

## LMS4684 0.5Ω Low-Voltage, Dual SPDT Analog Switch

Check for Samples: [LMS4684](#)

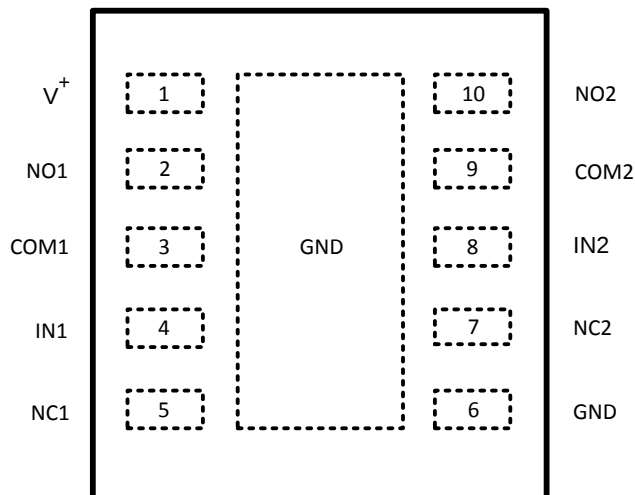
### FEATURES

- NC Switch  $R_{ON}$  0.5Ω max @ 2.7V
- NO Switch  $R_{ON}$  0.8Ω max @ 2.7V
- 5 nA (typ) Supply Current  $T_A = 25^{\circ}\text{C}$
- 1.8 to 5.5V Single Supply Operation
- 12-Bump DSBGA Package
- WSON-10 Package, 3x4mm

### APPLICATIONS

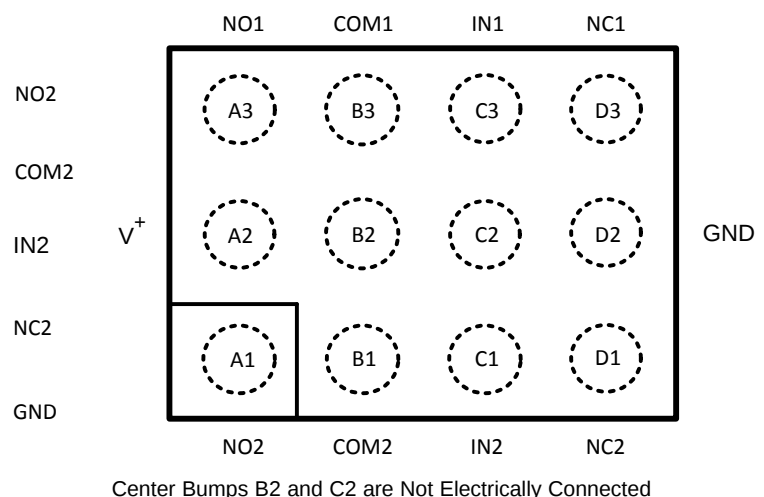
- Power Routing
- Battery-Operated Equipment
- Communications Circuits
- Modems
- Cell Phones

### Connection Diagram



Exposed pad on back of package needs to be connected to pin 6 on the board

**Figure 1. 10-WSON Package-Top View**



**Figure 2. 12-Bump DSBGA Package-Top View (Bumped Side Down)**



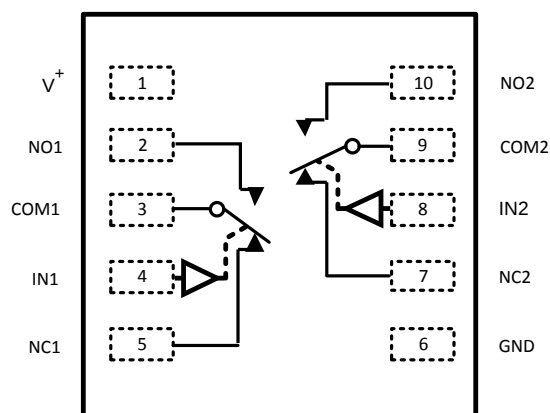
Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

All trademarks are the property of their respective owners.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of the Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

Copyright © 2004–2013, Texas Instruments Incorporated

## SCHEMATIC DIAGRAM



| IN                                 | NO  | NC  |
|------------------------------------|-----|-----|
| 0                                  | Off | On  |
| 1                                  | On  | Off |
| Switches shown for Logic "0" input |     |     |

## PIN DESCRIPTIONS

| Name           | Pin ID |        | Description                                                                              |
|----------------|--------|--------|------------------------------------------------------------------------------------------|
|                | WSO    | DSBGA  |                                                                                          |
| NC             | 5, 7   | D3, D1 | Analog switch normally closed terminal                                                   |
| IN             | 4, 8   | C3, C1 | Digital control input                                                                    |
| COM            | 3, 9   | B3, B1 | Analog switch common terminal                                                            |
| NO             | 2, 10  | A3, A1 | Analog switch normally open terminal                                                     |
| V <sup>+</sup> | 1      | A2     | Positive supply voltage                                                                  |
| GND            | 6      | D2     | Ground                                                                                   |
|                |        | B2, C2 | Not electrically connected. Can be used to help dissipate heat by connecting to GND pin. |



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.

