



Low-Voltage, 0.31Ω, Quad-SPDT Analog Switch

MAX4735

General Description

The MAX4735 quad-SPDT switch routes audio signals in portable applications. Each channel has a 0.31Ω typical on-resistance, allowing the MAX4735 to drive 8Ω loudspeakers with less than 0.02% distortion.

The MAX4735 is configured as a quad-SPDT switch with two common control inputs. Each digital input controls two pairs of SPDT switches. The switches are fully bidirectional, allowing both multiplexing and demultiplexing operation. Break-before-make operation is guaranteed.

The device operates from a +1.6V to +3.6V supply and over the extended -40°C to +85°C temperature range. It is offered in both 16-pin 3mm x 3mm TQFN and TSSOP packages.

Features

- ◆ Low 0.31Ω R_{ON}
- ◆ 0.06Ω On-Resistance Flatness
- ◆ Excellent 0.015Ω On-Resistance Matching
- ◆ Low 0.02% THD into 8Ω
- ◆ Low 0.015% THD into 32Ω
- ◆ Audio Signal Routing
- ◆ Space-Saving, 3mm x 3mm TQFN Package
- ◆ 1.8V Logic Compatible

Applications

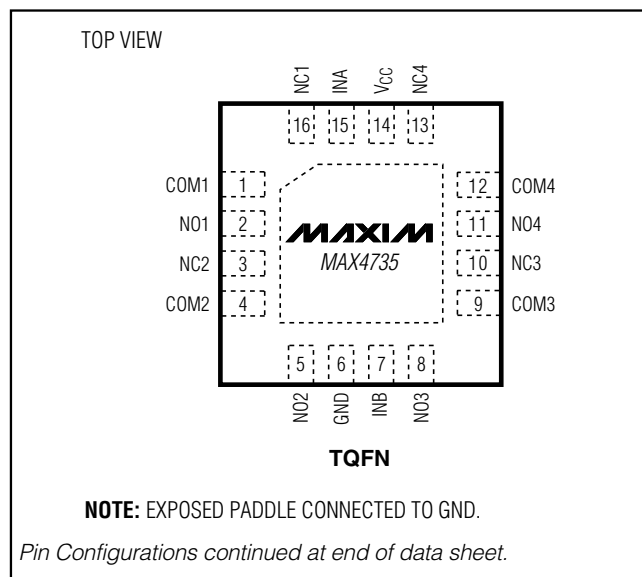
- Cell Phones
- Digital Still Cameras
- PDA's and Palmtop Devices
- MP3 Players

Ordering Information

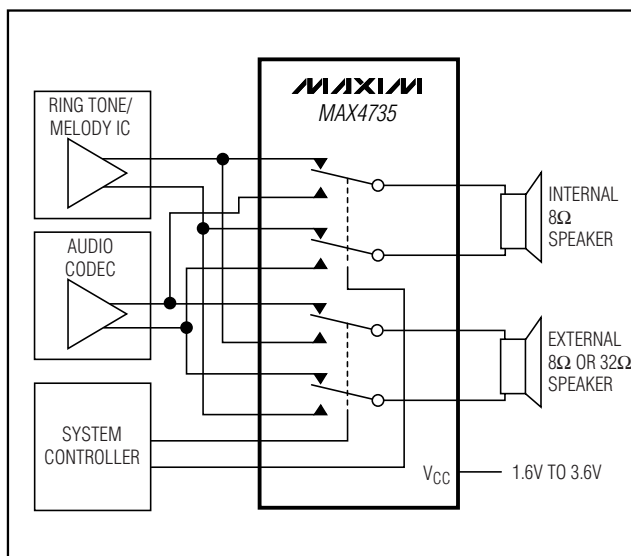
| PART | PIN-PACKAGE | TOP MARK | PKG CODE |
|------------|-------------|----------|----------|
| MAX4735ETE | 16 TQFN | ACT | T1633-4 |
| MAX4735EUE | 16 TSSOP | — | U16-2 |

Note: All products specified across the -40°C to +85°C temperature range.

Pin Configurations



Typical Application Circuit



Low-Voltage, 0.31Ω, Quad-SPDT Analog Switch

ABSOLUTE MAXIMUM RATINGS

| | | |
|---|-----------------------------------|---|
| V _{CC} , INA, INB to GND | -0.3V to +4.0V | Continuous Power Dissipation (T _A = +70°C) |
| All Other Pins to GND (Note 1)..... | -0.3V to (V _{CC} + 0.3V) | 16-Pin TQFN (derate 15.6mW/°C above +70°C) |
| Continuous Current (NO ₋ , NC ₋ , COM ₋)..... | ±300mA | 16-Pin TSSOP (derate 9.4mW/°C above +70°C) |
| Peak Current (NO ₋ , NC ₋ , COM ₋) | | Operating Temperature Range |
| (pulsed at 1ms, 50% duty cycle)..... | ±400mA | -40°C to +85°C |
| Peak Current (NO ₋ , NC ₋ , COM ₋) | | Storage Temperature Range |
| (pulsed at 1ms, 10% duty cycle)..... | ±500mA | -65°C to +150°C |
| | | Junction Temperature |
| | | +150°C |
| | | Lead Temperature (soldering, 10s) |
| | | +300°C |

Note 1: Signals on NO₋, NC₋, COM₋ exceeding V_{CC} or GND are clamped by internal diodes. IN₋ is clamped to GND by an internal diode. Limit forward-diode current to maximum current rating.

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 in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

