19-0563; Rev 0; 5/06

# Low-Voltage, Dual SPDT, Audio Clickless Switches With Negative Rail Capability



## General Description

The MAX4744/MAX4744H/MAX4745/MAX4745H dual SPDT (single pole/double throw) audio switches feature negative signal capability that allows signals as low as $V_{CC}$ - 5.5V to pass through without distortion. These analog switches have a low on-resistance, low supply current, and operate from a single +1.8V to +5.5V supply.

The MAX4744/MAX4744H have internal shunt resistors that automatically discharge the capacitance at the normally open (NO) and normally closed (NC) terminals when they are not connected. This reduces click-and-pop sounds that occur when switching audio signals between pre-charged points. A break-before-make feature further reduces popping. The MAX4744/MAX4745 control the switches with two control bits CB1 and CB2. The MAX4744H/MAX4745H have one control bit to switch both switches and an enable input $\overline{EN}$ to put the switches in a high-impedance mode. The MAX4744H/MAX4745H also have an internal protection network against voltages applied to COM_ when $V_{CC}$ = 0V.

These devices are available in a space-saving 10-pin µDFN (2mm x 2mm) package and operate over the -40°C to +85°C extended temperature range.

## Applications

Speaker Switching

Power Routing

Cellular Phones

MP3 Players

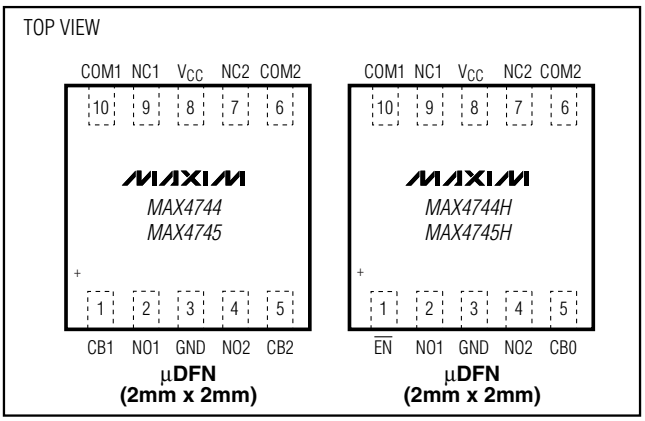
PDAs and other Handheld Devices

Notebook Computers

## Features

- **Distortion-Free Negative Signal Throughput Down to $V_{CC}$ - 5.5V**
- **Internal Shunt Resistor Reduces Click/Pop (MAX4744/MAX4744H)**
- **0.6Ω (typ) Low On-Resistance**
- **0.1Ω (max) Channel-to-Channel Matching**
- **0.55Ω (max) On-Resistance Flatness**
- **+1.8V to +5.5V Single-Supply Voltage**
- **0.01% (typ) Total Harmonic Distortion**
- **-75dB (typ) Crosstalk (100kHz)**
- **-68dB (typ) Off-Isolation (100kHz)**
- **Available in 10-pin µDFN Package (2mm x 2mm)**

## Pin Configurations




## Ordering Information

| PART | PIN-PACKAGE | TOP MARK | CLICKLESS | COM PROTECTION | PKG CODE |
|---|---|---|---|---|---|
| **MAX4744**ELB+T | 10 µDFN-10 | +AAF | Yes | No | L1022-1 |
| **MAX4744H**ELB+T | 10 µDFN-10 | +AAG | Yes | Yes | L1022-1 |
| **MAX4745**ELB+T | 10 µDFN-10 | +AAH | No | No | L1022-1 |
| **MAX4745H**ELB+T | 10 µDFN-10 | +AAI | No | Yes | L1022-1 |

***Note:*** *All devices are specified over the -40°C to +85°C operating temperature range.*
*+Denotes lead-free package.*



***For pricing, delivery, and ordering information, please contact Maxim/Dallas Direct! at 1-888-629-4642, or visit Maxim's website at www.maxim-ic.com.***

# Low-Voltage, Dual SPDT, Audio Clickless Switches With Negative Rail Capability

## ABSOLUTE MAXIMUM RATINGS

(All voltages referenced to GND.)
$V_{CC}$, CB_, $\overline{EN}$ .....-0.3V to +6.0V
NC_, NO_ .....($V_{CC}$ - 6V) to ($V_{CC}$ + 0.3V)
COM_ (MAX4744/MAX4745).....($V_{CC}$ - 6V) to ($V_{CC}$ + 0.3V)
COM_ (MAX4744H/MAX4745H).....(Note 1)
Continuous Current NO_, NC_, COM_. .....±300mA
Peak Current NO_, NC_, COM_ (Pulsed at 1ms, 50% Duty Cycle).....±400mA
Peak Current NO_, NC_, COM_ (Pulsed at 1ms, 10% Duty Cycle).....±500mA
ESD Protection per Method 3015.7
NO_, NC_, COM_, $V_{CC}$, GND, CB_, $\overline{EN}$.....±2kV
Continuous Power Dissipation ($T_A$ = +70°C)
10-Pin µDFN (derate 5mW/°C above +70°C) .....403mW
Operating Temperature Range .....-40°C to +85°C
Storage Temperature Range .....-65°C to +150°C

**Note 1:** If $V_{CC}$ > 0.5V, limits are ($V_{CC}$ - 6V) to ($V_{CC}$ + 0.3V). If $V_{CC}$ < 0.5V, limits are ($V_{CC}$ - 6.0V) to +6.0V.

