



# High-Bandwidth T1/E1 Dual-SPDT Switches/ 4:1 Muxes

MAX4818/MAX4819

## General Description

The MAX4818/MAX4819 high-bandwidth, low-on-resistance analog dual SPDT switches/4:1 multiplexers are designed to serve as integrated T1/E1 protection switches for 1+1 and N+1 line-card redundancy applications. Each MAX4818/MAX4819 replaces four electromechanical relays, significantly reducing board space, simplifying PC board routing, and reducing power consumption. These devices operate with  $\pm 3.3\text{V}$  or  $\pm 5\text{V}$  dual supplies for applications requiring T1/E1 signal switching in the line side of the interface transformer. Internal voltage multipliers drive the analog switches, yielding excellent linearity and low  $4\Omega$  typical on-resistance within the T1/E1 analog signal range. This high-bandwidth family of products is optimized for low return loss and matched pulse template performance in T1/E1 long-haul and short-haul applications.

The MAX4818/MAX4819 are available in a tiny 16-pin, 5mm x 5mm, thin QFN package and are specified over the extended  $-40^\circ\text{C}$  to  $+85^\circ\text{C}$  temperature range.

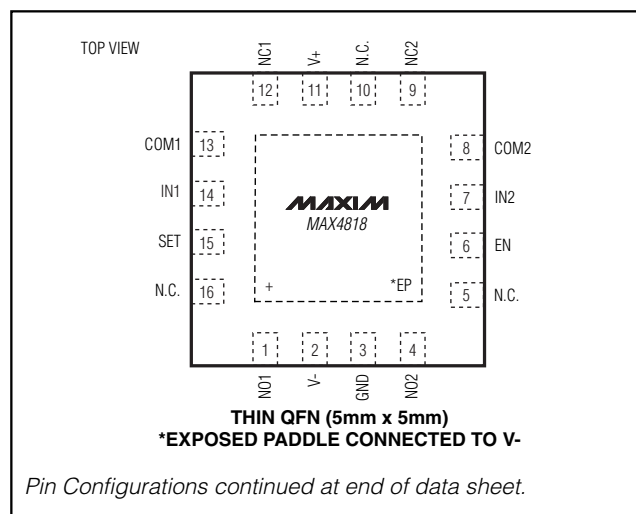
## Applications

T1/E1 Redundancy Switching  
Base Stations and Base-Station Controllers  
Add and Drop Multiplexers  
Multi-Service Provisioning Platforms  
Edge Routers  
Multi-Service-Switches (MSSs)  
Digital Loop Carriers  
Industrial Applications  
Data Acquisition  
Telecom Signal Switching  
Test Equipment  
Avionics

## Features

- ◆ Dual SPDT and 4:1 Multiplexer Configurations
- ◆ Dual-Supply Operation from  $\pm 3.3\text{V}$  to  $\pm 5\text{V}$
- ◆ Single-Supply Operation from  $+6\text{V}$  to  $+11\text{V}$
- ◆ Hot-Insertion Tolerant with No DC Path to the Supplies
- ◆ Low On-Resistance,  $R_{ON} = 4\Omega$  (typ) and  $6\Omega$  (max)
- ◆ Over 350MHz -3dB Signal Bandwidth (MAX4818)
- ◆ Excellent Crosstalk and Off-Isolation Performance Over the T1/E1 Signal Spectrum: Over 110dB Crosstalk Attenuation at 1MHz (MAX4818)
- ◆ Low Current Consumption of 2mA (max)
- ◆  $-40^\circ\text{C}$  to  $+85^\circ\text{C}$  Extended Temperature Range
- ◆ Space-Saving, 16-Pin, 5mm x 5mm Thin QFN
- ◆ SET Controls All Switches Simultaneously For Redundancy Switching (MAX4819)

## Pin Configurations



## Ordering Information

| PART        | TEMP RANGE                                 | PIN-PACKAGE | CONFIGURATION | PACKAGE CODE |
|-------------|--|-------------|---------------|--------------|
| MAX4818ETE+ | $-40^\circ\text{C}$ to $+85^\circ\text{C}$ | 16 TQFN-EP* | 2 x SPDT      | T1655-3      |
| MAX4819ETE+ | $-40^\circ\text{C}$ to $+85^\circ\text{C}$ | 16 TQFN-EP* | 4:1 MUX       | T1655-3      |

\*EP = Exposed Paddle

Devices are available in lead-free packages.



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**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](http://www.maxim-ic.com).**

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## ABSOLUTE MAXIMUM RATINGS

(All voltages referenced to GND unless otherwise noted.)

|  |                           |
|--|---------------------------|
| V+   | .....-0.3V to +6V         |
| V-   | .....-6V to +0.3V         |
| V+ to V-   | .....-0.3V to +12V        |
| IN <sub>+</sub> , A0, A1, SET, EN  | .....-0.3V to (V+) + 0.3V |
| NO <sub>+</sub> , NC <sub>+</sub> , COM <sub>+</sub>                       | .....-12V to +12V         |
| NO <sub>-</sub> to COM <sub>-</sub> , NC <sub>-</sub> to COM <sub>-</sub>  | .....-18V to +18V         |
| Continuous Current (NO <sub>+</sub> , NC <sub>+</sub> , COM <sub>+</sub> ) | ..... ±100mA              |
| Continuous Current (Any Other Terminal)                                    | .....±30mA                |

Peak Current (NO<sub>+</sub>, NC<sub>+</sub>, COM<sub>+</sub>)

(pulsed at 1ms, 10% duty cycle).....±300mA

Continuous Power Dissipation (T<sub>A</sub> = +70°C)

16-Pin Thin QFN 5mm x 5mm (derate 33.3mW/°C

above T<sub>A</sub> = +70°C) .....2667mW

Operating Temperature Range ..... -40°C to +85°C

Storage Temperature Range ..... -65°C to +150°C

Junction Temperature .....+150°C

Lead Temperature (soldering, 10s) ..... +300°C

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—Dual ±3.3V Supplies

(V+ = +3.3V ±10%, V- = -3.3V ±10%, T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>, unless otherwise noted. Typical values are at T<sub>A</sub> = +25°C.) (Note 1)

| PARAMETER                               | SYMBOL  | CONDITIONS  |  | MIN | TYP | MAX            | UNITS |
|---|---|---|--|-----|-----|----------------|-------|
| ANALOG SWITCH                           |   |   |  |     |     |                |       |
| Fault-Free Analog Signal Range          | V <sub>COM_</sub><br>V <sub>NO_</sub><br>V <sub>NC_</sub> |   |  | V-  |     | V+             | V     |
| MAX4818<br>On-Resistance                | R <sub>ON</sub>   | V+ = +3V, V- = -3V,<br>I <sub>COM_</sub> = 30mA,<br>V <sub>NO_</sub> or V <sub>NC_</sub> = +3V<br>(Note 2)              | T <sub>A</sub> = +25°C<br><br>T <sub>A</sub> = T <sub>MIN</sub> to<br>T <sub>MAX</sub> | 4   |     | 5<br><br>6     | Ω     |
| MAX4819<br>On-Resistance                | R <sub>ON</sub>   | V+ = +3V, V- = -3V,<br>I <sub>COM_</sub> = 30mA,<br>V <sub>NO_</sub> or V <sub>NC_</sub> = +3V<br>(Note 2)              | T <sub>A</sub> = +25°C<br><br>T <sub>A</sub> = T <sub>MIN</sub> to<br>T <sub>MAX</sub> | 4   |     | 5<br><br>6.2   | Ω     |
| On-Resistance Match<br>Between Channels | ΔR <sub>ON</sub>  | V+ = +3V, V- = -3V,<br>I <sub>COM_</sub> = 30mA,<br>V <sub>NO_</sub> or V <sub>NC_</sub> = +3V<br>(Notes 2, 3)          | T <sub>A</sub> = +25°C<br><br>T <sub>A</sub> = T <sub>MIN</sub> to<br>T <sub>MAX</sub> | 0.3 |     | 0.6<br><br>0.8 | Ω     |
| On-Resistance Flatness                  | R <sub>FLAT(ON)</sub>                                     | V+ = +3V, V- = -3V,<br>I <sub>COM_</sub> = 30mA,<br>V <sub>NO_</sub> or V <sub>NC_</sub> = -3V, 0V,<br>+3V (Notes 2, 4) | T <sub>A</sub> = +25°C<br><br>T <sub>A</sub> = T <sub>MIN</sub> to<br>T <sub>MAX</sub> | 0.5 |     | 1.2<br><br>1.5 | Ω     |
| NO or NC Off-Leakage<br>Current         | I <sub>NO_(OFF)</sub><br>I <sub>NC_(OFF)</sub>            | V+ = +3.6V, V- = -3.6V,<br>V <sub>COM_</sub> = -3V, +3V,<br>V <sub>NO_</sub> or V <sub>NC_</sub> = +3V, -3V             |  | -10 |     | +10            | nA    |
| COM Off-Leakage Current                 | I <sub>COM_(OFF)</sub>                                    | V+ = +3.6V, V- = -3.6V,<br>V <sub>COM_</sub> = -3V, +3V,<br>V <sub>NO_</sub> or V <sub>NC_</sub> = +3V, -3V             |  | -10 |     | +10            | nA    |
| COM On-Leakage Current                  | I <sub>COM_(ON)</sub>                                     | V+ = +3.6V, V- = -3.6V,<br>V <sub>COM_</sub> = -3V, +3V,<br>V <sub>NO_</sub> or V <sub>NC_</sub> unconnected            |  | -15 |     | +15            | nA    |