(V_{CC} = 2.7V to 3.6V, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at V_{CC} = 3V, T_A = +25°C.) (Note 2)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|--|-------------------|---|---|-------|-----------------|-------|
| POWER SUPPLY | | | | | | |
| Supply Voltage Range | V _{CC} | | 1.6 | | 3.6 | V |
| Supply Current | I _{CC} | V _{CC} = 3.6V, V _{IN₋} = 0 or V _{CC} , NO ₋ = NC ₋ = COM ₋ = floating | | 0.015 | 1 | μA |
| ANALOG SWITCH | | | | | | |
| Analog Signal Range | | NO ₋ , NC ₋ , COM ₋ | 0 | | V _{CC} | V |
| On-Resistance | R _{ON} | V _{CC} = 2.7V, I _{COM₋} = 100mA, V _{NO₋} or V _{NC₋} = 0 to V _{CC} (Note 3) | T _A = +25°C | 0.31 | 0.4 | Ω |
| | | | T _A = T _{MIN} to T _{MAX} | | 0.45 | |
| On-Resistance Match | ΔR _{ON} | V _{CC} = 2.7V, I _{COM₋} = 100mA, V _{NO₋} or V _{NC₋} = 1.5V (Notes 3, 4) | T _A = +25°C | 0.015 | 0.03 | Ω |
| | | | T _A = T _{MIN} to T _{MAX} | | 0.03 | |
| On-Resistance Flatness | R _{FLAT} | V _{CC} = 2.7V; I _{COM₋} = 100mA; V _{NO₋} or V _{NC₋} = 0.6V, 1.2V, 1.8V (Note 5) | T _A = +25°C | 0.06 | 0.75 | Ω |
| | | | T _A = T _{MIN} to T _{MAX} | | 0.080 | |
| NO ₋ or NC ₋ Off-Leakage Current | I _{OFF} | V _{CC} = 3.3V; V _{COM₋} = 3V, 0.3V or floating; V _{NO₋} or V _{NC₋} = 0.3V, 3V or floating | T _A = +25°C | 20 | 20 | nA |
| | | | T _A = T _{MIN} to T _{MAX} | 100 | 100 | |
| COM ₋ On-Leakage Current | I _{ON} | V _{CC} = 3.3V; V _{NO₋} or V _{NC₋} = 0.3V, 3V or floating; V _{COM₋} = 0.3V, 3V or floating | T _A = +25°C | 20 | 20 | nA |
| | | | T _A = T _{MIN} to T _{MAX} | 100 | 100 | |

Low-Voltage, 0.31Ω, Quad-SPDT Analog Switch

MAX4735

ELECTRICAL CHARACTERISTICS (continued)

($V_{CC} = 2.7V$ to $3.6V$, $T_A = T_{MIN}$ to T_{MAX} , unless otherwise noted. Typical values are at $V_{CC} = 3V$, $T_A = +25^\circ C$.) (Note 2)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|--------------------------------------|--|------------------------------|------|-----------|-------|
| DYNAMIC CHARACTERISTICS | | | | | | |
| Turn-On Time | t_{ON} | $V_{CC} = 2.7V$, $V_{NO_}$ or $V_{NC_} = 1.5V$, $R_L = 50\Omega$, $C_L = 35pF$, Figure 1 | $T_A = +25^\circ C$ | 40 | 200 | ns |
| | | | $T_A = T_{MIN}$ to T_{MAX} | | 200 | |
| Turn-Off Time | t_{OFF} | $V_{CC} = 2.7V$, $V_{NO_}$ or $V_{NC_} = 1.5V$, $R_L = 50\Omega$, $C_L = 35pF$, Figure 1 | $T_A = +25^\circ C$ | 20 | 180 | ns |
| | | | $T_A = T_{MIN}$ to T_{MAX} | | 180 | |
| Break-Before-Make Time | t_{BBM} | $V_{CC} = 2.7V$, $V_{NO_}$ or $V_{NC_} = 1.5V$, $R_L = 50\Omega$, $C_L = 35pF$, Figure 2 (Note 6) | $T_A = +25^\circ C$ | 2 | 15 | ns |
| | | | $T_A = T_{MIN}$ to T_{MAX} | 2 | | |
| Charge Injection | Q | $V_{GEN} = 0V$, $R_{GEN} = 0\Omega$, $C_L = 1nF$, Figure 3 | | 100 | | pC |
| On-Channel Bandwidth -3dB | BW | $R_L = 50\Omega$, Figure 4 | | 20 | | MHz |
| Off-Isolation | V_{ISO} | $V_{COM_} = 1V_{RMS}$, $R_L = 50\Omega$, $f = 100kHz$, $C_L = 5pF$, Figure 4 (Note 7) | | -66 | | dB |
| Crosstalk | V_{CT} | $V_{COM_} = 1V_{RMS}$, $R_L = 50\Omega$, $f = 100kHz$, $C_L = 5pF$, Figure 4 (Note 8) | | -86 | | dB |
| Total Harmonic Distortion Plus Noise | THD+N | $f = 20Hz$ to $20kHz$; $V_{NC_}$, $V_{NO_}$, $V_{COM_} = 0.5V_{P-P}$; $R_L = 32\Omega$ | | 0.02 | | % |
| NC_ or NO_ Off- Capacitance | $C_{NC_}(OFF)$, $C_{NO_}(OFF)$ | $f = 1MHz$, $V_{NO_} = V_{NC_} = V_{COM_} = 1.5V$, Figure 5 | | 70 | | pF |
| COM_ On-Capacitance | $C_{COM_}(ON)$ | $f = 1MHz$, $V_{NO_} = V_{NC_} = V_{COM_} = 1.5V$, Figure 5 | | 250 | | pF |
| Power-Supply Rejection Ratio | PSRR | $V_{AC} = 100mV_{P-P}$, $V_{COM_} = 1.5V$, $R_L = 50\Omega$, $f = 100kHz$ | | -34 | | dB |
| DIGITAL INPUTS (INA, | | | | | | |
| Input-Logic High | V_{IH} | | 1.4 | | | V |
| Input-Logic Low | V_{IL} | | | | 0.5 | V |
| Input Leakage Current | I_{IN} | $V_{IN_} = 0$ or V_{CC} | | | ± 200 | nA |

Note 2: Devices are 100% tested at $T_A = +85^\circ C$. Limits across the full temperature range are guaranteed by design and correlation.

Note 3: R_{ON} and R_{ON} matching specifications are guaranteed by design for MAX4735ETE only.

Note 4: $\Delta R_{ON} = R_{ON}(MAX) - R_{ON}(MIN)$.

Note 5: Flatness is defined as the difference between the maximum and minimum value of on-resistance, as measured over the specified analog signal ranges.

Note 6: Guaranteed by design, not production tested.

Note 7: Off-isolation = $20\log_{10} [V_{COM_} / (V_{NO_} \text{ or } V_{NC_})]$, $V_{COM_}$ = output, $V_{NO_}$ or $V_{NC_}$ = input to off switch.

Note 8: Between any two switches.