## ABSOLUTE MAXIMUM RATINGS <sup>(1)(2)(3)</sup>

|                                     |                                  |       |
|-------------------------------------|----------------------------------|-------|
| V <sup>+</sup>                      | –0.3V to 6.0V                    |       |
| IN                                  | –0.3V to 6.0V                    |       |
| COM, NO, NC                         | –0.3V to (V <sup>+</sup> + 0.3V) |       |
| Continuous Switch Current           | ±400 mA                          |       |
| ESD Tolerance <sup>(4)</sup>        | Human Body Model                 | 2000V |
|                                     | Machine Model                    | 200V  |
| Storage Temperature Range           | –65°C to 150°C                   |       |
| Junction Temperature <sup>(5)</sup> | 150°C Max                        |       |

- (1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but specific performance is not guaranteed.
- (2) All voltages are with respect to GND, unless otherwise specified.
- (3) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/ Distributors for availability and specifications.
- (4) Human body model: 1.5 kΩ in series with 100 pF. Machine model, 0Ω in series with 200 pF.
- (5) The maximum power dissipation is a function of T<sub>J(max)</sub>, θ<sub>JA</sub> and T<sub>A</sub>.

## OPERATING RATINGS

|                                   |               |
|-----------------------------------|---------------|
| Nominal Supply Voltage            | 1.8V to 5.5V  |
| IN Voltage (regardless of supply) | –0.3V to 5.5V |
| Temperature Range                 | –40°C to 85°C |

- (1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but specific performance is not guaranteed.
- (2) All voltages are with respect to GND, unless otherwise specified.

## PACKAGE THERMAL RESISTANCE

| Package  | $\theta_{JA}$ |
|----------|---------------|
| WSO-10   | 43°C / W      |
| DSBGA-12 | 57°C / W      |

## ELECTRICAL CHARACTERISTICS

Unless otherwise specified,  $V^+ = 2.7$  to  $3.3V$ ,  $V_{IH} = 1.4V$ ,  $V_{IL} = 0.5V$ . Typical values are measured at  $3V$ , and  $T_J = 25^\circ C$ .