# High-Bandwidth T1/E1 Dual-SPDT Switches/ 4:1 Muxes

MAX4818/MAX4819

## ELECTRICAL CHARACTERISTICS—Dual $\pm 3.3\text{V}$ Supplies (continued)

( $V_+ = +3.3\text{V} \pm 10\%$ ,  $V_- = -3.3\text{V} \pm 10\%$ ,  $T_A = T_{\text{MIN}}$  to  $T_{\text{MAX}}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ\text{C}$ .) (Note 1)

| PARAMETER                                 | SYMBOL   | CONDITIONS  | MIN   | TYP | MAX | UNITS         |
|---|--|---|---|-----|-----|---------------|
| <b>FAULT</b>                              |  |   |   |     |     |               |
| Fault Analog Signal Range                 | $V_{\text{COM}_-}$<br>$V_{\text{NO}_-}$<br>$V_{\text{NC}_-}$ | $V_+ = +3.3\text{V}$ , $V_- = -3.3\text{V}$   | -11   |     | +11 | V             |
| NO or NC Off-Leakage Current              | $I_{\text{NO}_-}$<br>$I_{\text{NC}_-}$                       | $V_+ = +3.3\text{V}$ , $V_- = -3.3\text{V}$ ,<br>$V_{\text{COM}_-} = +11\text{V}$ , $-11\text{V}$ ,<br>$V_{\text{NO}_-}$ or $V_{\text{NC}_-} = -5.5\text{V}$ , $+5.5\text{V}$ | -1  |     | +1  | $\mu\text{A}$ |
| COM Off-Leakage Current                   | $I_{\text{COM}_-}$   | $V_+ = +3.3\text{V}$ , $V_- = -3.3\text{V}$ ,<br>$V_{\text{COM}_-} = +11\text{V}$ , $-11\text{V}$ ,<br>$V_{\text{NO}_-}$ or $V_{\text{NC}_-} = -5.5\text{V}$ , $+5.5\text{V}$ | -1  |     | +1  | $\mu\text{A}$ |
| <b>SWITCH DYNAMIC CHARACTERISTICS</b>     |  |   |   |     |     |               |
| MAX4818<br>Crosstalk (Note 5)             | $V_{\text{CT1}}$   | $R_L = 50\Omega$ , $f = 1.024\text{MHz}$ , Figure 4   |   | 110 |     | dB            |
|   | $V_{\text{CT2}}$   | $R_L = 50\Omega$ , $f = 30\text{MHz}$ , Figure 4  |   | 77  |     |               |
| MAX4819<br>All-Hostile Crosstalk (Note 6) | $V_{\text{HCT1}}$  | $R_L = 50\Omega$ , $f = 1.024\text{MHz}$  |   | 50  |     | dB            |
|   | $V_{\text{HCT2}}$  | $R_L = 50\Omega$ , $f = 30\text{MHz}$   |   | 17  |     |               |
| Off-Isolation (Note 7)                    | $V_{\text{ISO1}}$  | $V_{\text{COM}_-}$ to $V_{\text{NO}_-}$ or $V_{\text{NC}_-}$ ,<br>$R_L = 50\Omega$ , $f = 1.024\text{MHz}$ , Figure 4   |   | 60  |     | dB            |
|   | $V_{\text{ISO2}}$  | $V_{\text{COM}_-}$ to $V_{\text{NO}_-}$ or $V_{\text{NC}_-}$ ,<br>$R_L = 50\Omega$ , $f = 30\text{MHz}$ , Figure 4  |   | 30  |     |               |
| On-Channel -3dB Bandwidth                 | BW   | $R_S = R_L = 50\Omega$ , Figure 4   | MAX4818                                       | 350 |     | MHz           |
|   |  |   | MAX4819                                       | 220 |     |               |
| COM On-Capacitance                        | $C_{\text{ON}}(\text{COM}_-)$                                | $f = 1\text{MHz}$ , Figure 5  | MAX4818                                       | 20  |     | pF            |
|   |  |   | MAX4819                                       | 40  |     |               |
| COM Off-Capacitance                       | $C_{\text{OFF}}(\text{COM}_-)$                               | $f = 1\text{MHz}$ , Figure 5  | MAX4818                                       | 15  |     | pF            |
|   |  |   | MAX4819                                       | 30  |     |               |
| NC/NO Off-Capacitance                     | $C_{\text{OFF}}$   | $f = 1\text{MHz}$ , Figure 5  |   | 7   |     | pF            |
| Charge Injection                          | Q  | $C_L = 1.0\text{nF}$ , $V_{\text{GEN}} = 0$ ,<br>$R_{\text{GEN}} = 0$ , Figure 3  | MAX4818                                       | 35  |     | pC            |
|   |  |   | MAX4819                                       | 60  |     |               |
| Fault Recovery Time                       | $t_{\text{REC}}$   | $V_{\text{NO}_-}$ , $V_{\text{NC}_-}$ , $V_{\text{COM}_-} = -11\text{V}$  |   | 128 |     | $\mu\text{s}$ |
| Turn-On Time                              | $t_{\text{ON}}$  | $V_{\text{NO}_-}$ or $V_{\text{NC}_-} = +3\text{V}$ ,<br>$R_L = 300\Omega$ ,<br>$C_L = 35\text{pF}$ , Figure 2  | $T_A = +25^\circ\text{C}$                     | 20  | 50  | $\mu\text{s}$ |
|   |  |   | $T_A = T_{\text{MIN}}$ to<br>$T_{\text{MAX}}$ |     | 50  |               |
| Turn-Off Time                             | $t_{\text{OFF}}$   | $V_{\text{NO}_-}$ or $V_{\text{NC}_-} = +3\text{V}$ ,<br>$R_L = 300\Omega$ ,<br>$C_L = 35\text{pF}$ , Figure 2  | $T_A = +25^\circ\text{C}$                     | 0.5 | 1   | $\mu\text{s}$ |
|   |  |   | $T_A = T_{\text{MIN}}$ to<br>$T_{\text{MAX}}$ |     | 1   |               |
| Power-Up Delay                            | $t_{\text{DEL}}$   |   |   | 128 |     | $\mu\text{s}$ |

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## ELECTRICAL CHARACTERISTICS—Dual $\pm 3.3\text{V}$ Supplies (continued)