*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 +5.5V, $T_A$ = -40°C to +85°C, unless otherwise noted. Typical values are at $V_{CC}$ = 3.3V, $T_A$ = +25°C.) (Note 2)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| **POWER SUPPLY** | | | | | | | |
| Supply-Voltage Range | $V_{CC}$ | | | 1.8 | | 5.5 | V |
| Supply Current | $I_{CC}$ | $V_{CC}$ = 5.5V, $V_{CB_}$ = 0V or $V_{CC}$ | | | 0.3 | 1 | µA |
| | | $V_{CC}$ = 5.5V, $V_{CB_}$ = 0.5V or 1.4V | | | | 8 | |
| | | $V_{CC}$ = 2.7V, $V_{CB_}$ = 0.5V or 1.4V | | | | 4 | |
| **ANALOG SWITCH** | | | | | | | |
| Analog Signal Range (Note 3) | $V_{NC_}$, $V_{NO_}$, $V_{COM_}$, | | | $V_{CC}$ - 5.5V | | $V_{CC}$ | V |
| On-Resistance (Note 4) | $R_{ON}$ | $V_{CC}$ = 2.7V; $V_{NC_}$ or $V_{NO_}$ = $V_{CC}$ - 5.5V, -1V, 0V, 1V, 2V, $V_{CC}$; $I_{COM_}$ = 100mA | $T_A$ = +25°C | | 0.6 | 0.95 | Ω |
| | | | $T_A$ = $T_{MIN}$ to $T_{MAX}$ | | | 1.0 | |
| On-Resistance Match Between Channels (Notes 4 and 5) | $\Delta R_{ON}$ | $V_{CC}$ = 2.7V, $V_{NC_}$ or $V_{NO_}$ = 0V, $I_{COM_}$ = 100mA | $T_A$ = +25°C | | | 0.1 | Ω |
| | | | $T_A$ = $T_{MIN}$ to $T_{MAX}$ | | | 0.1 | |
| On-Resistance Flatness (Note 6) | $R_{FLAT}$ | $V_{CC}$ = 2.7V, $V_{NC_}$ or $V_{NO_}$ = $V_{CC}$ - 5.5V, - 1V, 0V, 1V, 2V, $V_{CC}$; $I_{COM_}$ = 100mA | $T_A$ = +25°C | | | 0.55 | Ω |
| | | | $T_A$ = $T_{MIN}$ to $T_{MAX}$ | | | 0.6 | |
| Shunt Switch Resistance | $R_{SH}$ | MAX4744/MAX4744H only, $V_{CC}$ = 2.7V | | 2 | | 5 | kΩ |
| NC_, NO_ Off-Leakage Current (Note 3) | $I_{NO_(OFF)}$, $I_{NC_(OFF)}$ | $V_{CC}$ = 2.7V switch open; $V_{NC_}$ or $V_{NO_}$ = -2.5, +2.5V (MAX4745/MAX4745H only) | $T_A$ = +25°C | -15 | | +15 | nA |
| | | | $T_A$ = $T_{MIN}$ to $T_{MAX}$ | -50 | | +50 | |
| COM_ On-Leakage Current (Note 3) | $I_{COM_(ON)}$ | $V_{CC}$ = 2.7V switch closed; $V_{NC_}$ or $V_{NO_}$ = -2.5, +2.5V; $V_{COM_}$ = -2.5, +2.5V | $T_A$ = +25°C | -15 | | +15 | nA |
| | | | $T_A$ = $T_{MIN}$ to $T_{MAX}$ | -100 | | +100 | |

## ELECTRICAL CHARACTERISTICS (continued)

($V_{CC}$ = +2.7V to +5.5V, $T_A$ = -40°C to +85°C, unless otherwise noted. Typical values are at $V_{CC}$ = 3.3V, $T_A$ = +25°C.) (Note 2)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| COM_ Leakage Under Protection Conditions | $I_{L(PROT)}$ | $V_{CC}$ = 0V; $V_{COM_}$ = +5.5V; $V_{NC_}$ and $V_{NO_}$ are unconnected or connected to GND; $V_{CB_}$ = 0V (MAX4744H/MAX4745H only) | $T_A$ = +25°C | | 30 | | nA |
| | | | $T_A$ = $T_{MIN}$ to $T_{MAX}$ | | 500 | | |
| **DYNAMIC CHARACTERISTICS** | | | | | | | |
| Turn-On Time | $t_{ON}$ | $V_{CC}$ = 2.7V, $R_L$ = 32Ω, $C_L$ = 35pF, Figure 2 | For NO_, $V_{NO_}$ = 1.5V, $V_{CB_}$ = 0V to $V_{CC}$ | | 55 | | ns |
| | | | For NC_, $V_{NC_}$ = 1.5V, $V_{CB_}$ = $V_{CC}$ to 0V | | 560 | | |
| Turn-Off Time | $t_{OFF}$ | $V_{CC}$ = 2.7V, $R_L$ = 32Ω, $C_L$ = 35pF, Figure 2 | For NO_, $V_{NO_}$ = 1.5V, $V_{CB_}$ = $V_{CC}$ to 0V | | 540 | | ns |
| | | | For NC_, $V_{NC_}$ = 1.5V, $V_{CB_}$ = 0V to $V_{CC}$ | | 36 | | |
| Break-Before-Make Delay Time | $t_D$ | $V_{CC}$ = 2.7V, $V_{NC_}$ = $V_{NO_}$ = 1.5V; for NO_, $V_{CB_}$ = $V_{CC}$ to 0V; for NC_, $V_{CB_}$ = 0V to $V_{CC}$; $R_L$ = 32Ω; $C_L$ = 35pF; Figure 3 | | | 20 | | ns |
| Power-Supply Rejection Ratio | PSRR | f = 100kHz, $V_{COM_}$ = $1V_{RMS}$, $R_L$ = 50Ω, $C_L$ = 5pF | | | 52 | | dB |
| Charge Injection | Q | $V_{GEN_}$ = 0V; $R_{GEN}$ = 0Ω, $C_L$ = 1nF, Figure 4 | | | 450 | | pC |
| Off-Isolation (Note 7) | $V_{ISO}$ | $C_L$ = 5pF; $R_L$ = 50Ω; f = 100kHz; $V_{COM_}$ = $1V_{RMS}$; Figure 5 | | | -68 | | dB |
| Crosstalk | $V_{CT}$ | $C_L$ = 5pF; $R_L$ = 50Ω; f = 100kHz; $V_{COM_}$ = $1V_{RMS}$; Figure 5 | | | -75 | | dB |
| Total Harmonic Distortion | THD | f = 20Hz to 20kHz, $V_{COM_}$ = $0.5V_{P-P}$, $R_L$ = 50Ω | | | 0.01 | | % |
| NO_, NC_ Off-Capacitance | $C_{NO_(OFF)}$, $C_{NC_(OFF)}$ | f = 1MHz, Figure 6 | | | 90 | | pF |
| COM On-Capacitance | $C_{COM_(ON)}$ | f = 1MHz, Figure 6 | | | 300 | | pF |

# Low-Voltage, Dual SPDT, Audio Clickless Switches With Negative Rail Capability

## ELECTRICAL CHARACTERISTICS (continued)

($V_{CC}$ = +2.7V to +5.5V, $T_A$ = -40°C to +85°C, unless otherwise noted. Typical values are at $V_{CC}$ = 3.3V, $T_A$ = +25°C.) (Note 2)