**Boldface** limits apply at temperature extremes.

| Symbol                                               | Parameter                                                | Conditions                                                                                                            |                                         | Min   | Typ        | Max            | Units |
|------------------------------------------------------|----------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|-----------------------------------------|-------|------------|----------------|-------|
| V <sub>NO</sub> , V <sub>NC</sub> , V <sub>COM</sub> | Analog Signal Range                                      |                                                                                                                       |                                         | 0     |            | V <sup>+</sup> | V     |
| R <sub>ON</sub> (NC)                                 | NC On-Resistance <sup>(1)</sup>                          | V <sup>+</sup> = 2.7V, I <sub>COM</sub> = 100 mA, V <sub>NC</sub> =0 to V <sup>+</sup>                                |                                         |       | 0.3        | <b>0.5</b>     | Ω     |
| R <sub>ON</sub> (NO)                                 | NO On-Resistance <sup>(1)</sup>                          | V <sup>+</sup> = 2.7V, I <sub>COM</sub> = 100 mA, V <sub>NO</sub> =0 to V <sup>+</sup>                                |                                         |       | 0.45       | <b>0.8</b>     | Ω     |
| ΔR <sub>ON</sub>                                     | On-Resistance Match Between Channels <sup>(1), (2)</sup> | V <sup>+</sup> = 2.7V, I <sub>COM</sub> = 100 mA, V <sub>NC</sub> or V <sub>NO</sub> =1.5V                            |                                         |       | 1.11       | <b>60</b>      | mΩ    |
| R <sub>FLAT</sub> (NC)                               | NC-On-Resistance Flatness <sup>(3)</sup>                 | V <sup>+</sup> = 2.7V, I <sub>COM</sub> = 100 mA, V <sub>NC</sub> = 0 to V <sup>+</sup>                               | WSON<br>T <sub>J</sub> = -40°C to 85°C  |       | 0.1        | 0.25           | Ω     |
|                                                      |                                                          |                                                                                                                       | DSBGA<br>T <sub>J</sub> = -40°C to 85°C |       | 0.1        | 0.25           |       |
| R <sub>FLAT</sub> (NO)                               | NO On-Resistance Flatness <sup>(3)</sup>                 | V <sup>+</sup> = 2.7V, I <sub>COM</sub> = 100 mA, V <sub>NO</sub> = 0 to V <sup>+</sup>                               |                                         |       | 0.18       | <b>0.35</b>    | Ω     |
| I <sub>NO</sub> (OFF) or I <sub>NC</sub> (OFF)       | NO or NC Off Leakage Current                             | V <sup>+</sup> = 3.3V, V <sub>NO</sub> or V <sub>NC</sub> = 3V, 0.3V; V <sub>COM</sub> = 0.3V, 3V                     | -1                                      | 0.014 | 1          | nA             |       |
|                                                      |                                                          |                                                                                                                       | <b>-10</b>                              |       | <b>10</b>  |                |       |
| I <sub>COM</sub> (ON)                                | COM On Leakage Current                                   | V <sup>+</sup> = 3.3V, V <sub>NO</sub> or V <sub>NC</sub> = 3V, 0.3V, or floating; V <sub>COM</sub> = 3V, or floating | -2                                      |       | 2          | nA             |       |
|                                                      |                                                          |                                                                                                                       | <b>-20</b>                              |       | <b>20</b>  |                |       |
| Dynamic Characteristics                              |                                                          |                                                                                                                       |                                         |       |            |                |       |
| t <sub>ON</sub>                                      | Turn-On Time                                             | V <sup>+</sup> = 2.7V, V <sub>NO</sub> or V <sub>NC</sub> = 1.5V; R <sub>L</sub> = 50Ω; C <sub>L</sub> = 35 pF;       |                                         | 38    | 60         | ns             |       |
|                                                      |                                                          |                                                                                                                       |                                         |       | <b>70</b>  |                |       |
| t <sub>OFF</sub>                                     | Turn-Off Time                                            | V <sup>+</sup> = 2.7V, V <sub>NO</sub> or V <sub>NC</sub> = 1.5V; R <sub>L</sub> = 50Ω; C <sub>L</sub> = 35 pF;       |                                         | 22    | 40         | ns             |       |
|                                                      |                                                          |                                                                                                                       |                                         |       | <b>50</b>  |                |       |
| t <sub>BBM</sub>                                     | Break-Before-Make Delay                                  | V <sup>+</sup> = 2.7V, V <sub>NO</sub> or V <sub>NC</sub> = 1.5V; R <sub>L</sub> = 50Ω; C <sub>L</sub> = 35 pF;       | <b>2</b>                                | 15    |            | ns             |       |
| Q                                                    | Charge Injection                                         | COM = 0; R <sub>S</sub> = 0; C <sub>L</sub> = 1 nF;                                                                   |                                         | 200   |            | pC             |       |
| V <sub>ISO</sub>                                     | Off-Isolation <sup>(4)</sup>                             | R <sub>L</sub> = 50Ω; C <sub>L</sub> = 5 pF; f = 100 kHz                                                              |                                         | -68   |            | dB             |       |
| V <sub>CT</sub>                                      | Crosstalk                                                |                                                                                                                       |                                         | -72   |            | dB             |       |
| Digital I/O                                          |                                                          |                                                                                                                       |                                         |       |            |                |       |
| V <sub>IH</sub>                                      | Input Logic High                                         |                                                                                                                       | <b>1.4</b>                              |       |            | V              |       |
| V <sub>IL</sub>                                      | Input Logic Low                                          |                                                                                                                       |                                         |       | <b>0.5</b> | V              |       |

- (1) Guaranteed by design.
- (2)  $\Delta R_{ON}$  is equal to the difference between NC1/NC2  $R_{ON}$  or NO1/NO2  $R_{ON}$  at a specified voltage.
- (3) Flatness is defined as the difference between the maximum and minimum value of on-resistance as measured over the specified analog signal ranges.
- (4) Off-isolation =  $20 \log_{10}(V_{COM}/V_{NO})$ , where  $V_{COM}$  = output,  $V_{NO}$  = input switch off.

## ELECTRICAL CHARACTERISTICS (continued)

Unless otherwise specified,  $V^+ = 2.7$  to  $3.3\text{V}$ ,  $V_{IH} = 1.4\text{V}$ ,  $V_{IL} = 0.5\text{V}$ . Typical values are measured at  $3\text{V}$ , and  $T_J = 25^\circ\text{C}$ .

**Boldface** limits apply at temperature extremes.

| Symbol              | Parameter                | Conditions            | Min        | Typ | Max        | Units         |
|---------------------|--------------------------|-----------------------|------------|-----|------------|---------------|
| $I_{IN}$            | IN Input Leakage Current | $V_{IN} = 0$ or $V^+$ | <b>-1</b>  |     | <b>1</b>   | $\mu\text{A}$ |
| <b>Power Supply</b> |                          |                       |            |     |            |               |
| $V^+$               | Power-Supply Range       |                       | <b>1.8</b> |     | <b>5.5</b> | V             |
| $I^+$               | Supply Current           | $V^+ = 5.5\text{V}$   |            | 5   |            | nA            |