( $V_+ = +3.3\text{V} \pm 10\%$ ,  $V_- = -3.3\text{V} \pm 10\%$ ,  $T_A = T_{\text{MIN}}$  to  $T_{\text{MAX}}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ\text{C}$ .) (Note 1)

| PARAMETER                                 | SYMBOL          | CONDITIONS   | MIN  | TYP | MAX  | UNITS         |
|---|-----------------|--|------|-----|------|---------------|
| <b>LOGIC INPUT (IN_, EN, SET, A0, A1)</b> |                 |  |      |     |      |               |
| Input Voltage Low                         | $V_{\text{IL}}$ |  |      |     | 0.8  | V             |
| Input Voltage High                        | $V_{\text{IH}}$ |  | 2.4  |     |      | V             |
| Input Leakage Current                     | $I_{\text{IN}}$ | $V_{\text{IN}_-} = 0$ or $V_+$   | -1   |     | +1   | $\mu\text{A}$ |
| <b>POWER SUPPLY</b>                       |                 |  |      |     |      |               |
| Quiescent Positive Supply Current         | $I_+$           | $V_+ = +3.6\text{V}$ , $V_- = -3.6\text{V}$ , $V_{\text{IN}_-} = 0$ or $V_+$ |      | 0.8 | 2    | mA            |
| Quiescent Negative Supply Current         | $I_-$           | $V_+ = +3.6\text{V}$ , $V_- = -3.6\text{V}$ , $V_{\text{IN}_-} = 0$ or $V_+$ |      | 0.8 | 2    | mA            |
| Positive Supply Voltage                   | $V_+$           |  | 3.0  |     | 3.6  | V             |
| Negative Supply Voltage                   | $V_-$           |  | -3.6 |     | -3.0 | V             |

## ELECTRICAL CHARACTERISTICS—Dual $\pm 5\text{V}$ Supplies

( $V_+ = +5\text{V} \pm 10\%$ ,  $V_- = -5\text{V} \pm 10\%$ ,  $T_A = T_{\text{MIN}}$  to  $T_{\text{MAX}}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ\text{C}$ .) (Note 1)

| PARAMETER                               | SYMBOL   | CONDITIONS  | MIN  | TYP | MAX   | UNITS    |
|---|--|---|--|-----|-------|----------|
| <b>ANALOG SWITCH</b>                    |  |   |  |     |       |          |
| Fault-Free Analog Signal Range          | $V_{\text{COM}_-}$<br>$V_{\text{NO}_-}$<br>$V_{\text{NC}_-}$   |   | $V_-$                                      |     | $V_+$ | V        |
| MAX4818<br>On-Resistance                | $R_{\text{ON}}$  | $V_+ = +4.5\text{V}$ , $V_- = -4.5\text{V}$ ,<br>$I_{\text{COM}_-} = 30\text{mA}$ ,<br>$V_{\text{NO}_-}$ or $V_{\text{NC}_-} = +3\text{V}$ (Note 2)                                     | $T_A = +25^\circ\text{C}$                  | 4   | 5     | $\Omega$ |
|   |  |   | $T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$ |     | 6     |          |
| MAX4819<br>On-Resistance                | $R_{\text{ON}}$  | $V_+ = +4.5\text{V}$ , $V_- = -4.5\text{V}$ ,<br>$I_{\text{COM}_-} = 30\text{mA}$ ,<br>$V_{\text{NO}_-}$ or $V_{\text{NC}_-} = +3\text{V}$ (Note 2)                                     | $T_A = +25^\circ\text{C}$                  | 4   | 5     | $\Omega$ |
|   |  |   | $T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$ |     | 6.2   |          |
| On-Resistance Match<br>Between Channels | $\Delta R_{\text{ON}}$   | $V_+ = +4.5\text{V}$ , $V_- = -4.5\text{V}$ ,<br>$I_{\text{COM}_-} = 30\text{mA}$ ,<br>$V_{\text{NO}_-}$ or $V_{\text{NC}_-} = +3\text{V}$<br>(Notes 2, 3)                              | $T_A = +25^\circ\text{C}$                  | 0.3 | 0.6   | $\Omega$ |
|   |  |   | $T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$ |     | 0.8   |          |
| On-Resistance Flatness                  | $R_{\text{FLAT(ON)}}$  | $V_+ = +4.5\text{V}$ , $V_- = -4.5\text{V}$ ,<br>$I_{\text{COM}_-} = 30\text{mA}$ ,<br>$V_{\text{NO}_-}$ or $V_{\text{NC}_-} = -3\text{V}$ , $0\text{V}$ , $+3\text{V}$<br>(Notes 2, 4) | $T_A = +25^\circ\text{C}$                  | 0.5 | 1.2   | $\Omega$ |
|   |  |   | $T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$ |     | 1.5   |          |
| NO or NC Off-Leakage Current            | $I_{\text{NO}_-}(\text{OFF})$<br>$I_{\text{NC}_-}(\text{OFF})$ | $V_+ = +5.5\text{V}$ , $V_- = -5.5\text{V}$ ,<br>$V_{\text{COM}_-} = -5\text{V}$ , $+5\text{V}$ ,<br>$V_{\text{NO}_-}$ or $V_{\text{NC}_-} = +5\text{V}$ , $-5\text{V}$                 |  | -10 | +10   | nA       |
| COM Off-Leakage Current                 | $I_{\text{COM}_-}(\text{OFF})$                                 | $V_+ = +5.5\text{V}$ , $V_- = -5.5\text{V}$ ,<br>$V_{\text{COM}_-} = -5\text{V}$ , $+5\text{V}$ ,<br>$V_{\text{NO}_-}$ or $V_{\text{NC}_-} = +5\text{V}$ , $-5\text{V}$                 |  | -10 | +10   | nA       |

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MAX4818/MAX4819

## ELECTRICAL CHARACTERISTICS—Dual $\pm 5V$ Supplies (continued)

(V+ = +5V  $\pm 10\%$ , V- = -5V  $\pm 10\%$ , T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>, unless otherwise noted. Typical values are at T<sub>A</sub> = +25°C.) (Note 1)