Low-Voltage, 0.31Ω, Quad-SPDT Analog Switch

Timing Circuits/Timing Diagrams

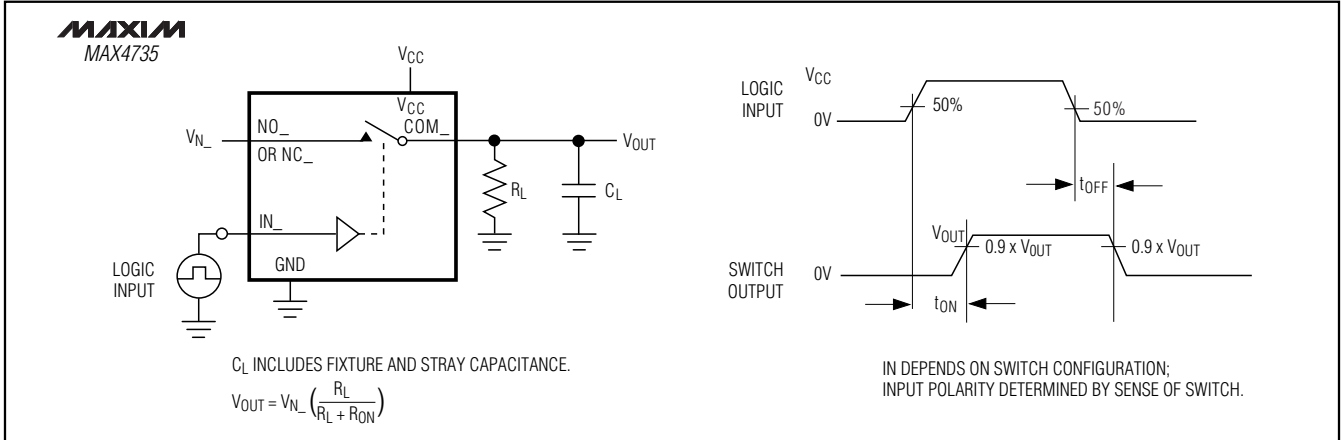


Figure 1. Switching Time

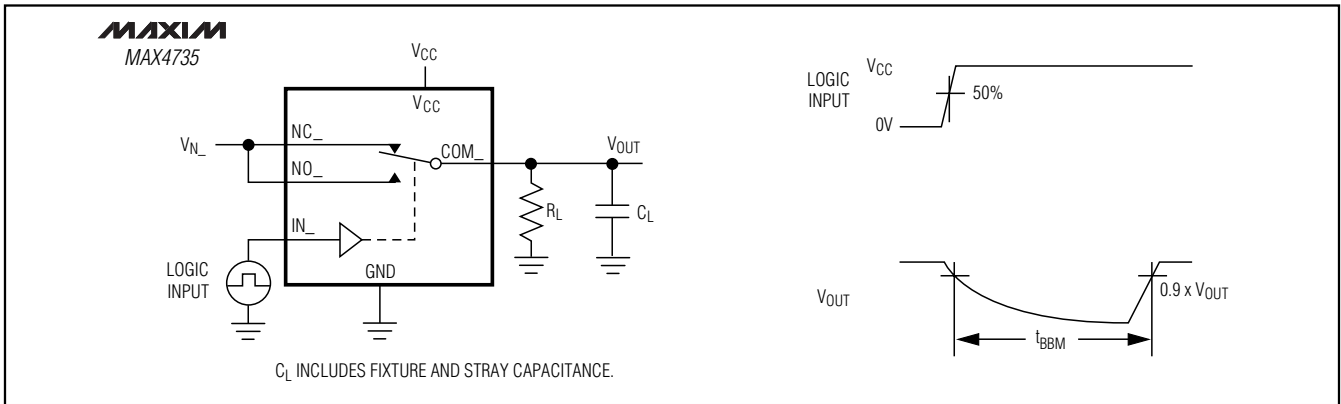


Figure 2. Break-Before-Make Interval

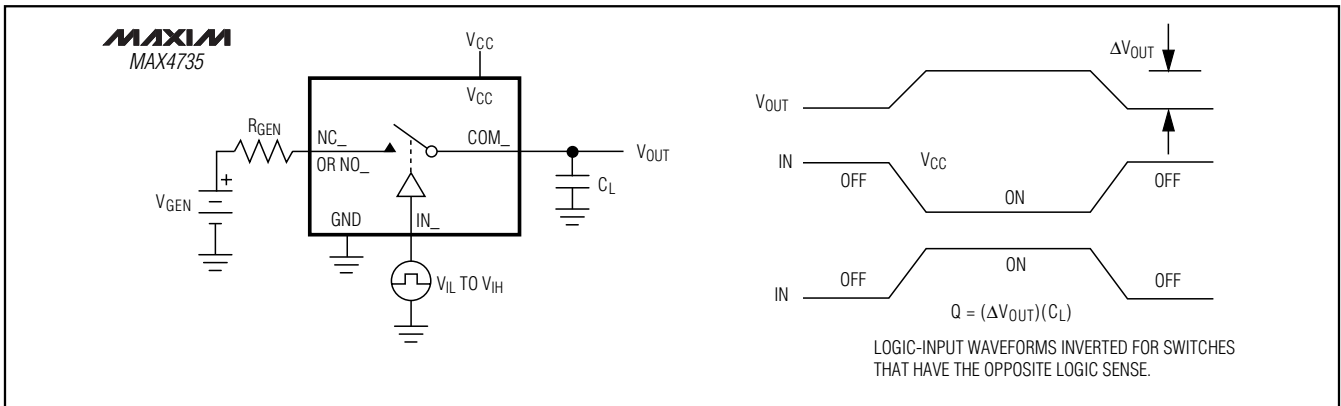


Figure 3. Charge Injection

Low-Voltage, 0.31Ω, Quad-SPDT Analog Switch

MAX4735

Timing Circuits/Timing Diagrams (continued)