## PARAMETRIC MEASUREMENT INFORMATION

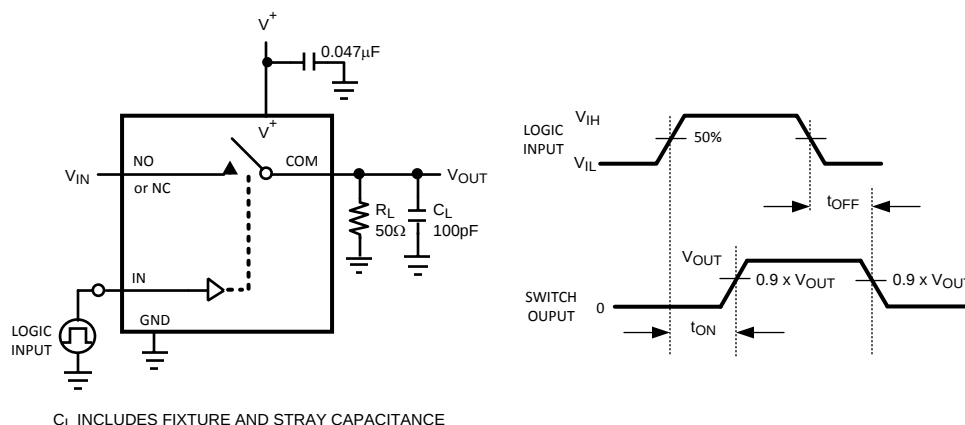


Figure 3.  $t_{ON} / t_{OFF}$  Time

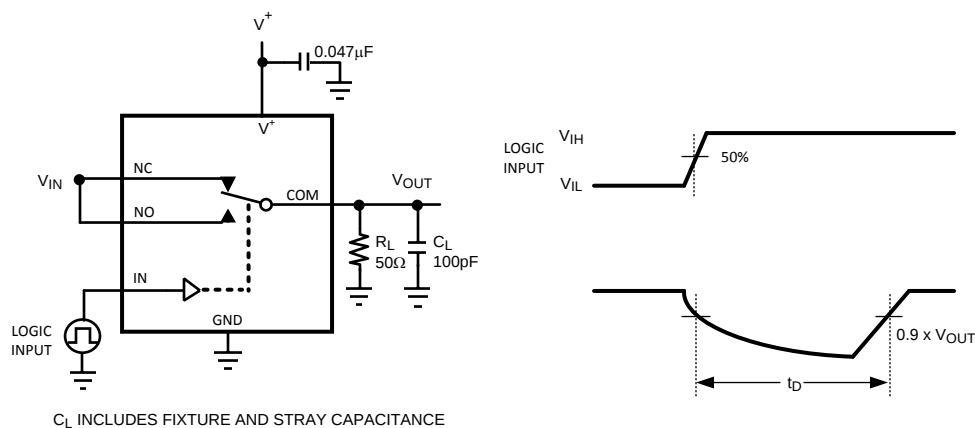


Figure 4. Break-Before Make Delay

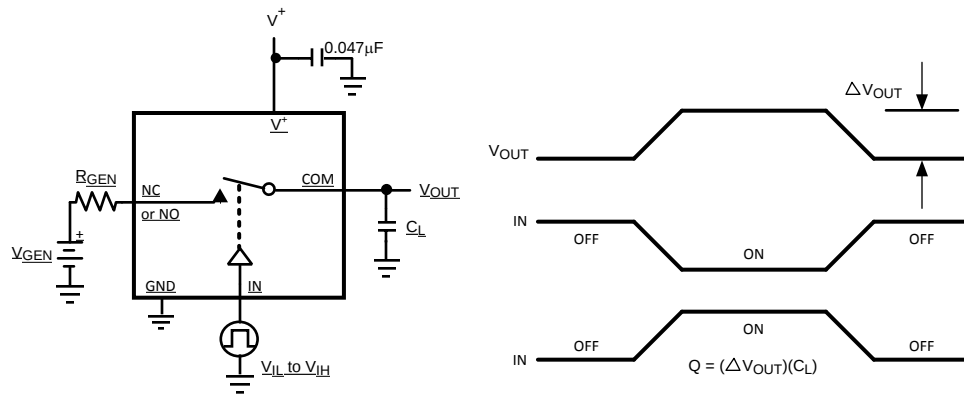


Figure 5. Charge Injection

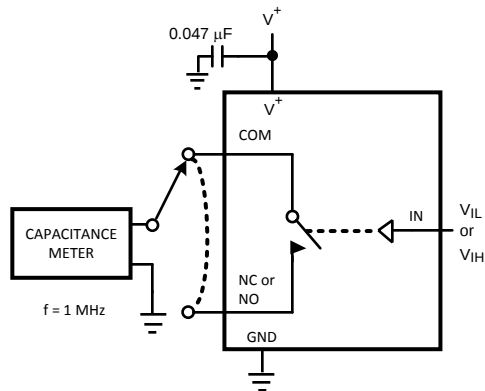


Figure 6. Channel Capacitance

## TYPICAL PERFORMANCE CHARACTERISTICS

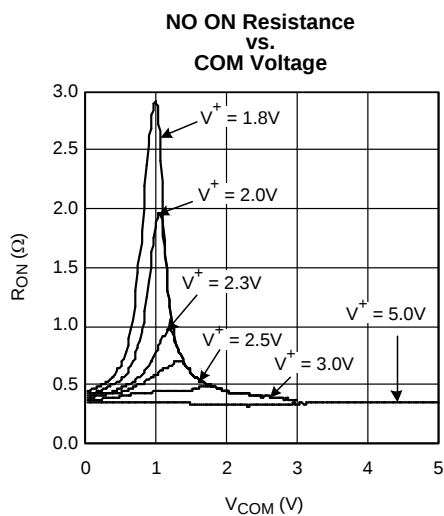


Figure 7.

