                                                                                                                                                                                                                                                                                                 |
| $C_{NO(ON)}$      | Capacitance at the NO port when the corresponding channel (NO to COM) is ON                                                                                                                                                                                                                                                                                                                   |
| $C_{COM(ON)}$     | Capacitance at the COM port when the corresponding channel (COM to NO) is ON                                                                                                                                                                                                                                                                                                                  |
| $C_I$             | Capacitance of control input (IN)                                                                                                                                                                                                                                                                                                                                                             |
| $O_{ISO}$         | OFF isolation of the switch is a measurement of OFF-state switch impedance. This is measured in dB in a specific frequency, with the corresponding channel (NO to COM) in the OFF state.                                                                                                                                                                                                      |
| BW                | Bandwidth of the switch. This is the frequency in which the gain of an ON channel is –3 dB below the DC gain.                                                                                                                                                                                                                                                                                 |
| THD               | Total harmonic distortion describes the signal distortion caused by the analog switch. This is defined as the ratio of root mean square (RMS) value of the second, third, and higher harmonic to the absolute magnitude of the fundamental harmonic.                                                                                                                                          |
| $I_+$             | Static power-supply current with the control (IN) pin at $V_+$ or GND                                                                                                                                                                                                                                                                                                                         |

## 12.2 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](http://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.

## 12.3 Trademarks

E2E is a trademark of Texas Instruments.  
All other trademarks are the property of their respective owners.

## 12.4 Electrostatic Discharge Caution



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

## 12.5 Glossary

[SLYZ022](#) — *TI Glossary*.

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

## 13 Mechanical, Packaging, and Orderable Information

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

**PACKAGING INFORMATION**

| Orderable Device | Status<br>(1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan<br>(2)         | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|-----------------|------|-------------|-------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| TS5A3166DBVR     | ACTIVE        | SOT-23       | DBV             | 5    | 3000        | Green (RoHS & no Sb/Br) | CU NIPDAU   CU SN       | Level-1-260C-UNLIM   | -40 to 85    | (JASF, JASR)            | <a href="#">Samples</a> |
| TS5A3166DBVRE4   | ACTIVE        | SOT-23       | DBV             | 5    | 3000        | Green (RoHS & no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 85    | JASF                    | <a href="#">Samples</a> |
| TS5A3166DBVRG4   | ACTIVE        | SOT-23       | DBV             | 5    | 3000        | Green (RoHS & no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 85    | JASF                    | <a href="#">Samples</a> |
| TS5A3166DCKR     | ACTIVE        | SC70         | DCK             | 5    | 3000        | Green (RoHS & no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 85    | (JF5, JFF, JFR)         | <a href="#">Samples</a> |
| TS5A3166DCKRE4   | ACTIVE        | SC70         | DCK             | 5    | 3000        | Green (RoHS & no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 85    | (JF5, JFF, JFR)         | <a href="#">Samples</a> |
| TS5A3166DCKRG4   | ACTIVE        | SC70         | DCK             | 5    | 3000        | Green (RoHS & no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 85    | (JF5, JFF, JFR)         | <a href="#">Samples</a> |
| TS5A3166YZPR     | ACTIVE        | DSBGA        | YZP             | 5    | 3000        | Green (RoHS & no Sb/Br) | SNAGCU                  | Level-1-260C-UNLIM   | -40 to 85    | JFN                     | <a href="#">Samples</a> |

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

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

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

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

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

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

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

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

**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=100ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

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

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

<sup>(6)</sup> Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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

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

**OTHER QUALIFIED VERSIONS OF TS5A3166 :**

- Automotive: [TS5A3166-Q1](#)

NOTE: Qualified Version Definitions:

- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects



**TAPE AND REEL INFORMATION**

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

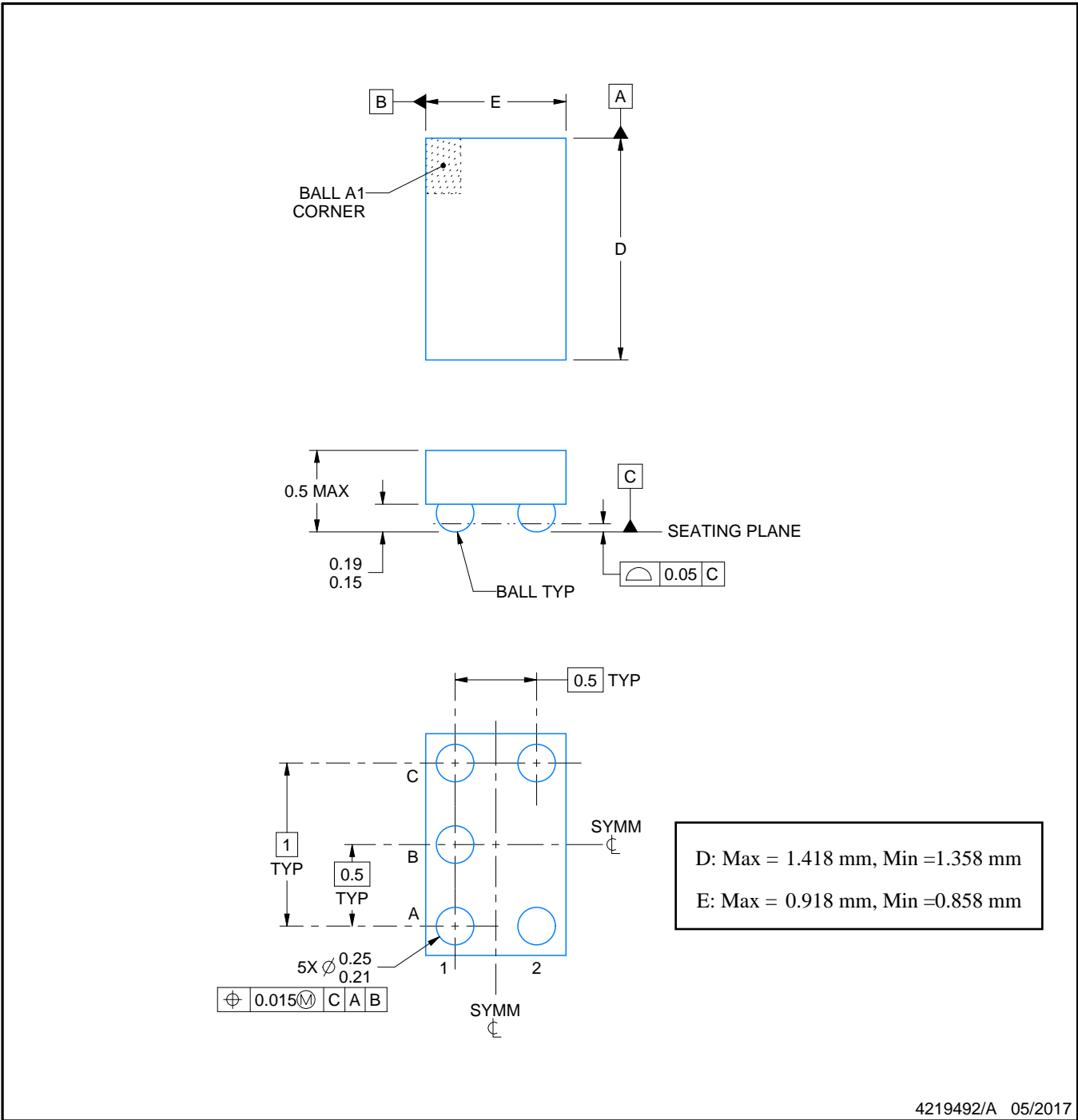

\*All dimensions are nominal

| Device         | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TS5A3166DBVR   | SOT-23       | DBV             | 5    | 3000 | 180.0              | 8.4                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TS5A3166DBVRG4 | SOT-23       | DBV             | 5    | 3000 | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TS5A3166DCKR   | SC70         | DCK             | 5    | 3000 | 180.0              | 8.4                | 2.47    | 2.3     | 1.25    | 4.0     | 8.0    | Q3            |
| TS5A3166DCKR   | SC70         | DCK             | 5    | 3000 | 178.0              | 9.0                | 2.4     | 2.5     | 1.2     | 4.0     | 8.0    | Q3            |
| TS5A3166YZPR   | DSBGA        | YZP             | 5    | 3000 | 178.0              | 9.2                | 1.02    | 1.52    | 0.63    | 4.0     | 8.0    | Q1            |