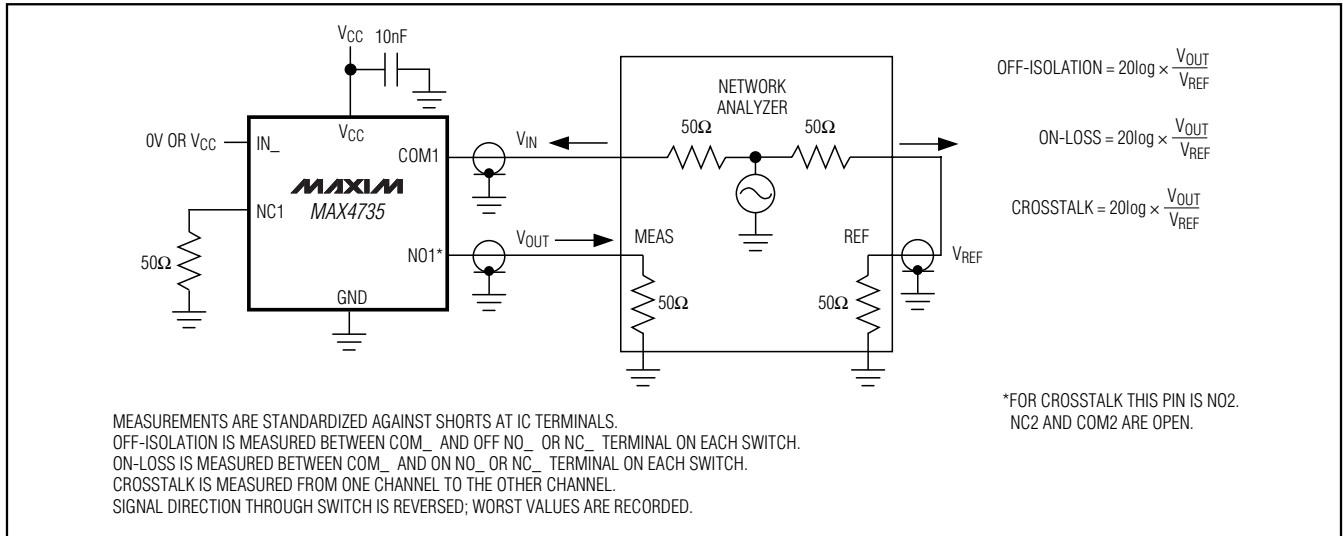


Figure 4. On-Loss, Off-Isolation, and Crosstalk

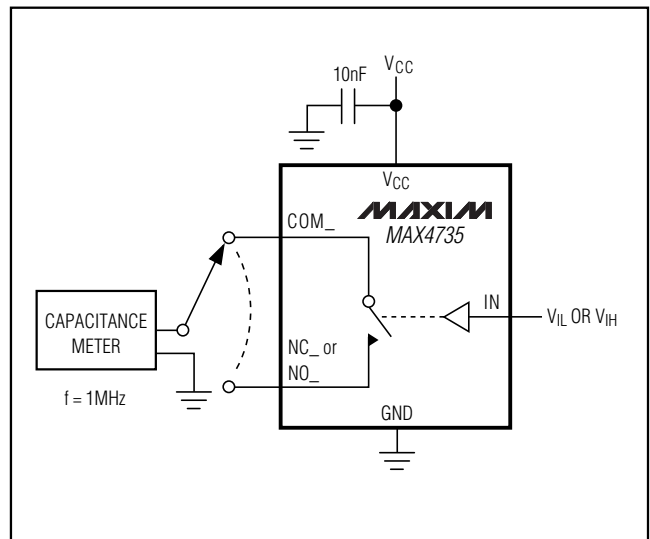
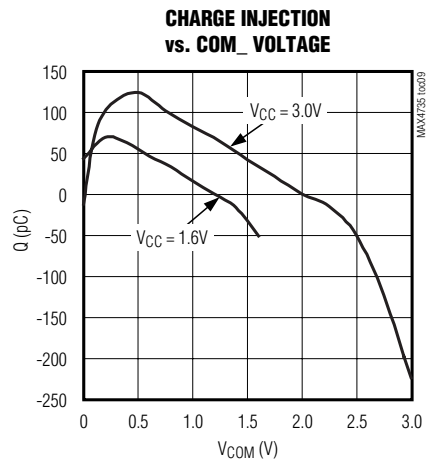
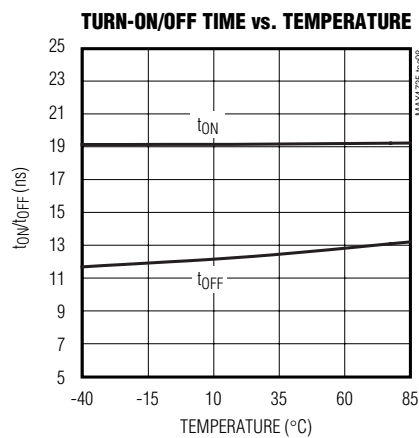
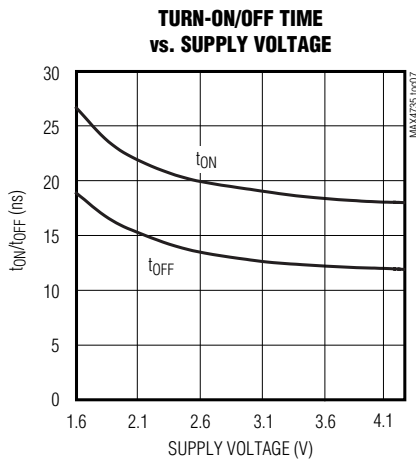
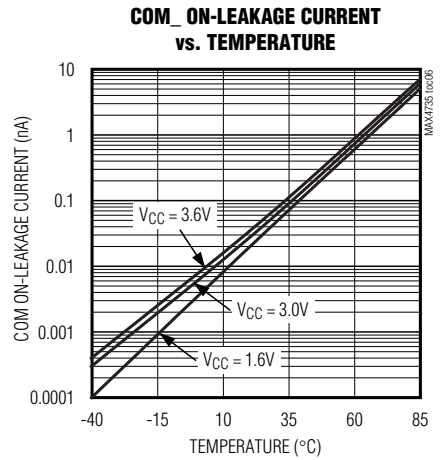
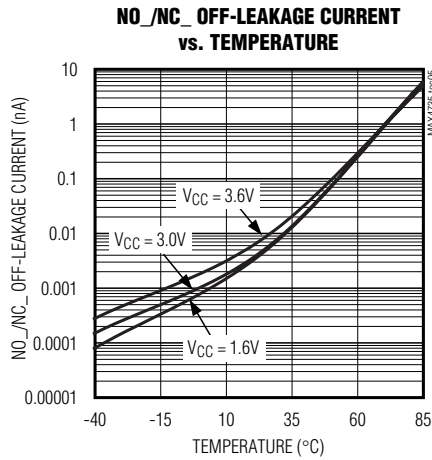
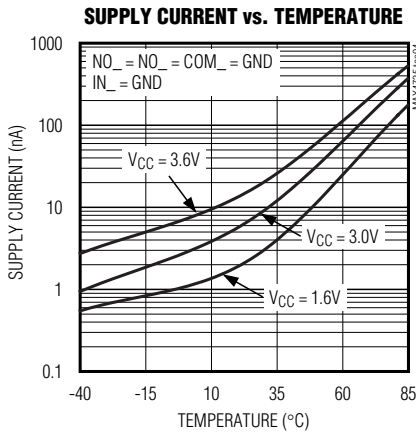
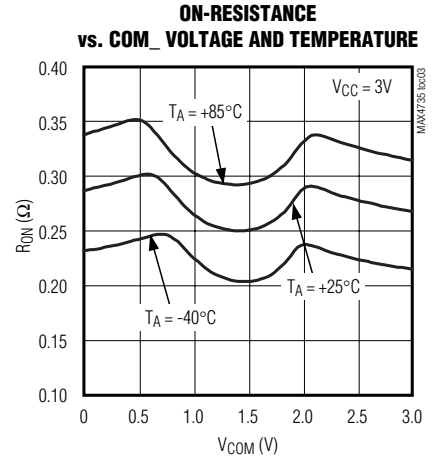
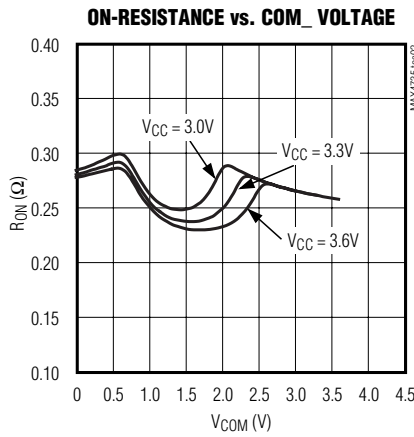
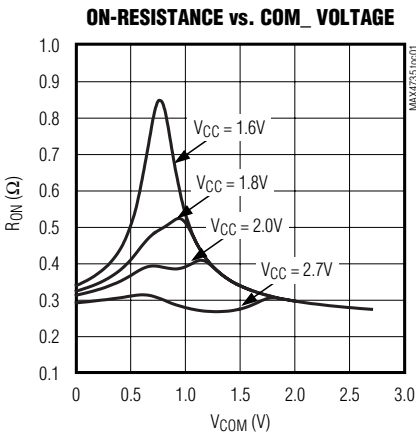