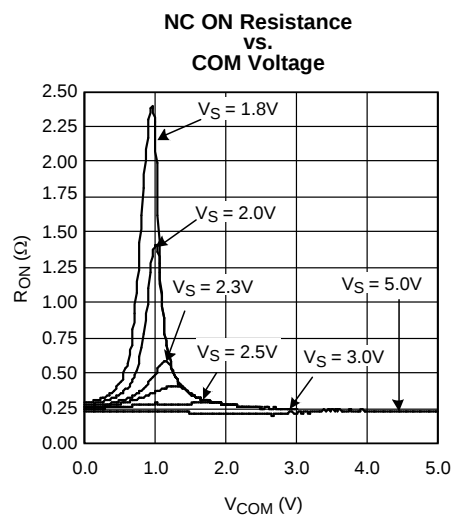


Figure 8.

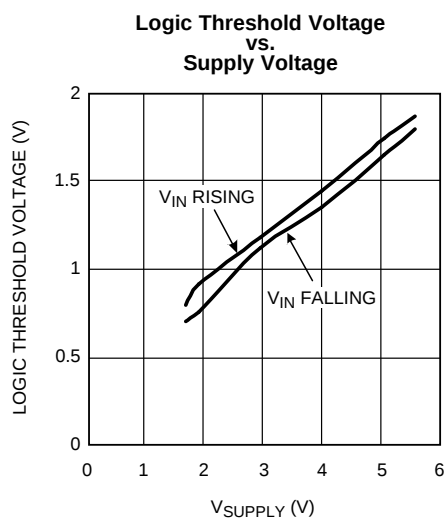


Figure 9.

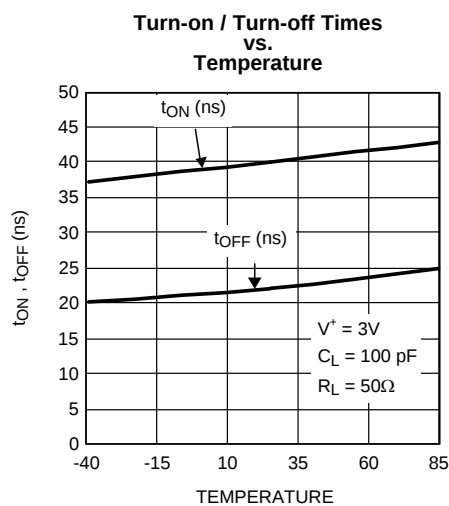


Figure 10.

## TYPICAL PERFORMANCE CHARACTERISTICS (continued)

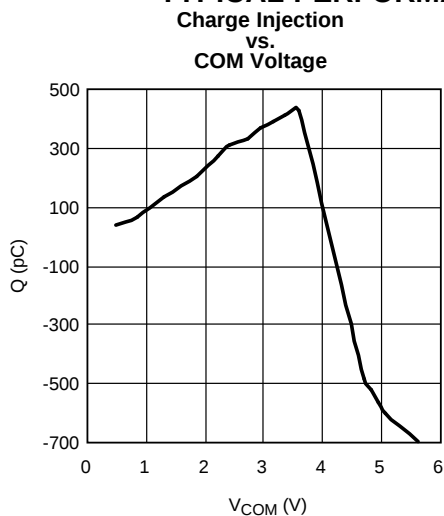


Figure 11.

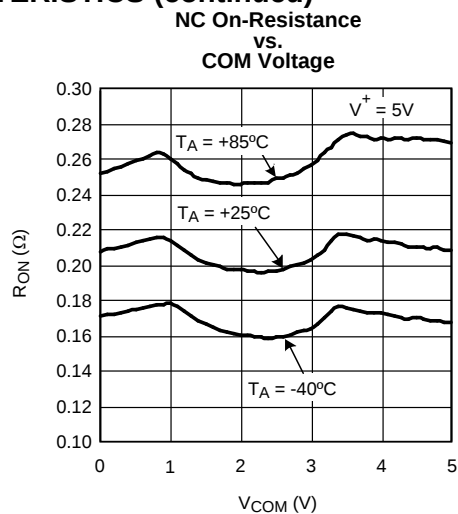


Figure 12.