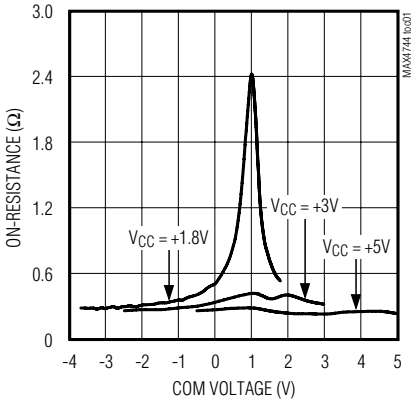
| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| **DIGITAL INPUTS (CB_, $\overline{EN}$)** | | | | | | |
| Input-Logic High | $V_{IH}$ | | 1.4 | | | V |
| Input-Logic Low | $V_{IL}$ | | | | 0.5 | V |
| Input Leakage Current | $I_{LEAK}$ | $V_{CB_}$ or $V_{\overline{EN}}$ = 0V or $V_{CC}$ | -1 | | +1 | µA |

**Note 2:** All parameters are production tested at $T_A$ = +25°C and guaranteed by design over the specified temperature range.
**Note 3:** Signals on COM_, NO_, or NC_ exceeding $V_{CC}$ are clamped by internal diodes. Limit forward-diode current to maximum current ratings.
**Note 4:** Guaranteed by design; not production tested.
**Note 5:** $\Delta R_{ON} = R_{ON(MAX)} - R_{ON(MIN)}$.
**Note 6:** Flatness is defined as the difference between the maximum and minimum value of on-resistance as measured over the specified analog signal ranges.
**Note 7:** Off-isolation = $20\log_{10}[VC_{OM_}/V_{NO_}]$, $V_{COM_}$ = output, $V_{NO_}$ = input to off switch.

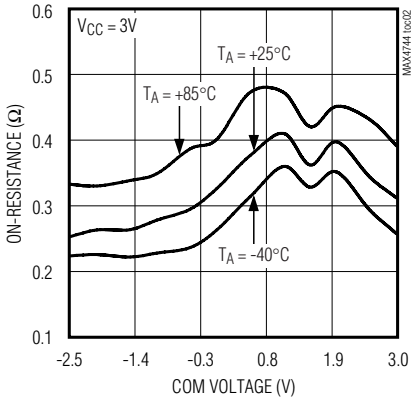
## Typical Operating Characteristics

($V_{CC}$ = +3.3V, $T_A$ = +25°C, unless otherwise noted.)

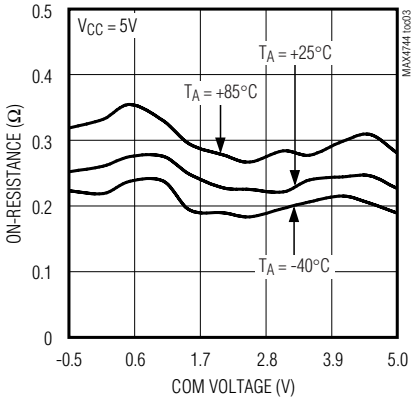
**ON-RESISTANCE vs. COM VOLTAGE**




**ON-RESISTANCE vs. COM VOLTAGE**



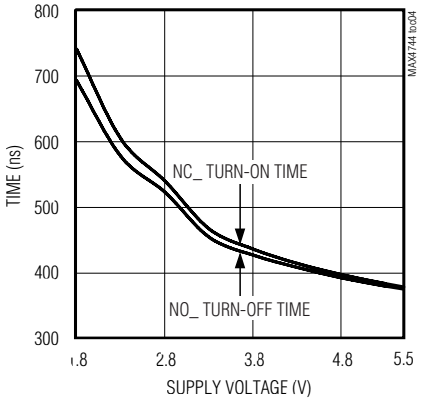

**ON-RESISTANCE vs. COM VOLTAGE**



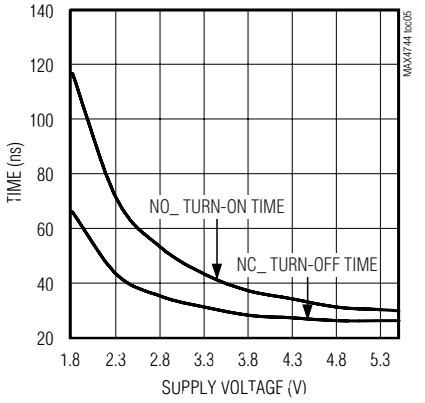
## Typical Operating Characteristics

($V_{CC}$ = +3.3V, $T_A$ = +25°C, unless otherwise noted.)

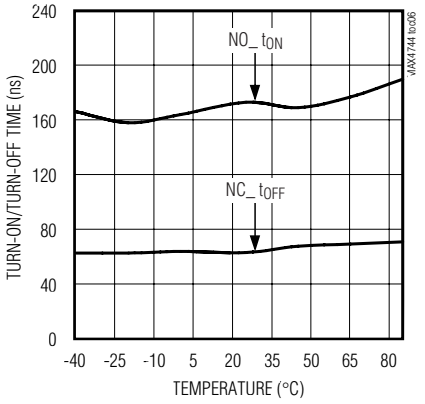
**NC_ TURN-ON/NO_ TURN-OFF TIME vs. SUPPLY VOLTAGE**