Figure 5. Channel On-/Off-Capacitance

Low-Voltage, 0.31Ω, Quad-SPDT Analog Switch

Typical Operating Characteristics

($V_{CC} = 3V$, $T_A = +25^\circ C$, unless otherwise noted.)

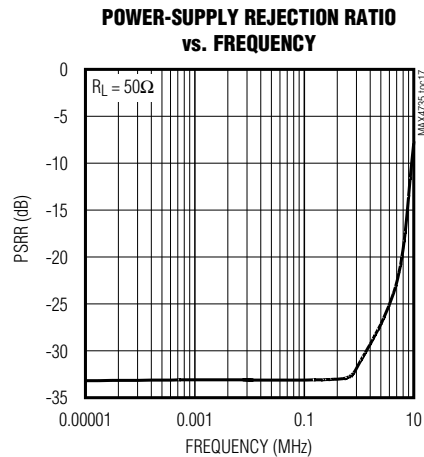
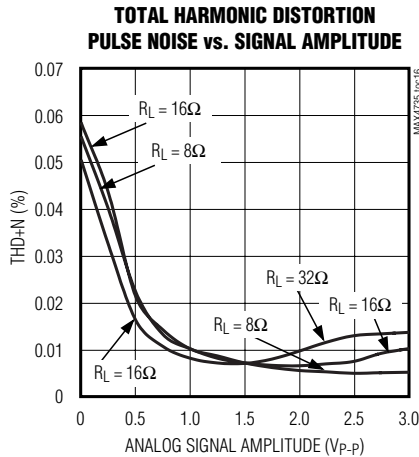
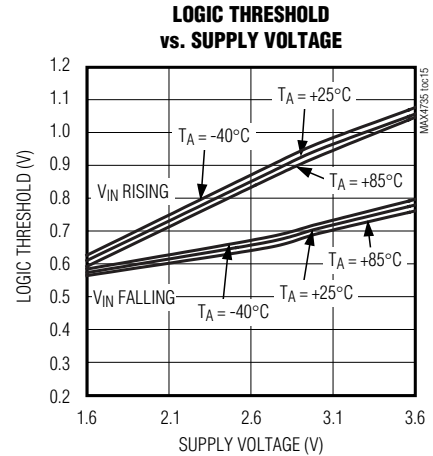
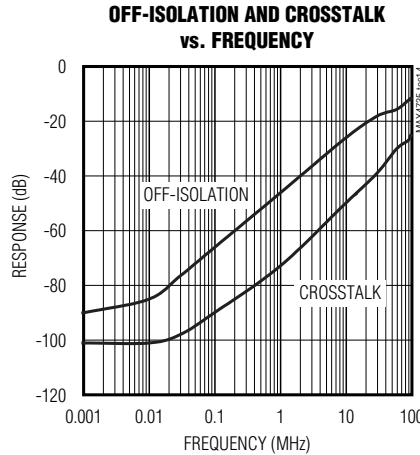
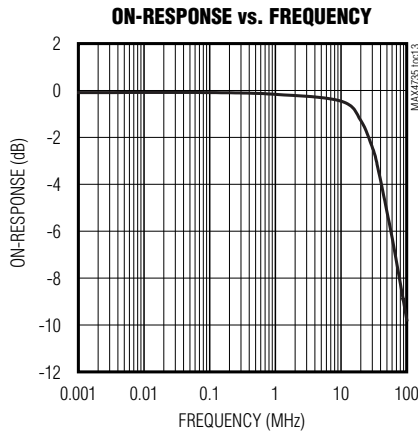
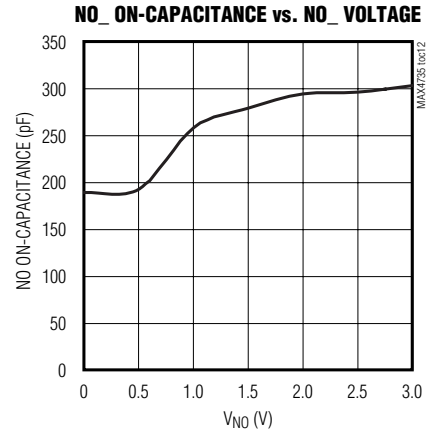
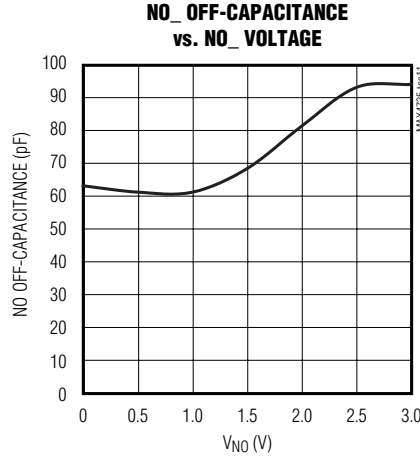
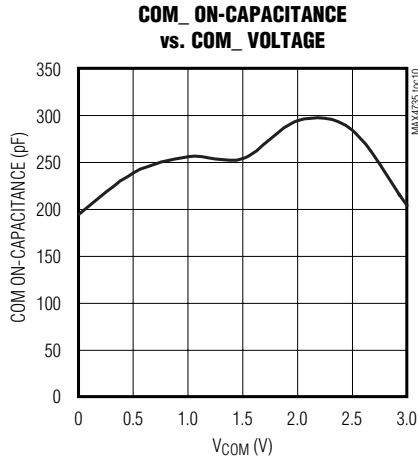


Low-Voltage, 0.31Ω, Quad-SPDT Analog Switch

MAX4735

Typical Operating Characteristics (continued)

($V_{CC} = 3V$, $T_A = +25^\circ C$, unless otherwise noted.)