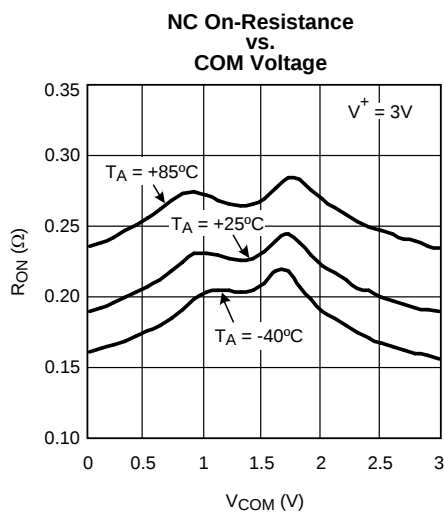


Figure 13.

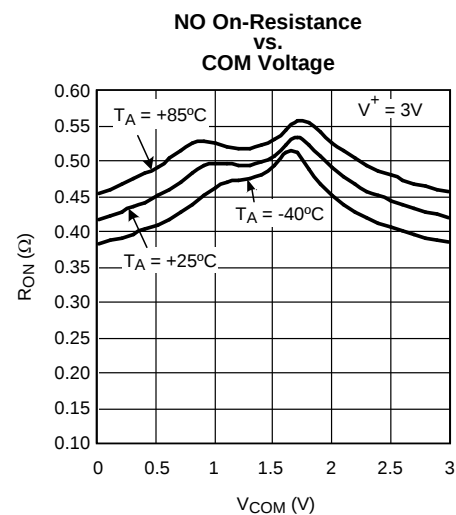


Figure 14.

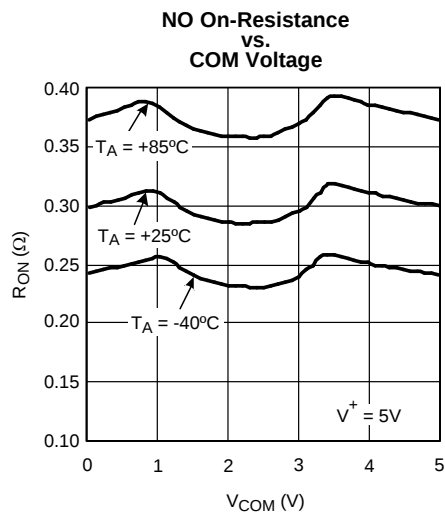


Figure 15.

## FUNCTIONAL DESCRIPTION

The LMS4684 is a low voltage dual, extremely low On-Resistance analog switch that can operate over a supply voltage range of 1.8V to 5.5V. The LMS4684 has been fully characterized to operate in applications with 3V nominal supply voltage and features very low on resistance and fast Turn-Off and Turn-On times with break-before-make switching.

The switch operates asymmetrically; one terminal is normally closed (NC) and the other terminal normally open (NO).

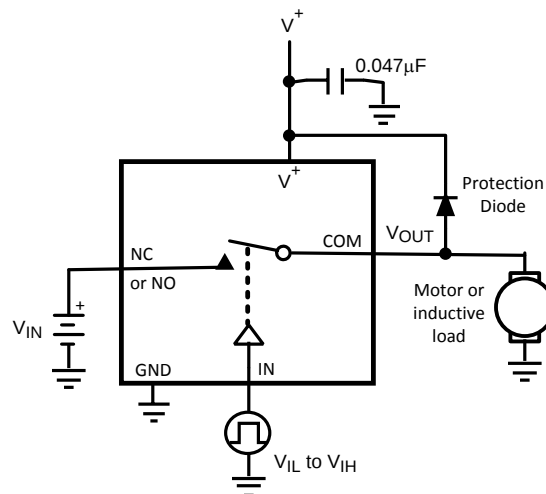
Both NC and NO terminals are connected to a common terminal (COM). This configuration is ideal for applications with asymmetric loads such as speaker handsets and internal speakers.

## Applications Information

### ANALOG INPUT SIGNAL

Analog input signals can range from GND to  $V^+$  and are passed through the switch with very little change. Each switch is bidirectional so any pin can be an input or output.

Exercise care when making connection to an inductive load, such as a motor. As is true with any analog switch used with an inductive load, the back emf produced when the switch is turned off can damage the LMS4684 by electrical overstress. For such applications, a diode should be connected across the motor to prevent damage to the switch, as indicated in [Figure 16](#). Be sure the diode has adequate current carrying capabilities.



**Figure 16. Inductive Load Over-Voltage Protection**

### DIGITAL CONTROL INPUTS

The IN pin can be driven to 5.5V regardless of the voltage level of the supply pin  $V^+$ . For example, if the LMS4684 is operated with a supply of 2V, the digital control input could still be driven to 5V. Power consumption is increased when the control pin is driven rail-to-rail.

### SUPPLY VOLTAGE

It is good general practice to first apply the supply voltage to a CMOS device before driving any other pins. This is also true for the LMS4684 analog switch, which is a CMOS device.

However, if it is necessary to have an analog signal applied before the supply voltage is applied and the analog signal source is not limited to 20 mA max, a diode connected between the supply voltage and the  $V^+$  pin as shown in [Figure 17](#) will provide input protection. This will limit the max analog voltage to a diode drop below  $V^+$ . This diode, D1, will also provide protection against some over voltage situations.