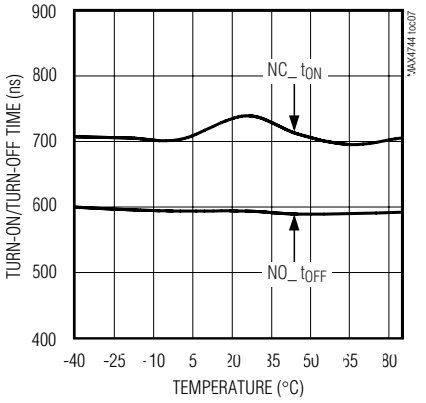

**NO_ TURN-ON/NC_ TURN-OFF TIME vs. SUPPLY VOLTAGE**



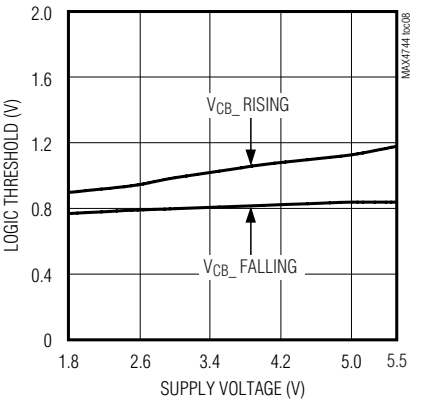

**NO_ TURN-ON/NC_ TURN-OFF TIME vs. TEMPERATURE**



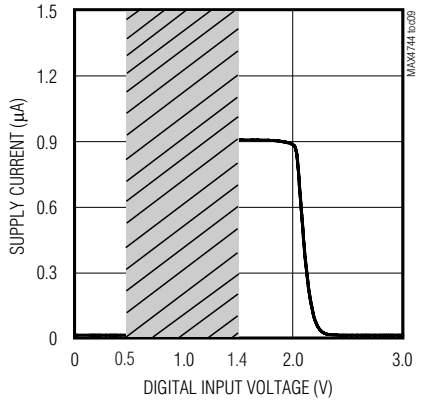

**NO_ TURN-ON/NC_ TURN-OFF TIME vs. TEMPERATURE**



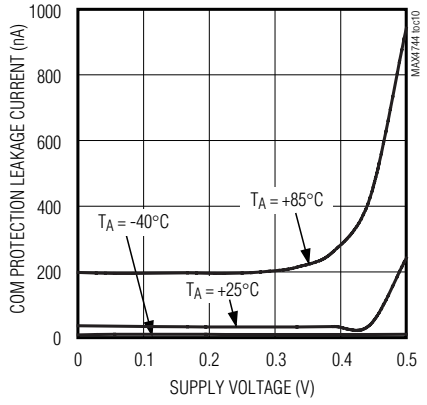

**LOGIC THRESHOLD vs. SUPPLY VOLTAGE**



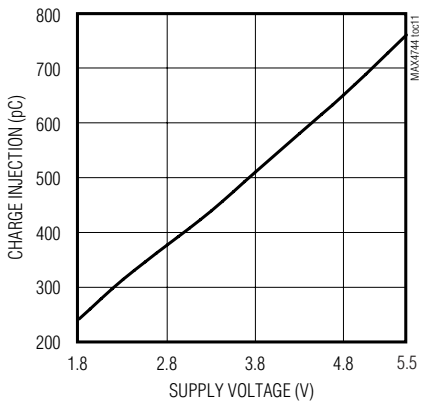

**SUPPLY CURRENT vs. LOGIC-INPUT VOLTAGE**




**COM PROTECTION LEAKAGE CURRENT vs. SUPPLY VOLTAGE**




**CHARGE INJECTION vs. SUPPLY VOLTAGE**

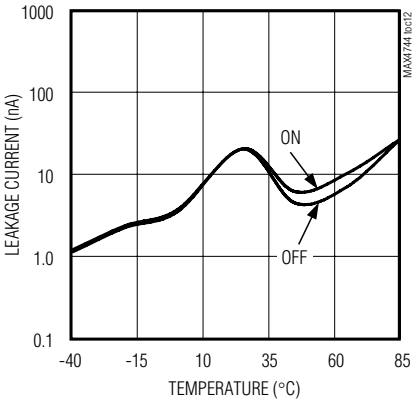


# Low-Voltage, Dual SPDT, Audio Clickless Switches With Negative Rail Capability

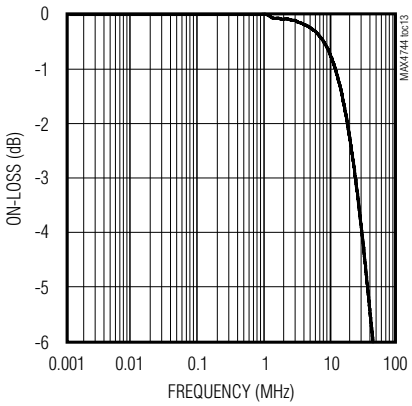
## Typical Operating Characteristics (continued)

($V_{CC}$ = +3.3V, $T_A$ = +25°C, unless otherwise noted.)