| PARAMETER                                 | SYMBOL  | CONDITIONS   | MIN  | TYP | MAX | UNITS   |
|---|---|--|--|-----|-----|---------|
| COM On-Leakage Current                    | I <sub>COM(ON)</sub>                                      | V+ = +5.5V, V- = -5.5V,<br>V <sub>COM_</sub> = -5V, +5V,<br>V <sub>NO_</sub> or V <sub>NC_</sub> unconnected         | -15  |     | +15 | nA      |
| <b>FAULT</b>                              |   |  |  |     |     |         |
| Fault Analog Signal Range                 | V <sub>COM_</sub><br>V <sub>NO_</sub><br>V <sub>NC_</sub> | V+ = 5V, V- = -5V  | -11  |     | +11 | V       |
| NO or NC Off-Leakage Current              | I <sub>NO_</sub><br>I <sub>NC_</sub>                      | V+ = 5V, V- = -5V,<br>V <sub>NO_</sub> or V <sub>NC_</sub> = +11V, -11V,<br>V <sub>COM_</sub> = -5.5, +5.5V          | -1   |     | +1  | $\mu$ A |
| COM Off-Leakage Current                   | I <sub>COM_</sub>   | V+ = 5V, V- = -5V,<br>V <sub>NO_</sub> or V <sub>NC_</sub> = +11V, -11V,<br>V <sub>COM_</sub> = -5.5, +5.5V          | -1   |     | +1  | $\mu$ A |
| <b>SWITCH DYNAMIC CHARACTERISTICS</b>     |   |  |  |     |     |         |
| MAX4818<br>Crosstalk (Note 5)             | V <sub>CT1</sub>  | R <sub>L</sub> = 50 $\Omega$ , f = 1.024MHz, Figure 4  |  | 110 |     | dB      |
|   | V <sub>CT2</sub>  | R <sub>L</sub> = 50 $\Omega$ , f = 30MHz, Figure 4   |  | 77  |     |         |
| MAX4819<br>All-Hostile Crosstalk (Note 6) | V <sub>HCT1</sub>   | R <sub>L</sub> = 50 $\Omega$ , f = 1.024MHz  |  | 50  |     | dB      |
|   | V <sub>HCT2</sub>   | R <sub>L</sub> = 50 $\Omega$ , f = 30MHz   |  | 17  |     |         |
| Off-Isolation<br>(Note 6)                 | V <sub>ISO1</sub>   | V <sub>COM_</sub> to V <sub>NO_</sub> or V <sub>NC_</sub> ,<br>R <sub>L</sub> = 50 $\Omega$ , f = 1.024MHz, Figure 4 |  | 60  |     | dB      |
|   | V <sub>ISO2</sub>   | V <sub>COM_</sub> to V <sub>NO_</sub> or V <sub>NC_</sub> ,<br>R <sub>L</sub> = 50 $\Omega$ , f = 30MHz, Figure 4    |  | 30  |     |         |
| On-Channel -3dB Bandwidth                 | BW  | R <sub>S</sub> = R <sub>L</sub> = 50 $\Omega$ ,<br>Figure 4  | MAX4818  | 350 |     | MHz     |
|   |   |  | MAX4819  | 220 |     |         |
| COM On-Capacitance                        | C <sub>ON(COM_)</sub>                                     | f = 1MHz, Figure 5   | MAX4818  | 20  |     | pF      |
|   |   |  | MAX4819  | 40  |     |         |
| COM Off-Capacitance                       | C <sub>OFF(COM_)</sub>                                    | f = 1MHz, Figure 5   | MAX4818  | 15  |     | pF      |
|   |   |  | MAX4819  | 30  |     |         |
| NC/NO Off-Capacitance                     | C <sub>OFF</sub>  | f = 1MHz, Figure 5   |  | 7   |     | pF      |
| Charge Injection                          | Q   | C <sub>L</sub> = 1.0nF, V <sub>GEN</sub> = 0,<br>R <sub>GEN</sub> = 0, Figure 3                                      | MAX4818  | 35  |     | pC      |
|   |   |  | MAX4819  | 60  |     |         |
| Fault Recovery Time                       | t <sub>REC</sub>  | V <sub>NO_</sub> , V <sub>NC_</sub> , V <sub>COM_</sub> = -11V   |  | 128 |     | $\mu$ s |
| Turn-On Time                              | t <sub>ON</sub>   | V <sub>NO_</sub> or V <sub>NC_</sub> = +3V,<br>R <sub>L</sub> = 300 $\Omega$ ,<br>C <sub>L</sub> = 35pF, Figure 2    | T <sub>A</sub> = +25°C                                   | 20  | 50  | $\mu$ s |
|   |   |  | T <sub>A</sub> = T <sub>MIN</sub> to<br>T <sub>MAX</sub> |     | 50  |         |
| Turn-Off Time                             | t <sub>OFF</sub>  | V <sub>NO_</sub> or V <sub>NC_</sub> = +3V,<br>R <sub>L</sub> = 300 $\Omega$ ,<br>C <sub>L</sub> = 35pF, Figure 2    | T <sub>A</sub> = +25°C                                   | 0.5 | 1   | $\mu$ s |
|   |   |  | T <sub>A</sub> = T <sub>MIN</sub> to<br>T <sub>MAX</sub> |     | 1   |         |
| Power-Up Delay                            | t <sub>DEL</sub>  |  |  | 128 |     | $\mu$ s |

# High-Bandwidth T1/E1 Dual-SPDT Switches/ 4:1 Muxes

## ELECTRICAL CHARACTERISTICS—Dual $\pm 5V$ Supplies (continued)

( $V_+ = +5V \pm 10\%$ ,  $V_- = -5V \pm 10\%$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .) (Note 1)

| PARAMETER                                 | SYMBOL   | CONDITIONS  | MIN  | TYP | MAX  | UNITS   |
|---|----------|---|------|-----|------|---------|
| <b>LOGIC INPUT (IN_, EN, SET, A0, A1)</b> |          |   |      |     |      |         |
| Input Voltage Low                         | $V_{IL}$ |   |      |     | 0.8  | V       |
| Input Voltage High                        | $V_{IH}$ |   | 2.4  |     |      | V       |
| Input Leakage Current                     | $I_{IN}$ | $V_{IN\_} = 0$ or $V_+$                                 | -1   |     | +1   | $\mu A$ |
| <b>POWER SUPPLY</b>                       |          |   |      |     |      |         |
| Quiescent Positive Supply Current         | $I_+$    | $V_+ = +5.5V$ , $V_- = -5.5V$ , $V_{IN\_} = 0$ or $V_+$ |      | 0.9 | 2    | mA      |
| Quiescent Negative Supply Current         | $I_-$    | $V_+ = +5.5V$ , $V_- = -5.5V$ , $V_{IN\_} = 0$ or $V_+$ |      | 0.9 | 2    | mA      |
| Positive Supply Voltage                   | $V_+$    |   | 4.5  |     | 5.5  | V       |
| Negative Supply Voltage                   | $V_-$    |   | -5.5 |     | -4.5 | V       |

**Note 1:** All parameters are production tested at  $T_A = +85^\circ C$  and guaranteed by design over specified temperature range.

**Note 2:** Guaranteed by design, not production tested.

**Note 3:**  $\Delta R_{ON} = R_{ON\_MAX} - R_{ON\_MIN}$ .

**Note 4:** Flatness is defined as the difference between the maximum and minimum value of on-resistance as measured over the specified analog signal range.

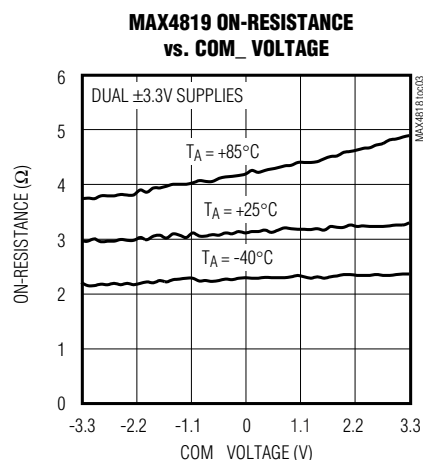
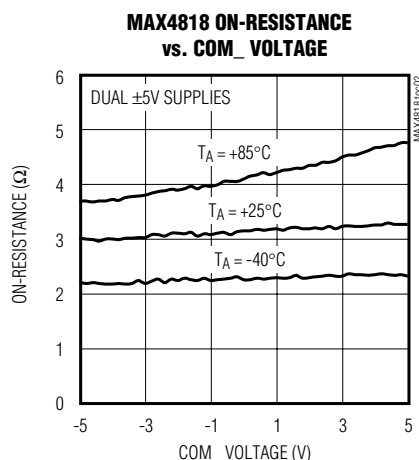
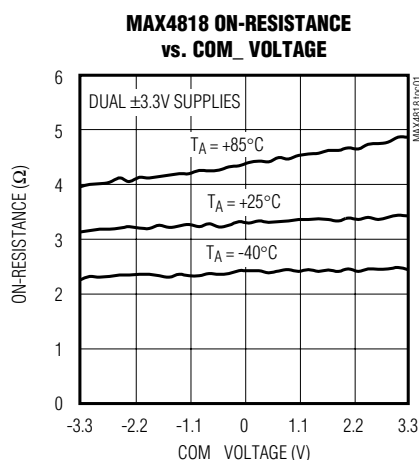
**Note 5:** Between any two switches.

**Note 6:** All-hostile crosstalk from all OFF multiplexer inputs to the ON multiplexer channel. All-hostile crosstalk is tested by applying the same signal to all OFF inputs and measuring the crosstalk on the ON channel (COM terminal of the multiplexer.)

**Note 7:** Off-Isolation =  $20 \log_{10} [V_{COM} / (V_{NC} \text{ or } V_{NO})]$ ,  $V_{COM}$  = output,  $V_{NC}$  or  $V_{NO}$  = input to OFF switch.