It is also good practice to provide adequate supply bypassing to all analog circuits. We recommend a that minimum bypass capacitor value of  $0.047\mu\text{F}$  be provided for the LMS4684. An inadequate bypass capacitor can lead to excessive supply current.

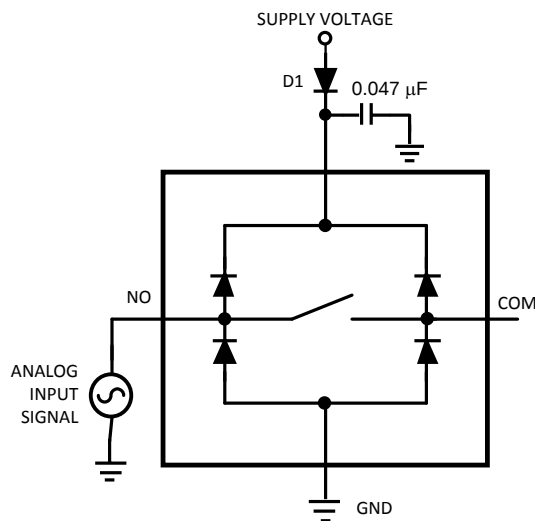


Figure 17. Input Over Voltage Protection Circuitry

## OFF-ISOLATION

Analog switches are composed of FETs (field Effect Transistors). The channel resistance is low when the pass transistors are "on" and that resistance is high when the pass transistors are "off". However, when the pass transistors are "off", the source to drain capacitance of the pass transistors will pass some energy. This capacitance is inversely proportional to the switch "on" resistance, so a switch with a low "on" resistance may not be suitable for some high frequency applications.

Figure 18 shows the equivalent circuit of an analog switch. Unless the load impedance after the switch is relatively low, the switch capacitance will couple excessive energy across the "open" switch at higher frequencies, degrading off isolation performance. Off Isolation of the LMS4684 is specified with a  $50\Omega$  load. Higher load impedances will degrade off isolation performance compared with what is specified.

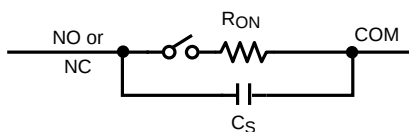
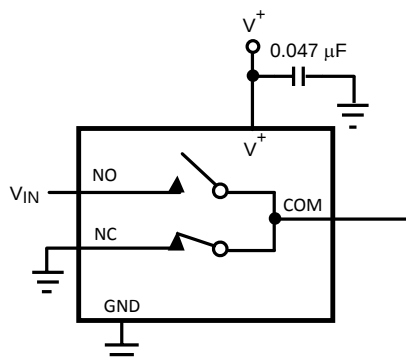


Figure 18. Equivalent Circuit of an Analog Switch

Off isolation may be improved by decreasing the LMS4684 load impedance below  $50\Omega$ . When doing this, be sure that the LMS4684 maximum current rating is not exceeded. Also, decreasing the load impedance too much can result in excessive signal distortion because the channel resistance variation with input signal voltage would then be a greater percentage of the load impedance.

If it is desired to extend the usable bandwidth of the LMS4684 while maintaining reasonable off-isolation is through the use of the circuit of Figure 19.



**Figure 19. Using the LMS4684 at higher frequencies**

### PCB LAYOUT AND THERMAL CONSIDERATIONS

Both the WSON and DSBGA packages offer enhanced board real estate savings because of their small footprints. These tiny packages are capable of handling high continuous currents because of the advanced package thermal handling capabilities.

The WSON package has the exposed die attach pad internally connected to the internal circuit GND. When this pad is soldered to copper on the PCB board according to Application Note AN-1187, the full thermal capability of the WSON package can be achieved without additional bulky heat sinks to dissipate the heat generated. The DSBGA package has a similar capability to dissipate heat through Bumps B2 and C2, which are not electrically connected. To enhance heat dissipation of the DSBGA package B2 and C2 could be connected to the GND pin through copper traces on the board.

See Application Note AN-1112 for DSBGA package considerations.

## REVISION HISTORY

| Changes from Revision B (April 2013) to Revision C         | Page               |
|------------------------------------------------------------|--------------------|
| • Changed layout of National Data Sheet to TI format ..... | <a href="#">10</a> |