**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

| Device         | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TS5A3166DBVR   | SOT-23       | DBV             | 5    | 3000 | 202.0       | 201.0      | 28.0        |
| TS5A3166DBVRG4 | SOT-23       | DBV             | 5    | 3000 | 180.0       | 180.0      | 18.0        |
| TS5A3166DCKR   | SC70         | DCK             | 5    | 3000 | 202.0       | 201.0      | 28.0        |
| TS5A3166DCKR   | SC70         | DCK             | 5    | 3000 | 180.0       | 180.0      | 18.0        |
| TS5A3166YZPR   | DSBGA        | YZP             | 5    | 3000 | 220.0       | 220.0      | 35.0        |



- 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.

# EXAMPLE BOARD LAYOUT

YZP0005

DSBGA - 0.5 mm max height

DIE SIZE BALL GRID ARRAY



LAND PATTERN EXAMPLE  
SCALE:40X



SOLDER MASK DETAILS  
NOT TO SCALE

4219492/A 05/2017

NOTES: (continued)

3. Final dimensions may vary due to manufacturing tolerance considerations and also routing constraints. For more information, see Texas Instruments literature number SNVA009 ([www.ti.com/lit/snva009](http://www.ti.com/lit/snva009)).

# EXAMPLE STENCIL DESIGN

YZP0005

DSBGA - 0.5 mm max height

DIE SIZE BALL GRID ARRAY



SOLDER PASTE EXAMPLE  
BASED ON 0.1 mm THICK STENCIL  
SCALE:40X

4219492/A 05/2017

NOTES: (continued)

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

## GENERIC PACKAGE VIEW

DBV 5

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



Images above are just a representation of the package family, actual package may vary.  
Refer to the product data sheet for package details.

4073253/P

DBV0005A



# PACKAGE OUTLINE

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



4214839/C 04/2017

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. Reference JEDEC MO-178.

# EXAMPLE BOARD LAYOUT

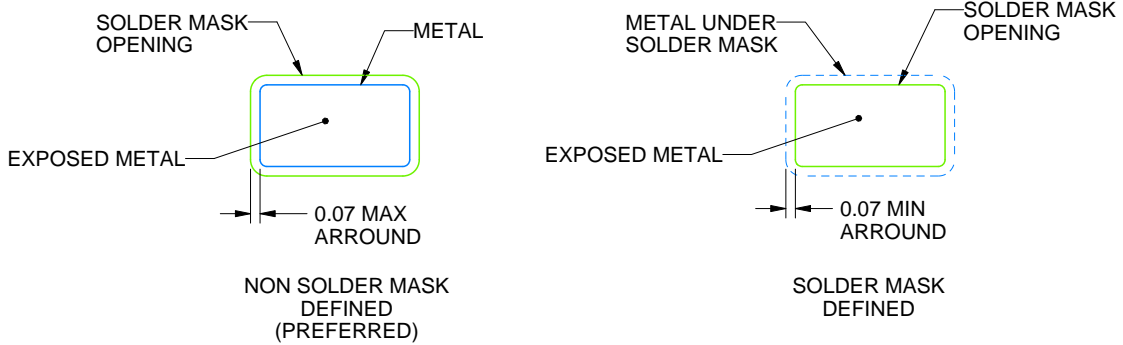
DBV0005A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:15X



SOLDER MASK DETAILS

4214839/C 04/2017

NOTES: (continued)

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



# EXAMPLE STENCIL DESIGN

DBV0005A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE:15X

4214839/C 04/2017

NOTES: (continued)

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

DCK (R-PDSO-G5)

PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
  - D. Falls within JEDEC MO-203 variation AA.

DCK (R-PDSO-G5)

PLASTIC SMALL OUTLINE



- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
  - Publication IPC-7351 is recommended for alternate designs.
  - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC-7525 for other stencil recommendations.

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