## Typical Operating Characteristics

( $V_+ = +3.3V$ ,  $V_- = -3.3V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

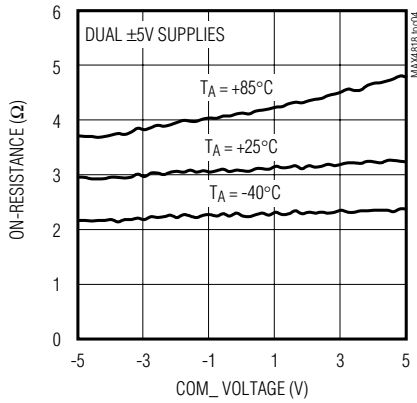


# High-Bandwidth T1/E1 Dual-SPDT Switches/ 4:1 Muxes

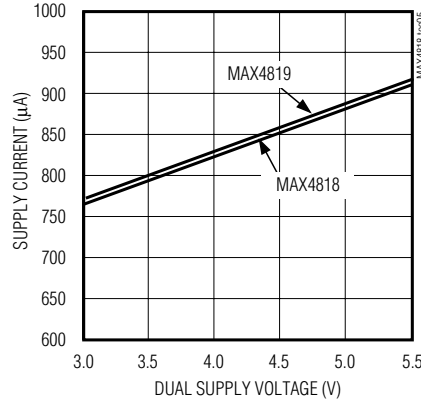
## Typical Operating Characteristics (continued)

(V+ = +3.3V, V- = -3.3V, T<sub>A</sub> = +25°C, unless otherwise noted.)

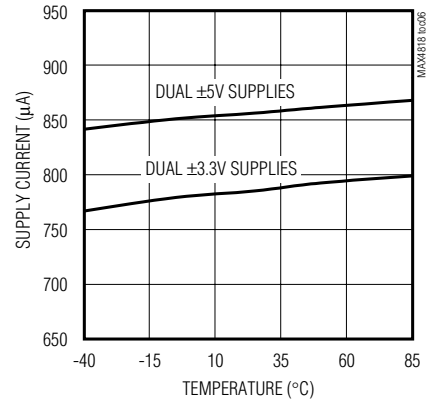
**MAX4819 ON-RESISTANCE  
vs. COM\_ VOLTAGE**



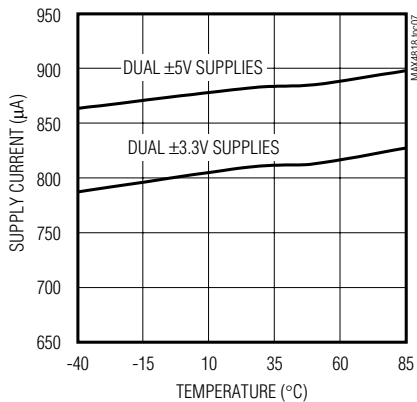
**SUPPLY CURRENT vs. SUPPLY VOLTAGE**



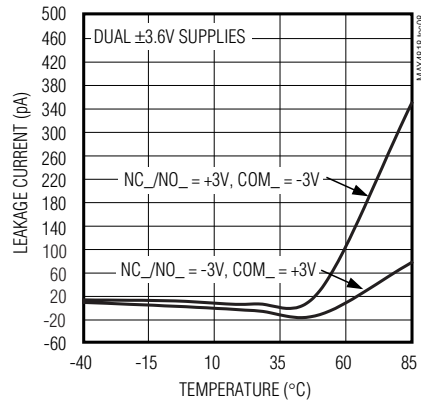
**MAX4818 SUPPLY CURRENT  
vs. TEMPERATURE**



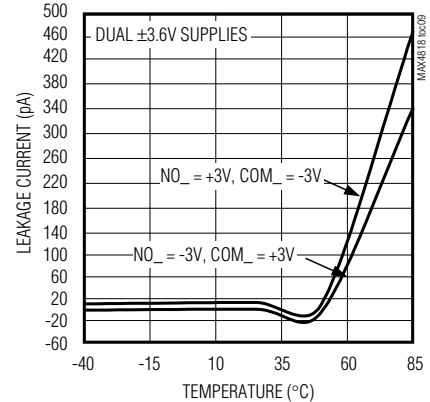
**MAX4819 SUPPLY CURRENT  
vs. TEMPERATURE**



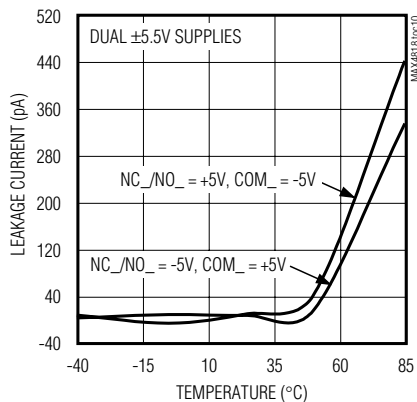
**MAX4818 NC/NO(OFF) LEAKAGE  
CURRENT vs. TEMPERATURE**



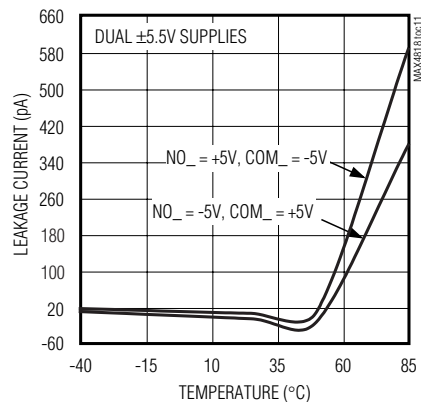
**MAX4819 NO(OFF) LEAKAGE  
CURRENT vs. TEMPERATURE**



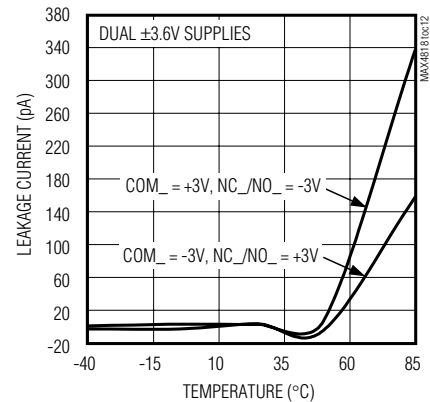
**MAX4818 NC/NO(OFF) LEAKAGE  
CURRENT vs. TEMPERATURE**



**MAX4819 NO(OFF) LEAKAGE  
CURRENT vs. TEMPERATURE**



**MAX4818 COM(OFF) LEAKAGE  
CURRENT vs. TEMPERATURE**

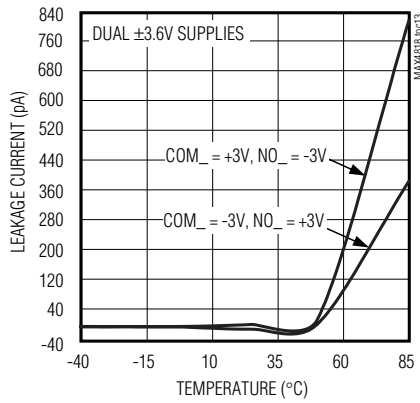


# High-Bandwidth T1/E1 Dual-SPDT Switches/ 4:1 Muxes

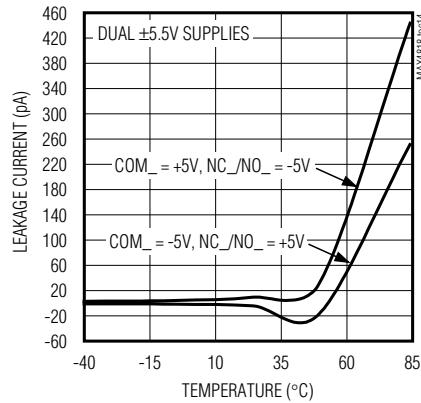
## Typical Operating Characteristics (continued)

(V+ = +3.3V, V- = -3.3V, T<sub>A</sub> = +25°C, unless otherwise noted.)