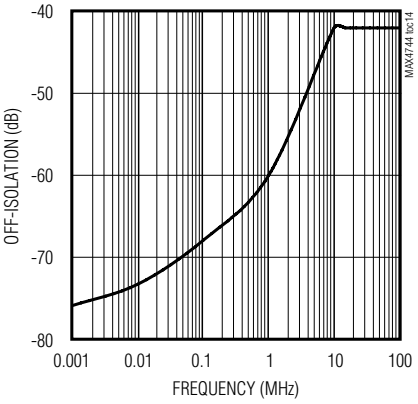
**LEAKAGE CURRENT vs. TEMPERATURE**



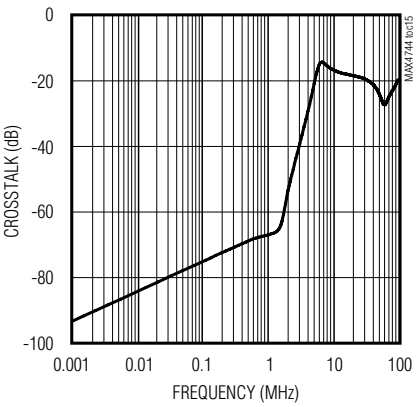

**FREQUENCY RESPONSE**



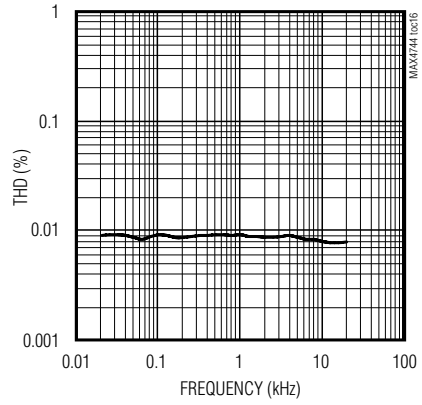

**OFF-ISOLATION vs. FREQUENCY**



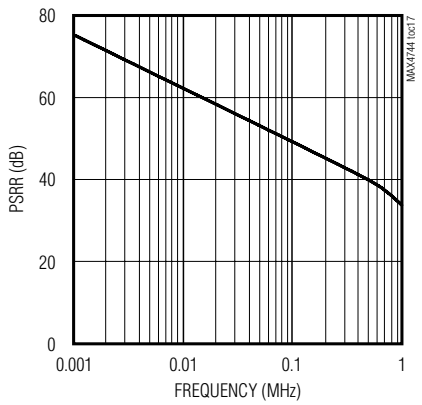

**CROSSTALK vs. FREQUENCY**




**TOTAL HARMONIC DISTORTION vs. FREQUENCY**




**POWER-SUPPLY REJECTION RATIO vs. FREQUENCY**



## Pin Description

| PIN | | NAME | FUNCTION |
|---|---|---|---|
| MAX4744/ MAX4745 | MAX4744H/ MAX4745H | | |
| 1 | — | CB1 | Digital Control Input for Analog Switch 1 |
| — | 1 | $\overline{EN}$ | Enable Input. Driving $\overline{EN}$ high causes all switches to be high impedance. Pull $\overline{EN}$ low for normal operation. |
| 2 | 2 | NO1 | Analog Switch 1 – Normally Open Terminal |
| 3 | 3 | GND | Ground |
| 4 | 4 | NO2 | Analog Switch 2 – Normally Open Terminal |
| 5 | — | CB2 | Digital Control Input for Analog Switch 2 |
| — | 5 | CB0 | Digital Control Input for Analog Switches 1 and 2 |
| 6 | 6 | COM2 | Analog Switch 2 – Common Terminal |
| 7 | 7 | NC2 | Analog Switch 2 – Normally Closed Terminal |
| 8 | 8 | $V_{CC}$ | Positive Supply Voltage from +1.8V to +5.5V |
| 9 | 9 | NC1 | Analog Switch 1 – Normally Closed Terminal |
| 10 | 10 | COM1 | Analog Switch 1 – Common Terminal |

## Detailed Description

The MAX4744/MAX4744H/MAX4745/MAX4745H are low on-resistance, low-voltage, dual-SPDT analog switches that operate from a +1.8V to +5.5V single supply. These devices feature a negative signal capability that allows signals as low as $V_{CC}$ - 5.5V to pass through without distortion.

The MAX4744/MAX4745 feature two digital control bits to control each switch independently (see Table 1). The MAX4744H/MAX4745H have one control bit to switch both switches and an enable input $\overline{EN}$ to put the switches in a high-impedance mode. Driving $\overline{EN}$ low takes the switches out of high impedance and CB0 controls both switches (see Table 2).

The MAX4744/MAX4744H have internal shunt resistors on all NO and NC terminals to suppress click-and-pop sounds that can occur when switching audio signals between pre-charged points.

## Applications Information

### Digital Control Inputs

The MAX4744/MAX4744H/MAX4745/MAX4745H logic inputs accept up to +5.5V, regardless of supply voltage. For example, with a +3.3V supply, CB0, CB1, CB2, and $\overline{EN}$ can be driven low to GND and high to +5.5V, allowing for mixed logic levels in a system.

**Table 1. MAX4744/MAX4745 Truth Table**

| CONTROL | | SWITCH STATE | |
|---|---|---|---|
| CB1 | CB2 | Switch 1 | Switch 2 |
| 0 | 0 | Connected to NC1 | Connected to NC2 |
| 0 | 1 | Connected to NC1 | Connected to NO2 |
| 1 | 0 | Connected to NO1 | Connected to NC2 |
| 1 | 1 | Connected to NO1 | Connected to NO2 |

**Table 2. MAX4744H/MAX4745H Truth Table**

| CONTROL | | SWITCH STATE | |
|---|---|---|---|
| $\overline{EN}$ | CB0 | Switch 1 | Switch 2 |
| 0 | 0 | Connected to NC1 | Connected to NC2 |
| 0 | 1 | Connected to NO1 | Connected to NO2 |
| 1 | X | High Impedance | High Impedance |

*X = Don't Care*

Driving CB0, CB1, CB2, and $\overline{EN}$ rail-to-rail minimizes power consumption.