Low-Voltage, 0.31Ω , Quad-SPDT Analog Switch

Pin Description

| PIN | | NAME | FUNCTION |
|-------|------|------|---|
| TSSOP | TQFN | | |
| 1 | 15 | INA | Select Input A. Controls switch 1 and switch 2. |
| 2 | 16 | NC1 | Normally Closed Terminal Switch 1 |
| 3 | 1 | COM1 | Common Terminal Switch 1 |
| 4 | 2 | NO1 | Normally Open Terminal Switch 1 |
| 5 | 3 | NC2 | Normally Closed Terminal Switch 2 |
| 6 | 4 | COM2 | Common Terminal Switch 2 |
| 7 | 5 | NO2 | Normally Open Terminal Switch 2 |
| 8 | 6 | GND | Ground |
| 9 | 7 | INB | Select Input B. Controls switch 3 and switch 4. |
| 10 | 8 | NO3 | Normally Open Terminal Switch 3 |
| 11 | 9 | COM3 | Common Terminal Switch 3 |
| 12 | 10 | NC3 | Normally Closed Terminal Switch 3 |
| 13 | 11 | NO4 | Normally Open Terminal Switch 4 |
| 14 | 12 | COM4 | Common Terminal Switch 4 |
| 15 | 13 | NC4 | Normally Closed Terminal Switch 4 |
| 16 | 14 | VCC | Positive Power Supply |
| — | PAD | EP | Exposed Pad. Connect to GND. |

Detailed Description

The MAX4735 quad-SPDT analog switch operates from a single +1.6V to +3.6V supply. These devices are fully specified for +3V applications.

The MAX4735 features fully bidirectional, rail-to-rail CMOS analog switch channels. They can be configured as dual-DPDT switches, dual 4:2 multiplexers/demultiplexers, or as a single 8:4 multiplexer/demultiplexer. See Figure 6.

Applications Information

Analog Signal Range

The CMOS switches in the MAX4735 function on any signal within the power-supply voltages. If any channel exceeds V_{CC} , it is clamped to V_{CC} by a silicon diode. If any channel goes below GND, it is clamped to GND by a silicon diode. Ensure that if either of these diodes becomes forward biased, the continuous and peak currents do not exceed those listed in the *Absolute Maximum Ratings* section of this data sheet.

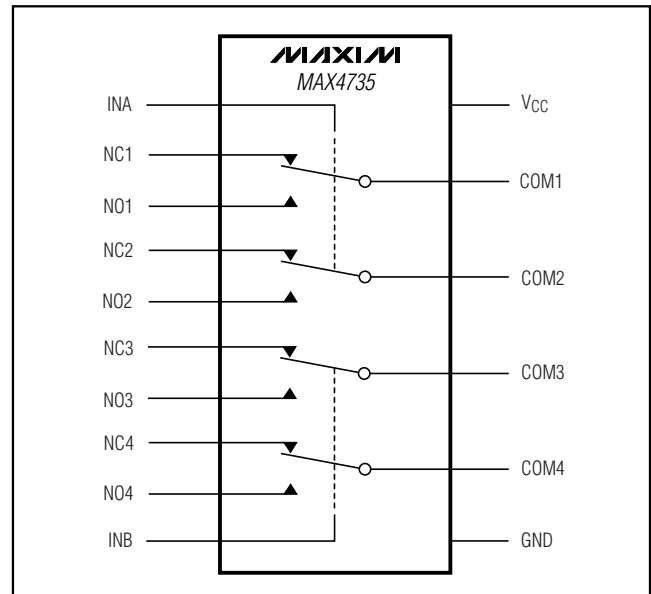


Figure 6. Functional Diagram

Low-Voltage, 0.31Ω, Quad-SPDT Analog Switch

MAX4735

As seen in the *Typical Operating Characteristics*, the on-resistance of the MAX4735 is inversely proportional to the supply voltage. Best performance is obtained by using the highest supply voltage available within the +1.6V to +3.6V range.

Digital Logic Inputs

Digital control inputs INA and INB control the position of the switches in the MAX4735. These inputs are diode clamped to GND only. It is acceptable to leave these pins driven in the absence of a VCC power supply.

For best performance, drive INA and INB to the full supply voltage range of the MAX4735.

The two switch sections of the MAX4735 operate independently. Drive INA low to connect COM1 to NC1 and connect COM2 to NC2. Drive INA high to connect COM1 to NO1 and connect COM2 to NO2. Drive INB low to connect COM3 to NC3 and connect COM4 to NC4. Drive INB high to connect COM3 to NO3 and connect COM4 to NO4. See Table 1.

INA and INB have typical hysteresis of 100mV by including positive feedback in the internal buffer. Thus, for applications using DC or very slow ramp rate of the digital input voltage level, connect a 100pF capacitor from IN_ to GND to limit the ICC current at the trip point. The switching point is typically 0.7V between V_{IL} and V_{IH} levels.

Power Supply

The MAX4735 operates from a +1.6V to +3.6V power supply. For best results, bypass VCC to GND with a 0.1μF ceramic chip capacitor located close to the IC.

Audio Signal Routing

The MAX4735's low R_{ON} makes it an excellent choice for multiplexing loudspeakers in portable equipment. THD performance is inversely proportional to load impedance. Within the audio signal range, there is no frequency component to THD. The only distortion mechanism is the R_{ON} flatness' modulation of the signal into a load. Therefore, for best distortion performance, use higher impedance transducers.

Table 1. Truth Table

| INA | INB | SWITCH 1 AND SWITCH 2 STATE | SWITCH 3 AND SWITCH 4 STATE |
|-----|-----|-----------------------------|-----------------------------|
| 0 | — | COM1 to NC1 COM2 to NC2 | — |
| 1 | — | COM1 to NO1 COM2 to NO2 | — |
| — | 0 | — | COM3 to NC3 COM4 to NC4 |
| — | 1 | — | COM3 to NO3 COM4 to NO4 |

Each switch channel on the MAX4735 has an absolute maximum rating 300mA continuous current, and 400mA peak current at 50% duty cycle. When driving low-impedance loudspeakers, the peak signal amplitude should be limited so these peak currents are not exceeded. For an 8Ω load, this corresponds to 2.3VRMS. For a 4Ω load, this is 1.1VRMS.

Package Information

The MAX4735 is offered in 16-pin TSSOP and 3mm x 3mm x 0.8mm TQFN packages. The mechanical drawings for these packages are located at the end of this data sheet. Please check www.maxim-ic.com/packages to ensure working with the latest information.