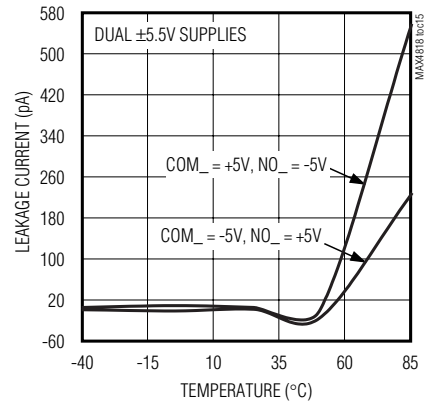
**MAX4819 COM(OFF) LEAKAGE  
CURRENT vs. TEMPERATURE**



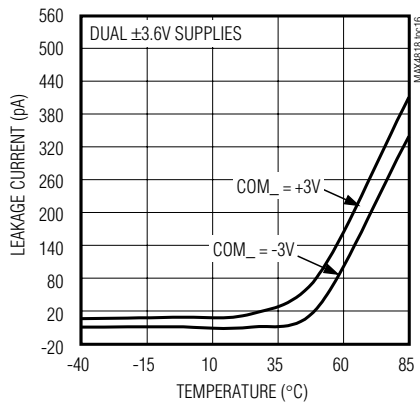
**MAX4818 COM(OFF) LEAKAGE  
CURRENT vs. TEMPERATURE**



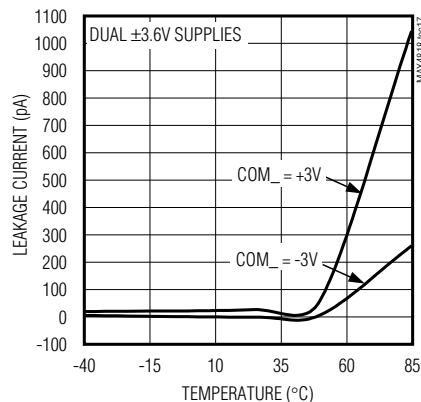
**MAX4819 COM(OFF) LEAKAGE  
CURRENT vs. TEMPERATURE**



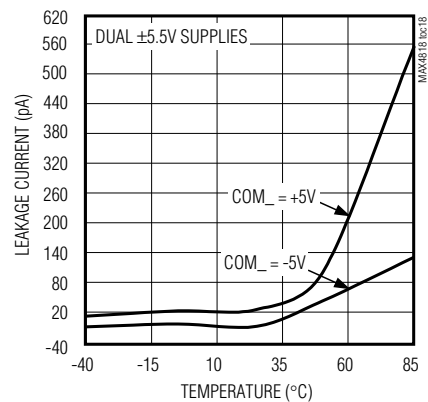
**MAX4818 COM(ON) LEAKAGE  
CURRENT vs. TEMPERATURE**



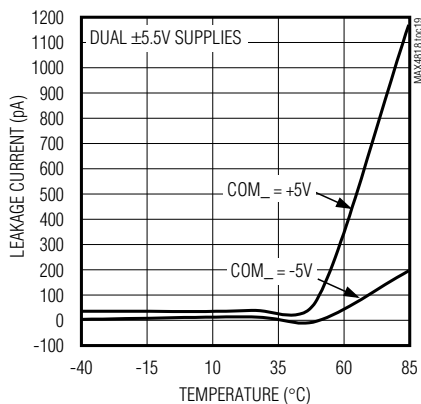
**MAX4819 COM(ON) LEAKAGE  
CURRENT vs. TEMPERATURE**



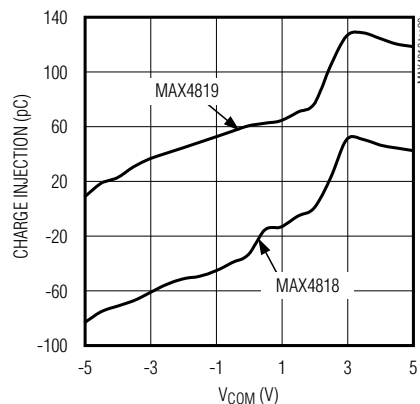
**MAX4818 COM(ON) LEAKAGE  
CURRENT vs. TEMPERATURE**



**MAX4819 COM(ON) LEAKAGE  
CURRENT vs. TEMPERATURE**



**CHARGE INJECTION  
vs. COMMON VOLTAGE**

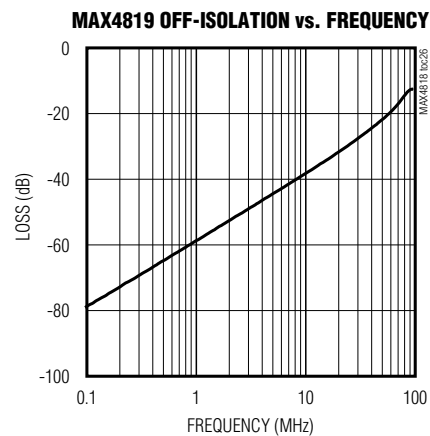
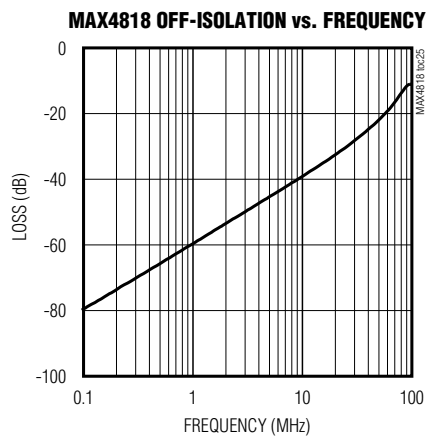
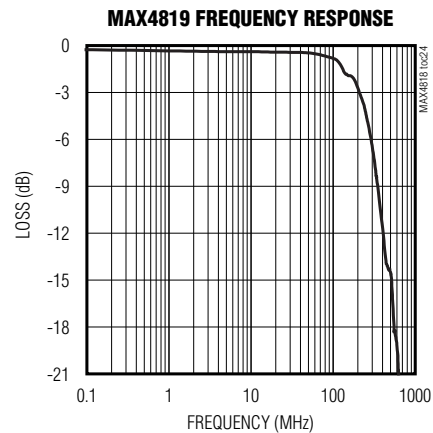
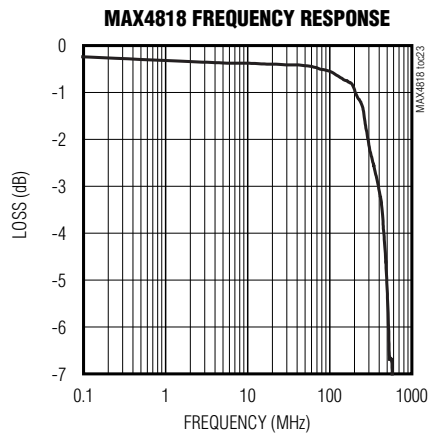
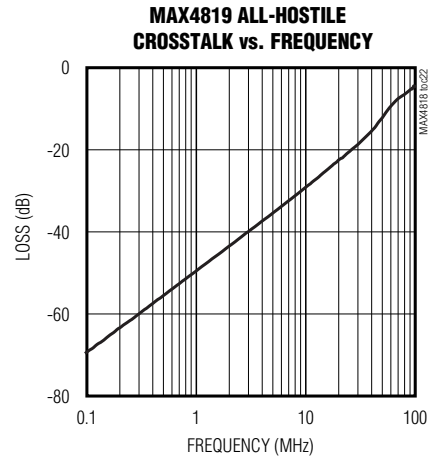
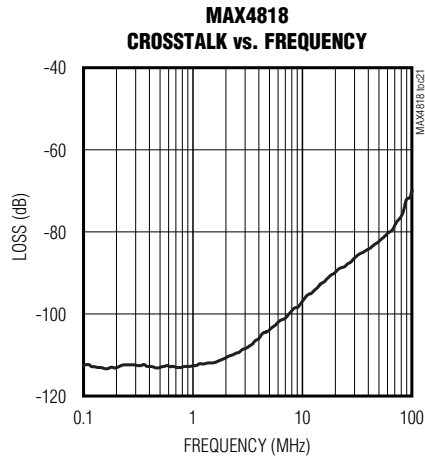




# High-Bandwidth T1/E1 Dual-SPDT Switches/ 4:1 Muxes

## Typical Operating Characteristics (continued)

(V+ = +3.3V, V- = -3.3V, T<sub>A</sub> = +25°C, unless otherwise noted.)