# Low-Voltage, Dual SPDT, Audio Clickless Switches With Negative Rail Capability

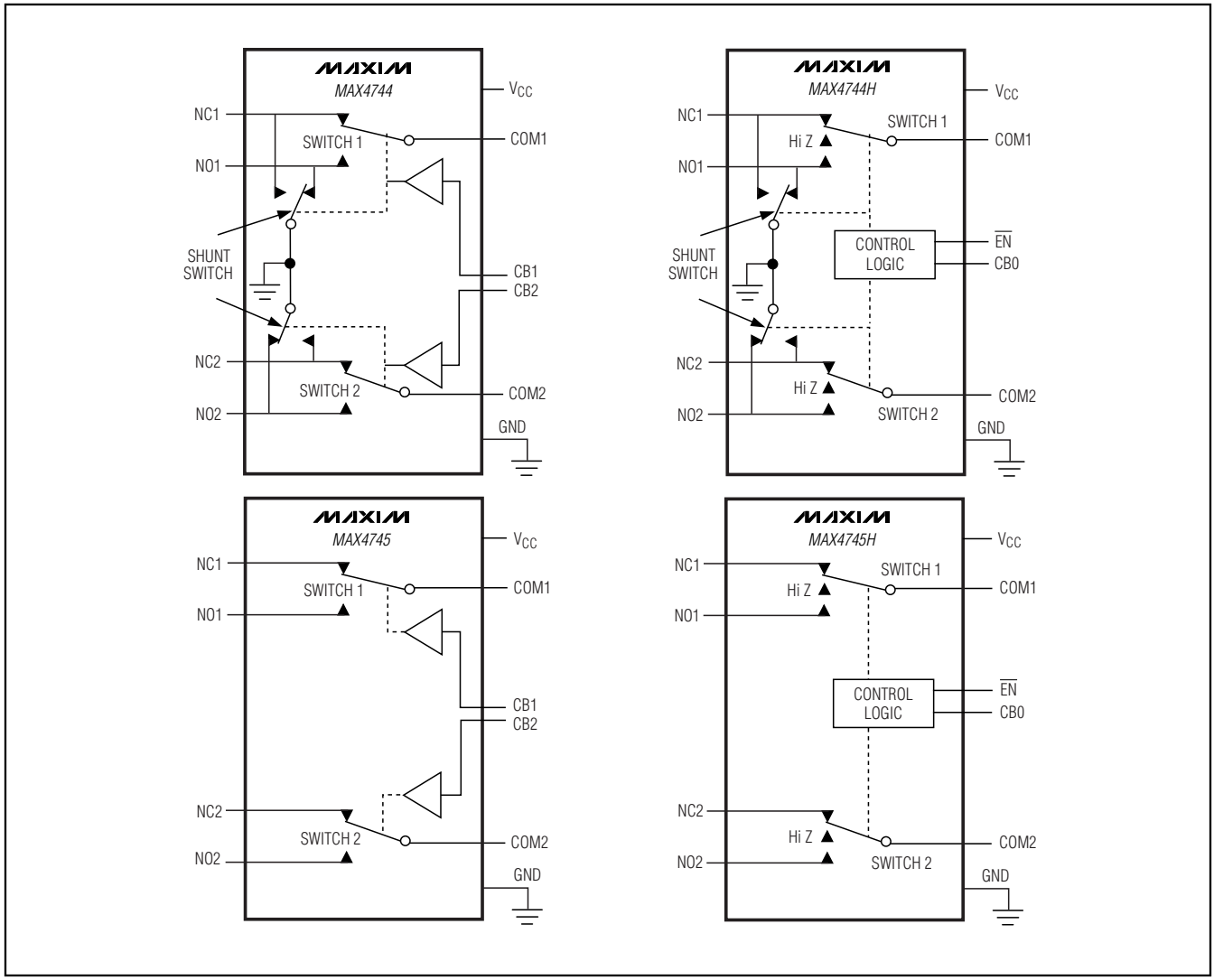



*Figure 1. Functional Diagram*

### Analog Signal Levels

These devices pass signals from $V_{CC}$ to as low as $V_{CC}$ - 5.5V, including signals below ground with minimal distortion and very little change in on-resistance (see the *Typical Operating Characteristics*). The switches are bidirectional, so the NO_, NC_, and COM_ terminals can be used as either inputs or outputs.

### COM_ Protection with $V_{CC}$ = 0V (MAX4744H/MAX4745H)

This feature prevents any damage to the device due to improper power-supply sequencing. The protection applies if a signal is applied on COM_ when $V_{CC}$ is less than 0.5V. The switch is not protected if $V_{CC}$ goes above 0.5V due to parasitic capacitive coupling or any leakage between COM_ and $V_{CC}$. The signal at COM_ ranges between $V_{CC}$ - 6.0V to 6.0V under protection conditions.

### Click-and-Pop Suppression

The MAX4744/MAX4744H have a shunt resistor on all their NO and NC terminals to automatically discharge any capacitance when they are not connected to COM. The shunt resistor reduces audible click-and-pop sounds that occur when switching between audio sources. Audible clicks and pops are caused when a

## Test Circuits/Timing Diagrams

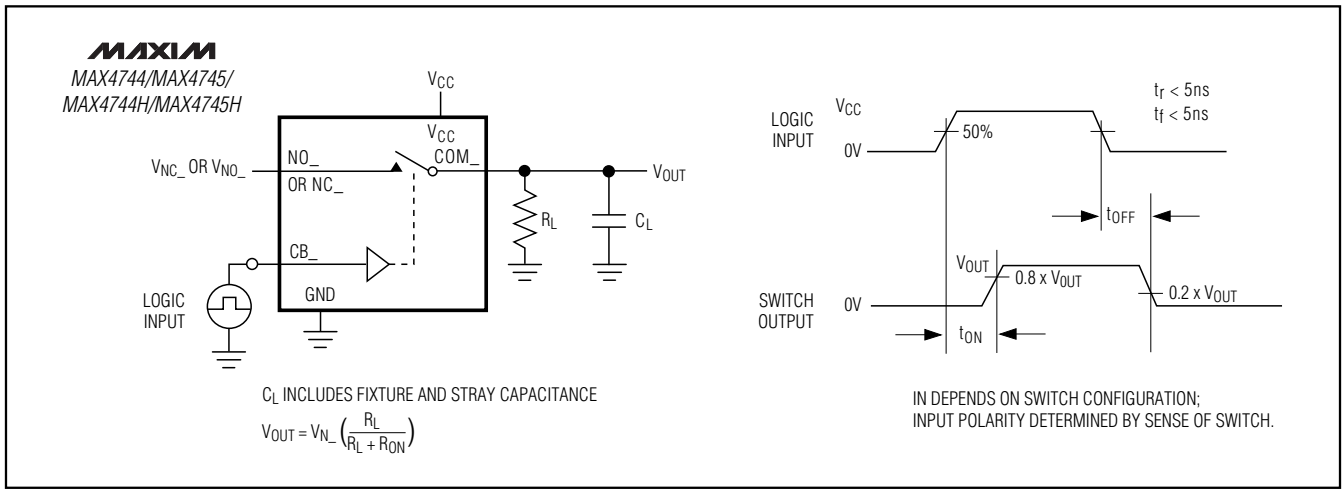



*Figure 2. Switching Time*

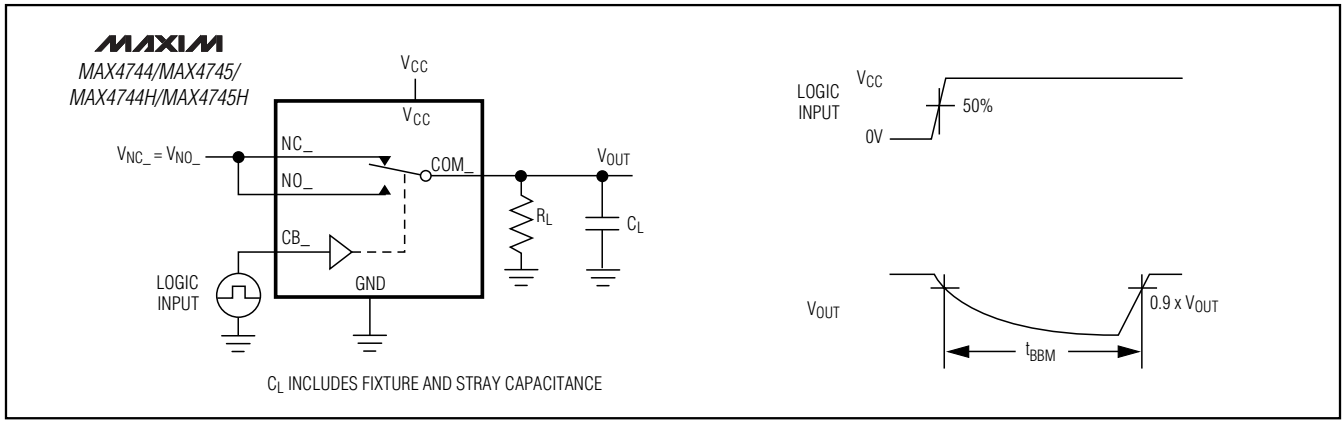



*Figure 3. Break-Before-Make Interval*

step DC voltage is switched into the speaker. The DC step transients can be reduced by automatically discharging the side that is not connected to the COM terminal, reducing any residual DC voltage and reducing clicks and pops.