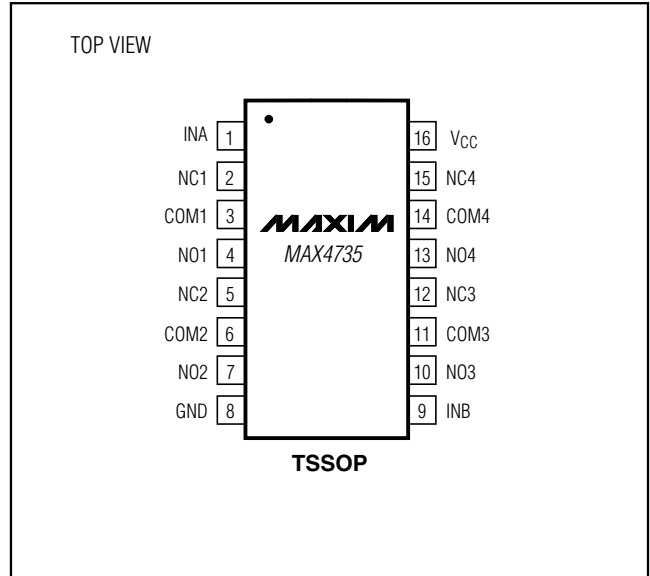
The TSSOP package is rated for a peak power dissipation of 755mW at +70°C, with a θ_{JA} of 106°C/W on a single-layer PC board. The TQFN package is rated for a peak power dissipation of 1.25W at +70°C, with a θ_{JA} of 64°C/W on a single-layer PC board. The TQFN package is the T1633-4 package code variant.

Low-Voltage, 0.31Ω, Quad-SPDT Analog Switch

Chip Information

TRANSISTOR COUNT: 487
PROCESS: CMOS

Pin Configurations (continued)

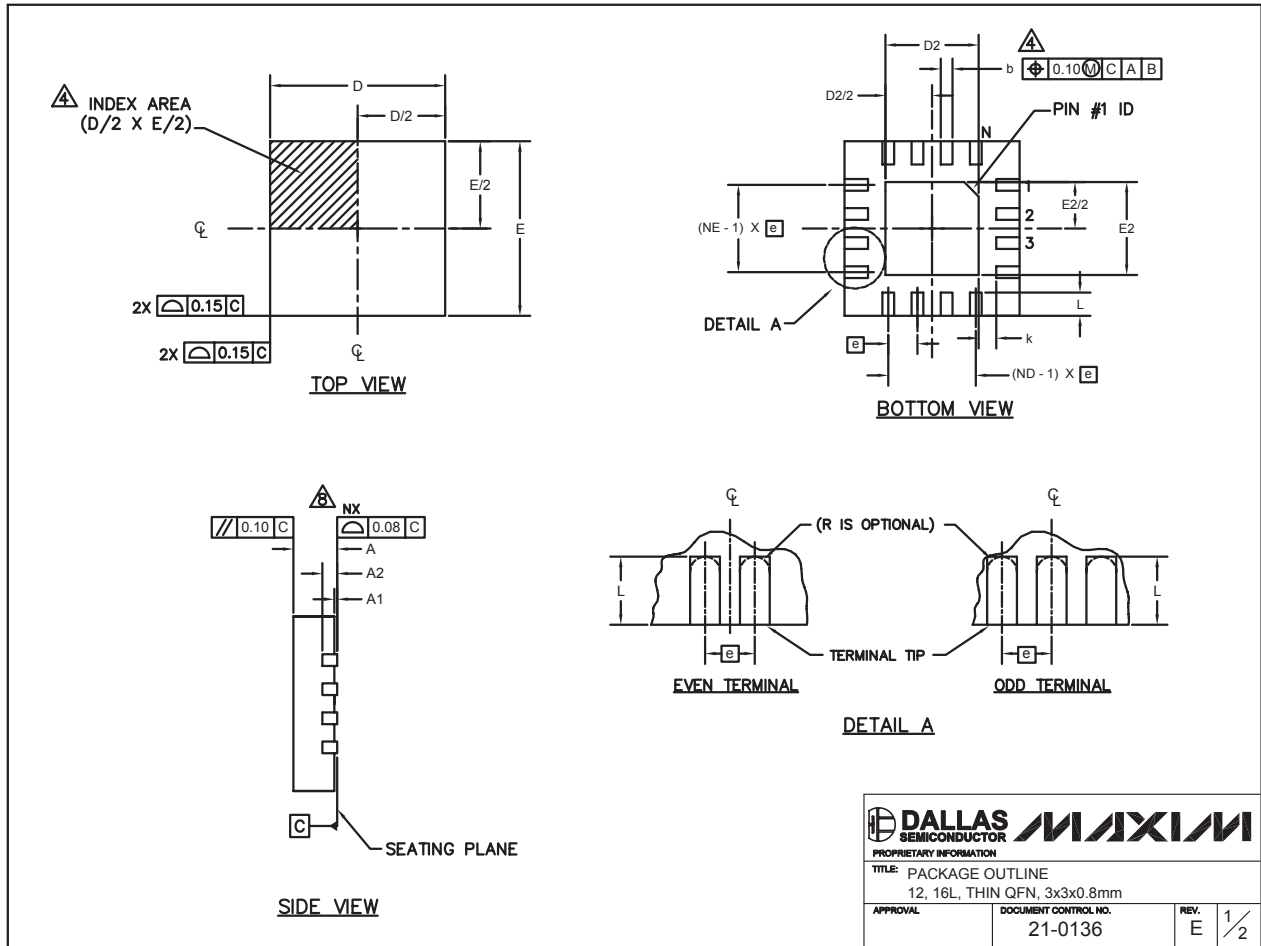


Low-Voltage, 0.31Ω, Quad-SPDT Analog Switch

Package Information

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information go to www.maxim-ic.com/packages.)