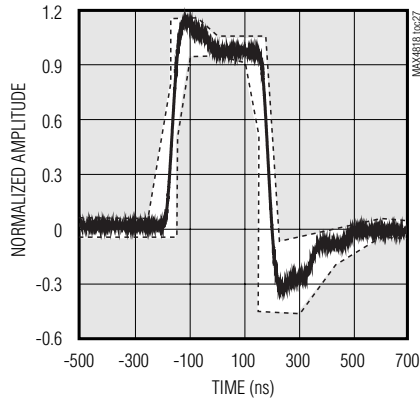
**MAX4818/MAX4819**

# High-Bandwidth T1/E1 Dual-SPDT Switches/ 4:1 Muxes

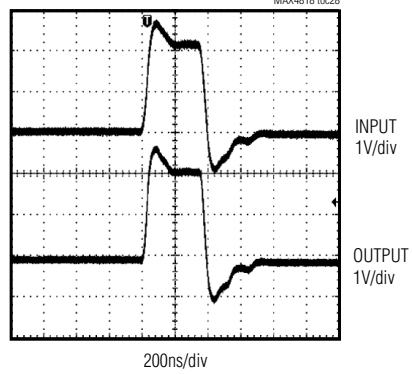
## Typical Operating Characteristics (continued)

(V+ = +3.3V, V- = -3.3V, T<sub>A</sub> = +25°C, unless otherwise noted.)

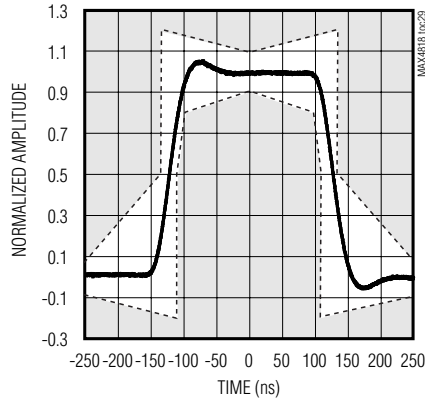
**T1 (100Ω) PULSE TEMPLATE TEST**



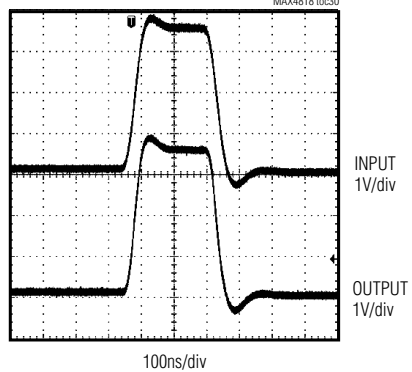
**T1 (100Ω) SCOPE SHOT OF THE  
INPUT AND OUTPUT OF DEVICE**



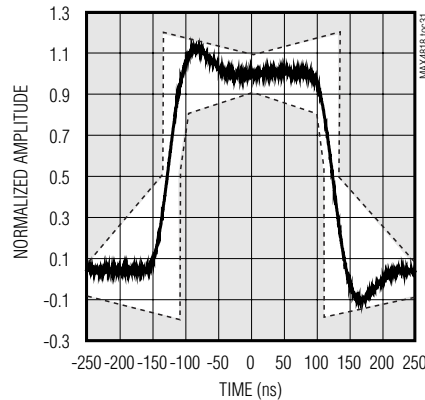
**E1 (120Ω) PULSE TEMPLATE TEST**



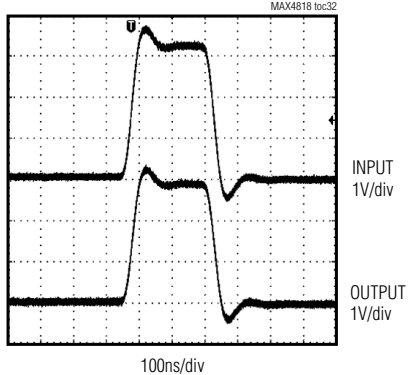
**T1 (120Ω) SCOPE SHOT OF THE  
INPUT AND OUTPUT OF DEVICE**



**E1 (75Ω) PULSE TEMPLATE TEST**



**E1 (75Ω) SCOPE SHOT OF THE  
INPUT AND OUTPUT OF DEVICE**



# High-Bandwidth T1/E1 Dual-SPDT Switches/ 4:1 Muxes

## Pin Description

| PIN       |              | NAME | FUNCTION   |
|-----------|--------------|------|--|
| MAX4818   | MAX4819      |      |  |
| 1         | 1            | NO1  | Analog Multiplexer Normally Open Terminal 1  |
| 2         | 2            | V-   | Negative Supply Voltage. Bypass V- to ground with a 0.1μF ceramic capacitor.                                       |
| 3         | 3            | GND  | Ground   |
| 4         | 12           | NO2  | Analog Multiplexer Normally Open Terminal 2  |
| 5, 10, 16 | 5, 8, 10, 16 | N.C. | No Connect. Not Internally Connected.  |
| 6         | 6            | EN   | Enable Input. Connect EN to V+ or a logic-high for normal operation. Connect EN to ground to disable all switches. |
| 7         | —            | IN2  | Switch 2 Logic-Level Input (See Table 1)   |
| 8         | —            | COM2 | Analog Switch Common Terminal 2  |
| 9         | —            | NC2  | Analog Switch Normally Close Terminal 2  |
| 11        | 11           | V+   | Positive Supply Voltage. Bypass V+ to ground with a 0.1μF ceramic capacitor.                                       |
| 12        | —            | NC1  | Analog Switch Normally Close Terminal 1  |
| 13        | —            | COM1 | Analog Switch Common Terminal 1  |
| 14        | —            | IN1  | Switch 1 Logic-Level Input (See Table 1)   |
| 15        | 15           | SET  | Logic Input. Drive SET logic-high to set all switches. (See Tables 1, 2)   |
| —         | 4            | NO4  | Analog Multiplexer Normally Open Terminal 4  |
| —         | 7            | A0   | Multiplexer Address Input 0 (See Table 2)  |
| —         | 9            | NO3  | Analog Multiplexer Normally Open Terminal 3  |
| —         | 13           | COM  | Analog Multiplexer Common Terminal   |
| —         | 14           | A1   | Multiplexer Address Input 1 (See Table 2)  |
| EP        | EP           | EP   | Exposed Paddle. Connect exposed paddle to V- or leave unconnected.   |

## Detailed Description

The MAX4818/MAX4819 are each a high-bandwidth, low-on-resistance dual-SPDT analog switch/4:1 multiplexer, respectively. Both the MAX4818 and the MAX4819 are designed to serve as integrated T1/E1 analog protection switches for 1+1 and N+1 line-card redundancy applications. These devices replace electromechanical relays to save board space, reduce power consumption, and simplify PC board routing. The MAX4818/ MAX4819 allow the user to live insert the boards with no adverse effects.

The MAX4818/MAX4819 operate from  $\pm 3.3\text{V}$  or  $\pm 5\text{V}$  dual supplies, which are required for E1/T1 signal switching in the line-side of the interface transformer. Internal voltage multipliers supply the switches yielding excellent linearity and low on-resistance, typically  $4\Omega$  within the E1/T1 analog signal range. This high-bandwidth family of devices is optimized for low return loss

and matched pulse template performance in E1/T1 short-haul and long-haul applications.

### Logic Inputs

The MAX4818 has four digital control inputs: EN, SET, IN1, and IN2. The EN input enables the switches. A logic 1 on SET connects COM to the NO\_ terminal. IN\_ controls the switch when SET is low, as shown in Table 1.

The MAX4819 has four digital control inputs: EN, SET, A1, and A0. The EN input enables the multiplexer. A logic 1 on SET connects all NO\_ to COM. A1 and A0 control which terminal will be connected to COM when SET is low, as shown in Table 2.

### Analog Signal Levels

The on-resistance of the MAX4818/MAX4819 is very low and stable as the analog signals are swept from V- to V+ (see the *Typical Operating Characteristics*).