### Break-Before-Make Switching

All devices feature break-before-make switching which is configured to break (open) the first set of contacts before engaging (closing) the new contacts. This prevents the momentary connection of the old and new signal paths to the output, reducing click-and-pop sounds.

### Power-Supply Sequencing and Overvoltage Protection

**Caution: Do not exceed the Absolute Maximum Ratings since stresses beyond the listed ratings may cause permanent damage to the device.**

Proper power-supply sequencing is recommended for all CMOS devices. Improper supply sequencing can force the switch into latch-up causing it to draw excessive supply current. The only way out of latch-up is to recycle the power and reapply properly. Connect all ground pins first, then apply power to $V_{CC}$, and finally apply signals to NO_, NC_, and COM_. Follow the reverse order upon power-down.

# Low-Voltage, Dual SPDT, Audio Clickless Switches With Negative Rail Capability

## Test Circuits/Timing Diagrams

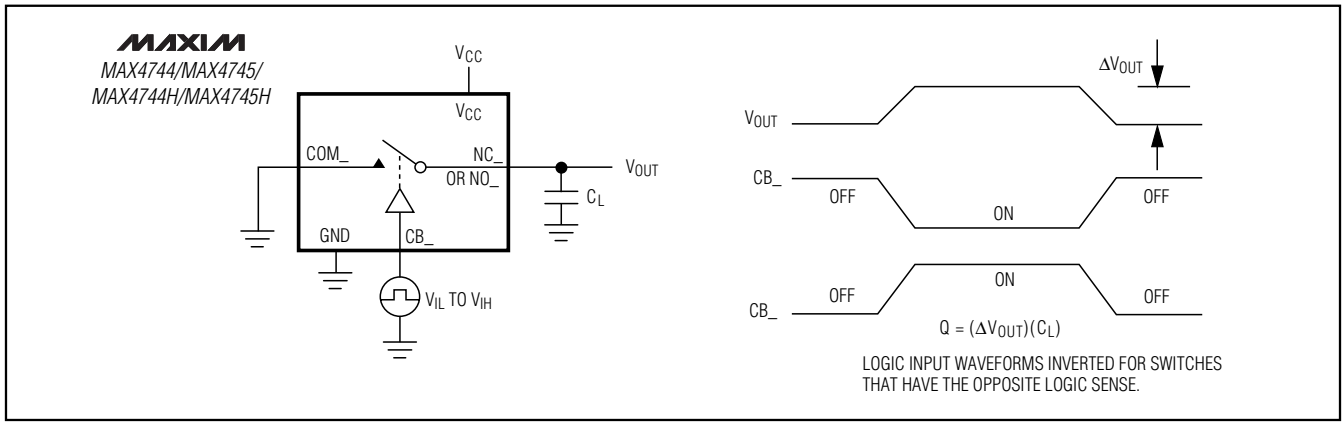



*Figure 4. Charge Injection*

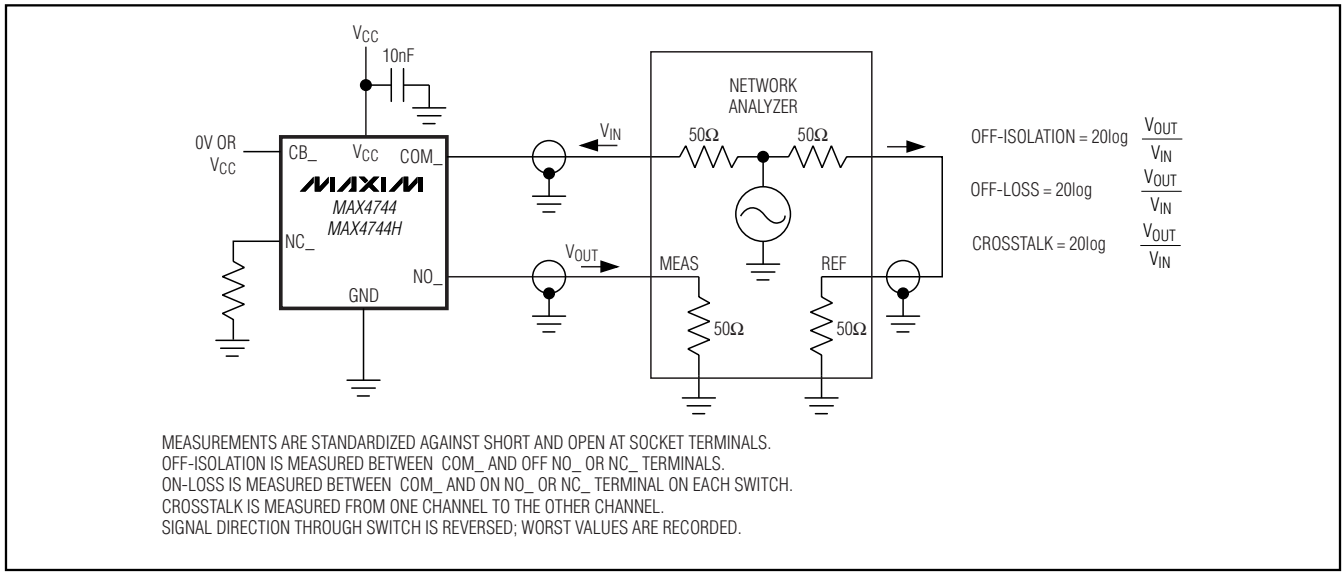



*Figure 5. Off-Isolation, On-Loss, and Crosstalk*

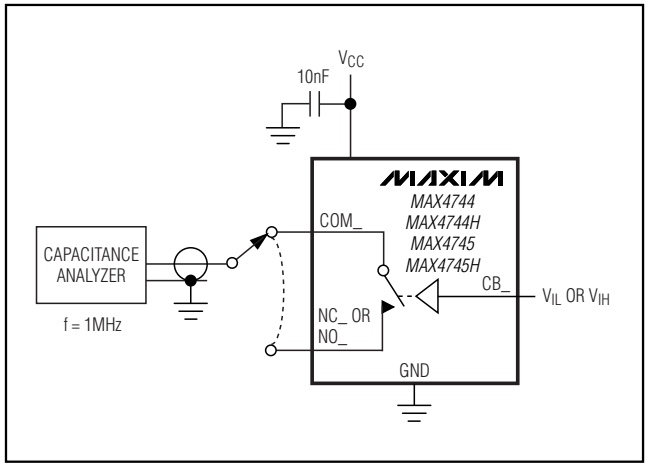
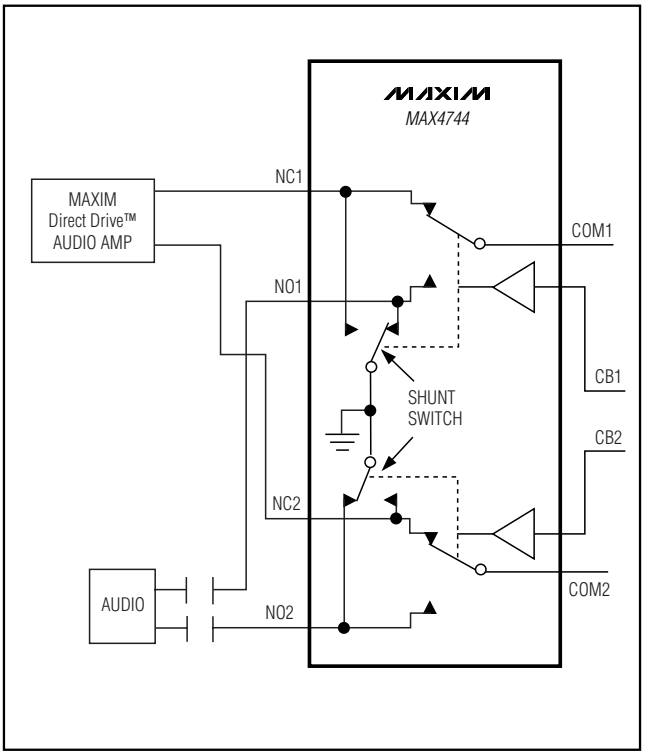



*Figure 6. Channel Off-/On-Capacitance*