## PACKAGING INFORMATION

| Orderable part number            | Status<br>(1) | Material type<br>(2) | Package   Pins   | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|----------------------------------|---------------|----------------------|------------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">LMS4684ITL/NOPB</a>  | Active        | Production           | DSBGA (YZR)   12 | 250   SMALL T&R       | Yes         | SNAGCU                               | Level-1-260C-UNLIM                | -40 to 85    | F09A                |
| LMS4684ITL/NOPB.A                | Active        | Production           | DSBGA (YZR)   12 | 250   SMALL T&R       | Yes         | SNAGCU                               | Level-1-260C-UNLIM                | -40 to 85    | F09A                |
| <a href="#">LMS4684ITLX/NOPB</a> | Active        | Production           | DSBGA (YZR)   12 | 3000   LARGE T&R      | Yes         | SNAGCU                               | Level-1-260C-UNLIM                | -40 to 85    | F09A                |
| LMS4684ITLX/NOPB.A               | Active        | Production           | DSBGA (YZR)   12 | 3000   LARGE T&R      | Yes         | SNAGCU                               | Level-1-260C-UNLIM                | -40 to 85    | F09A                |
| <a href="#">LMS4684LD/NOPB</a>   | Active        | Production           | WSON (NGZ)   10  | 1000   SMALL T&R      | Yes         | SN                                   | Level-3-260C-168 HR               | -40 to 85    | L4684               |
| LMS4684LD/NOPB.A                 | Active        | Production           | WSON (NGZ)   10  | 1000   SMALL T&R      | Yes         | SN                                   | Level-3-260C-168 HR               | -40 to 85    | L4684               |

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

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

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

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

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

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

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

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

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



## TAPE AND REEL INFORMATION



\*All dimensions are nominal

| Device           | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|------------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| LMS4684ITL/NOPB  | DSBGA        | YZR             | 12   | 250  | 178.0              | 8.4                | 1.73    | 2.46    | 0.76    | 4.0     | 8.0    | Q1            |
| LMS4684ITLX/NOPB | DSBGA        | YZR             | 12   | 3000 | 178.0              | 8.4                | 1.73    | 2.46    | 0.76    | 4.0     | 8.0    | Q1            |
| LMS4684LD/NOPB   | WSO          | NGZ             | 10   | 1000 | 177.8              | 12.4               | 4.3     | 3.3     | 1.0     | 8.0     | 12.0   | Q1            |

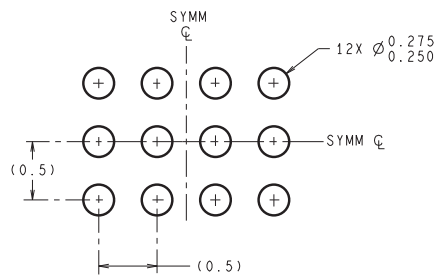
## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

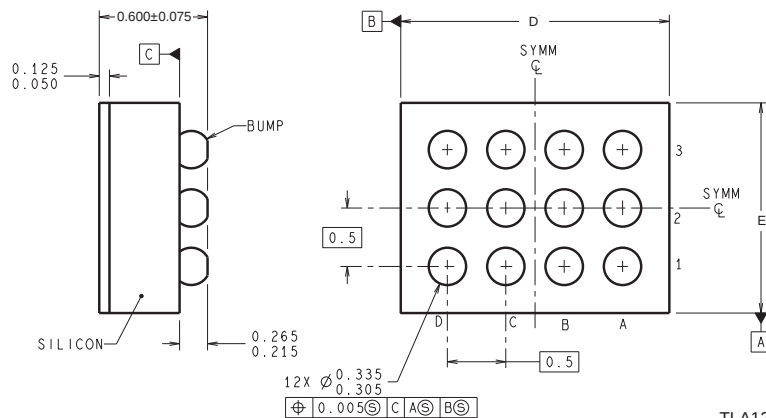
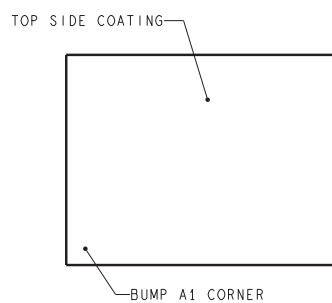
| Device           | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|------------------|--------------|-----------------|------|------|-------------|------------|-------------|
| LMS4684ITL/NOPB  | DSBGA        | YZR             | 12   | 250  | 208.0       | 191.0      | 35.0        |
| LMS4684ITLX/NOPB | DSBGA        | YZR             | 12   | 3000 | 208.0       | 191.0      | 35.0        |
| LMS4684LD/NOPB   | WSON         | NGZ             | 10   | 1000 | 208.0       | 191.0      | 35.0        |

YZR0012



**DIMENSIONS ARE IN MILLIMETERS**  
DIMENSIONS IN ( ) FOR REFERENCE ONLY

## LAND PATTERN RECOMMENDATION



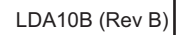
TLA12XXX (Rev C)

D: Max = 2.378 mm, Min =2.317 mm

E: Max = 1.641 mm, Min =1.581 mm

4215049/A 12/12

NOTES: A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.  
B. This drawing is subject to change without notice.



## IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you fully indemnify TI and its representatives against any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#), [TI's General Quality Guidelines](#), or other applicable terms available either on [ti.com](#) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products. Unless TI explicitly designates a product as custom or customer-specified, TI products are standard, catalog, general purpose devices.

TI objects to and rejects any additional or different terms you may propose.

Copyright © 2025, Texas Instruments Incorporated

Last updated 10/2025