MAX4735



Low-Voltage, 0.31Ω, Quad-SPDT Analog Switch

Package Information (continued)

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information go to www.maxim-ic.com/packages.)

| PKG REF. | 12L 3x3 | | | 16L 3x3 | | |
|----------|-----------|------|------|-----------|------|------|
| | MIN. | NOM. | MAX. | MIN. | NOM. | MAX. |
| A | 0.70 | 0.75 | 0.80 | 0.70 | 0.75 | 0.80 |
| b | 0.20 | 0.25 | 0.30 | 0.20 | 0.25 | 0.30 |
| D | 2.90 | 3.00 | 3.10 | 2.90 | 3.00 | 3.10 |
| E | 2.90 | 3.00 | 3.10 | 2.90 | 3.00 | 3.10 |
| e | 0.50 BSC. | | | 0.50 BSC. | | |
| L | 0.45 | 0.55 | 0.65 | 0.30 | 0.40 | 0.50 |
| N | 12 | | | 16 | | |
| ND | 3 | | | 4 | | |
| NE | 3 | | | 4 | | |
| A1 | 0 | 0.02 | 0.05 | 0 | 0.02 | 0.05 |
| A2 | 0.20 REF | | | 0.20 REF | | |
| k | 0.25 | - | - | 0.25 | - | - |

| PKG CODES | EXPOSED PAD VARIATIONS | | | | | | PIN ID | JEDEC | DOWN BONDS ALLOWED |
|-----------|------------------------|------|------|------|------|------|-------------|--------|--------------------|
| | D2 | | | E2 | | | | | |
| | MIN. | NOM. | MAX. | MIN. | NOM. | MAX. | | | |
| T1233-1 | 0.95 | 1.10 | 1.25 | 0.95 | 1.10 | 1.25 | 0.35 x 45° | WEED-1 | NO |
| T1233-3 | 0.95 | 1.10 | 1.25 | 0.95 | 1.10 | 1.25 | 0.35 x 45° | WEED-1 | YES |
| T1633-1 | 0.95 | 1.10 | 1.25 | 0.95 | 1.10 | 1.25 | 0.35 x 45° | WEED-2 | NO |
| T1633-2 | 0.95 | 1.10 | 1.25 | 0.95 | 1.10 | 1.25 | 0.35 x 45° | WEED-2 | YES |
| T1633F-3 | 0.65 | 0.80 | 0.95 | 0.65 | 0.80 | 0.95 | 0.225 x 45° | WEED-2 | N/A |
| T1633-4 | 0.95 | 1.10 | 1.25 | 0.95 | 1.10 | 1.25 | 0.35 x 45° | WEED-2 | NO |

NOTES:

- DIMENSIONING & TOLERANCING CONFORM TO ASME Y14.5M-1994.
- ALL DIMENSIONS ARE IN MILLIMETERS. ANGLES ARE IN DEGREES.
- N IS THE TOTAL NUMBER OF TERMINALS.
- △ THE TERMINAL #1 IDENTIFIER AND TERMINAL NUMBERING CONVENTION SHALL CONFORM TO JESD 95-1 SPP-012. DETAILS OF TERMINAL #1 IDENTIFIER ARE OPTIONAL, BUT MUST BE LOCATED WITHIN THE ZONE INDICATED. THE TERMINAL #1 IDENTIFIER MAY BE EITHER A MOLD OR MARKED FEATURE.
- △ DIMENSION b APPLIES TO METALLIZED TERMINAL AND IS MEASURED BETWEEN 0.20 mm AND 0.25 mm FROM TERMINAL TIP.
- △ ND AND NE REFER TO THE NUMBER OF TERMINALS ON EACH D AND E SIDE RESPECTIVELY.
- DEPOPULATION IS POSSIBLE IN A SYMMETRICAL FASHION.
- △ COPLANARITY APPLIES TO THE EXPOSED HEAT SINK SLUG AS WELL AS THE TERMINALS.
- DRAWING CONFORMS TO JEDEC MO220 REVISION C.

| | |
|---|--|
|  | |
| <small>PROPRIETARY INFORMATION</small> | |
| TITLE: PACKAGE OUTLINE 12, 16L, THIN QFN, 3x3x0.8mm | |
| <small>APPROVAL</small> | <small>DOCUMENT CONTROL NO.</small> 21-0136 |
| <small>REV.</small> E | <small>REV.</small> 2/2 |

Low-Voltage, 0.31Ω, Quad-SPDT Analog Switch

Package Information (continued)

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information go to www.maxim-ic.com/packages.)

MAX4735

TSSOP4, 4.0mm, EPS

| Symbol | COMMON DIMENSIONS | | | |
|----------------|-------------------|------|----------------|------|
| | MILLIMETERS | | INCHES | |
| | MIN. | MAX. | MIN. | MAX. |
| A | — | 1.10 | | .043 |
| A ₁ | 0.05 | 0.15 | .002 | .006 |
| A ₂ | 0.85 | 0.95 | .033 | .037 |
| b | 0.19 | 0.30 | .007 | .012 |
| b ₁ | 0.19 | 0.25 | .007 | .010 |
| c | 0.09 | 0.20 | .004 | .008 |
| c ₁ | 0.09 | 0.14 | .004 | .006 |
| D | SEE VARIATIONS | | SEE VARIATIONS | |
| E | 4.30 | 4.50 | .169 | .177 |
| e | 0.65 BSC | | .026 BSC | |
| H | 6.25 | 6.55 | .246 | .258 |
| L | 0.50 | 0.70 | .020 | .028 |
| N | SEE VARIATIONS | | SEE VARIATIONS | |
| α | 0° | 8° | 0° | 8° |

| JEDEC | N | VARIATIONS | | | |
|--------|----|-------------|------|--------|------|
| | | MILLIMETERS | | INCHES | |
| MO-153 | | MIN. | MAX. | MIN. | MAX. |
| AB-1 | 14 | 4.90 | 5.10 | .193 | .201 |
| AB | 16 | 4.90 | 5.10 | .193 | .201 |
| AC | 20 | 6.40 | 6.60 | .252 | .260 |
| AD | 24 | 7.70 | 7.90 | .303 | .311 |
| AE | 28 | 9.60 | 9.80 | .378 | .386 |

NOTES:
 1. DIMENSIONS D AND E DO NOT INCLUDE FLASH
 2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED 0.15mm PER SIDE
 3. CONTROLLING DIMENSION: MILLIMETER
 4. MEETS JEDEC OUTLINE MO-153. SEE JEDEC VARIATIONS TABLE
 5. "N" REFERS TO NUMBER OF LEADS
 6. THE LEAD TIPS MUST LIE WITHIN A SPECIFIED ZONE. THIS TOLERANCE ZONE IS DEFINED BY TWO PARALLEL PLANES. ONE PLANE IS THE SEATING PLANE, DATUM [-C-]; THE OTHER PLANE IS AT THE SPECIFIED DISTANCE FROM [-C-] IN THE DIRECTION INDICATED

| | | | |
|--|---------------------------------|--------------|-----|
| DALLAS SEMICONDUCTOR | | MAXIM | |
| PROPRIETARY INFORMATION | | | |
| TITLE: PACKAGE OUTLINE, TSSOP 4.40mm BODY | | | |
| APPROVAL | DOCUMENT CONTROL NO. 21-0066 | REV. F | 1/1 |

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