## Chip Information

PROCESS: BiCMOS

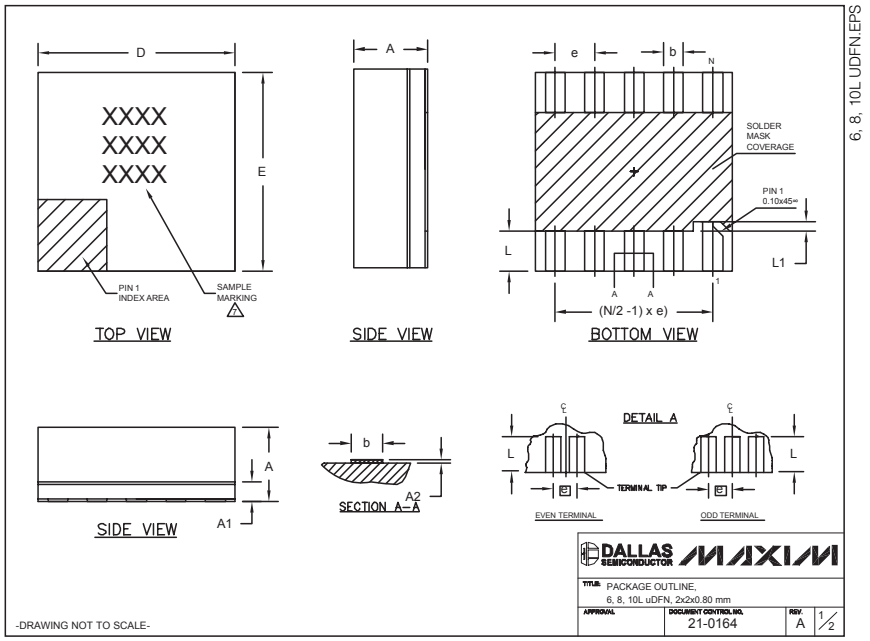
## Typical Operating Circuit



# Low-Voltage, Dual SPDT, Audio Clickless Switches With Negative Rail Capability

## 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**.)




| COMMON DIMENSIONS | | | |
|---|---|---|---|
| SYMBOL | MIN. | NOM. | MAX. |
| A | 0.70 | 0.75 | 0.80 |
| A1 | 0.15 | 0.20 | 0.25 |
| A2 | 0.020 | 0.025 | 0.035 |
| D | 1.95 | 2.00 | 2.05 |
| E | 1.95 | 2.00 | 2.05 |
| L | 0.30 | 0.40 | 0.50 |
| L1 | 0.10 REF. | | |

| PACKAGE VARIATIONS | | | | |
|---|---|---|---|---|
| PKG. CODE | N | e | b | (N/2 -1) x e |
| L622-1 | 6 | 0.65 BSC | 0.30±0.05 | 1.30 REF. |
| L822-1 | 8 | 0.50 BSC | 0.25±0.05 | 1.50 REF. |
| L1022-1 | 10 | 0.40 BSC | 0.20±0.03 | 1.60 REF. |

NOTES:
1. ALL DIMENSIONS ARE IN mm. ANGLES IN DEGREES.
2. COPLANARITY SHALL NOT EXCEED 0.08mm.
3. WARPAGE SHALL NOT EXCEED 0.10mm.
4. PACKAGE LENGTH/PACKAGE WIDTH ARE CONSIDERED AS SPECIAL CHARACTERISTIC(S).
5. "N" IS THE TOTAL NUMBER OF LEADS.
6. NUMBER OF LEADS SHOWN ARE FOR REFERENCE ONLY.
7. MARKING IS FOR PACKAGE ORIENTATION REFERENCE ONLY.

DALLAS SEMICONDUCTOR MAXIM
TITLE: PACKAGE OUTLINE, 6, 8, 10L uDFN, 2x2x0.80 mm
APPROVAL
DOCUMENT CONTROL NO. 21-0164
REV. A
2/2
-DRAWING NOT TO SCALE-

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