# High-Bandwidth T1/E1 Dual-SPDT Switches/ 4:1 Muxes

## Fault Protection

The fault protection of the MAX4818/MAX4819 allows the devices to handle input signals of more than twice the supply voltage without clamping the signal, latching up, or disturbing other cards in the system. The device detects when the input voltage drops below the negative supply. As soon as a fault condition is detected, the switch is immediately turned off for 128 clock cycles (typically 128 $\mu$ s). At the end of the 128 $\mu$ s time-out, the switch is turned back on for one clock cycle. At the end of the one clock cycle, if the signal is within the operating range, the switch will remain on. Otherwise, the device will turn the switch off again for 128 clock cycles. This will repeat until the signal is within the operating range. In T1/E1 redundancy applications, this can happen when the load resistor (RL) is removed or disconnected for any reason, as shown in Figure 1. Without a load resistor, the output voltage when using a 1:2 transformer can be as high as  $\pm 11V$ .

## Applications Information

### T1/E1 N+1 Redundancy

Figures 6, 7, and 8 show a basic architecture for twisted-pair interface (120 $\Omega$ , E1 or 100 $\Omega$ , T1). Coaxial cable interface (75 $\Omega$ , E1) can be illustrated with the same figures but without the single-ended to differential conversion stage. A single protection card can replace up to N line cards in a N+1 redundancy scheme. Figure 6 shows the switches sitting in the line cards where they can reroute any of the input/output signals to a protection line card. Figure 7 shows a “multiplexed” redundancy architecture using the MAX4819 where the multiplexers are in the line cards. This architecture is more scalable as the number of boards is increased. It also does not require a dedicated external switching card as the multiplexers reside in the line cards themselves. The number of signals routed through the back-plane is substantially higher than in the switching-card architecture. Figure 8 shows a similar architecture, but the multiplexers reside in the protection switching card. These figures do not show the surge-protection elements and resistors for line termination/impedance matching.

The low on-resistance and high-bandwidth of the MAX4818/MAX4819 yield good pulse template and return-loss performance (see the *Typical Operating Characteristics*). The pulse template tests for E1 (twisted-pair interface 120 $\Omega$  and coaxial interface 75 $\Omega$ ) and T1 (twisted-pair interface 100 $\Omega$ ) were tested using the Dallas DS2155 single-chip-transceiver evaluation board, and twelve switches in parallel with one switch closed and the other eleven open. The internal transmit termination feature must be disable when using this circuit. In order to use the same transmit resistors for E1

**Table 1. Dual SPDT Truth Table (MAX4818)**

| EN | SET | IN <sub>-</sub> | COM <sub>-</sub> CONNECTION |
|----|-----|-----------------|-----------------------------|
| 0  | X   | X               | NONE                        |
| 1  | 0   | 0               | NC <sub>-</sub>             |
| 1  | 0   | 1               | NO <sub>-</sub>             |
| 1  | 1   | X               | NO <sub>-</sub>             |

(X = don't care.)

**Table 2. 4:1 Multiplexer Truth Table (MAX4819)**

| EN | SET | A1 | A0 | COM CONNECTION     |
|----|-----|----|----|--------------------|
| 0  | X   | X  | X  | NONE               |
| 1  | 0   | 0  | 0  | NO1                |
| 1  | 0   | 0  | 1  | NO2                |
| 1  | 0   | 1  | 0  | NO3                |
| 1  | 0   | 1  | 1  | NO4                |
| 1  | 1   | X  | X  | NO1, NO2, NO3, NO4 |

(X = don't care.)

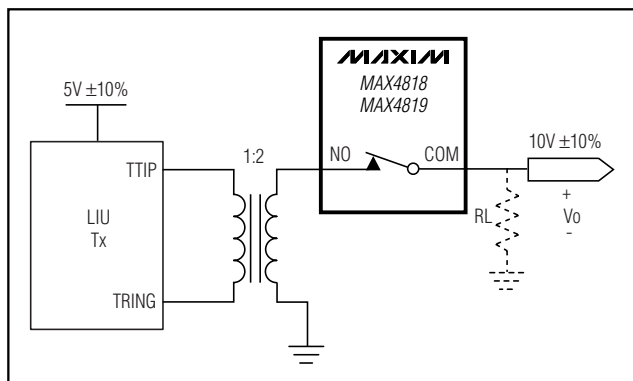


Figure 1. Fault Protection

twisted-pair and coaxial cables, the Transmit Line Buildout Control Register (TLBC) is set to the value 6Ah. This sets the driver voltage so the output pulse has the right amplitude for both 120 $\Omega$  (twisted pair) and 75 $\Omega$  (coaxial) loads. The analog switches were powered with dual power supplies at  $\pm 5V$ .

# High-Bandwidth T1/E1 Dual-SPDT Switches/ 4:1 Muxes

## Test Circuits/Timing Diagrams

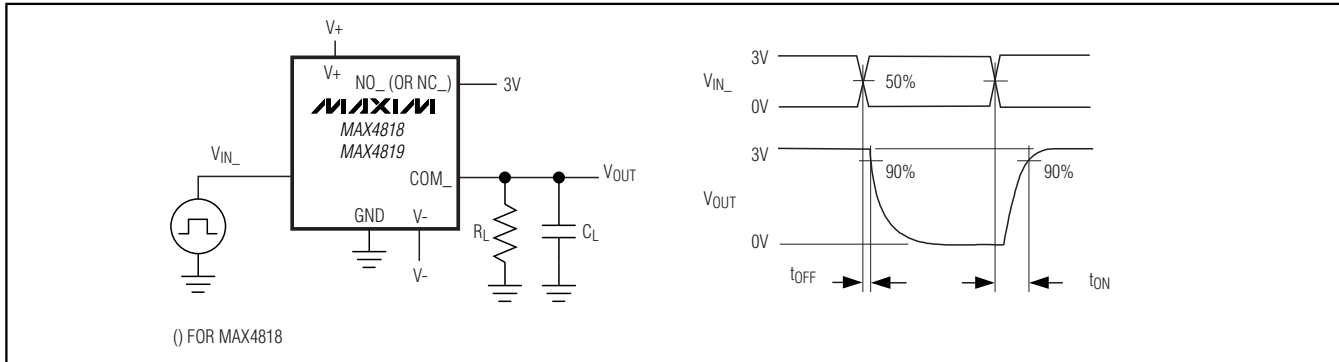


Figure 2. Switch Turn-On/Turn-Off Times

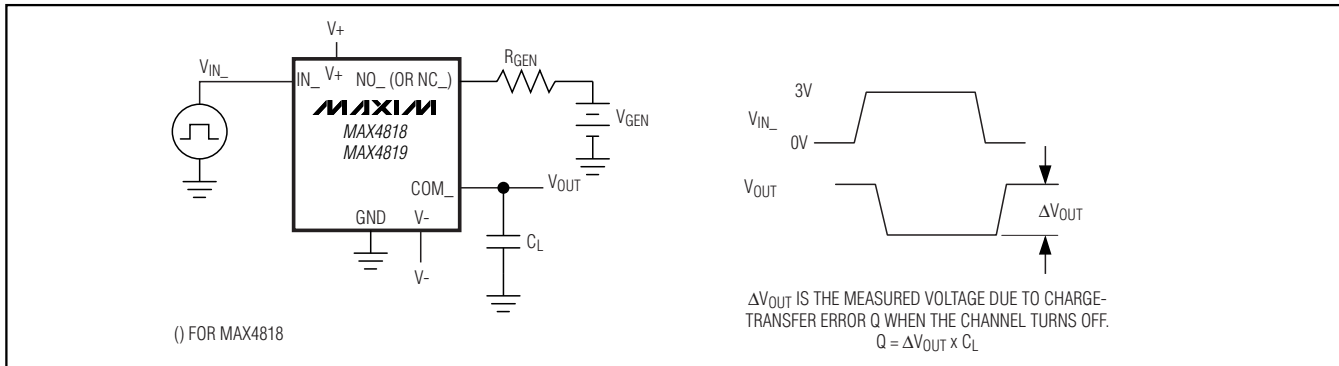


Figure 3. Charge Injection

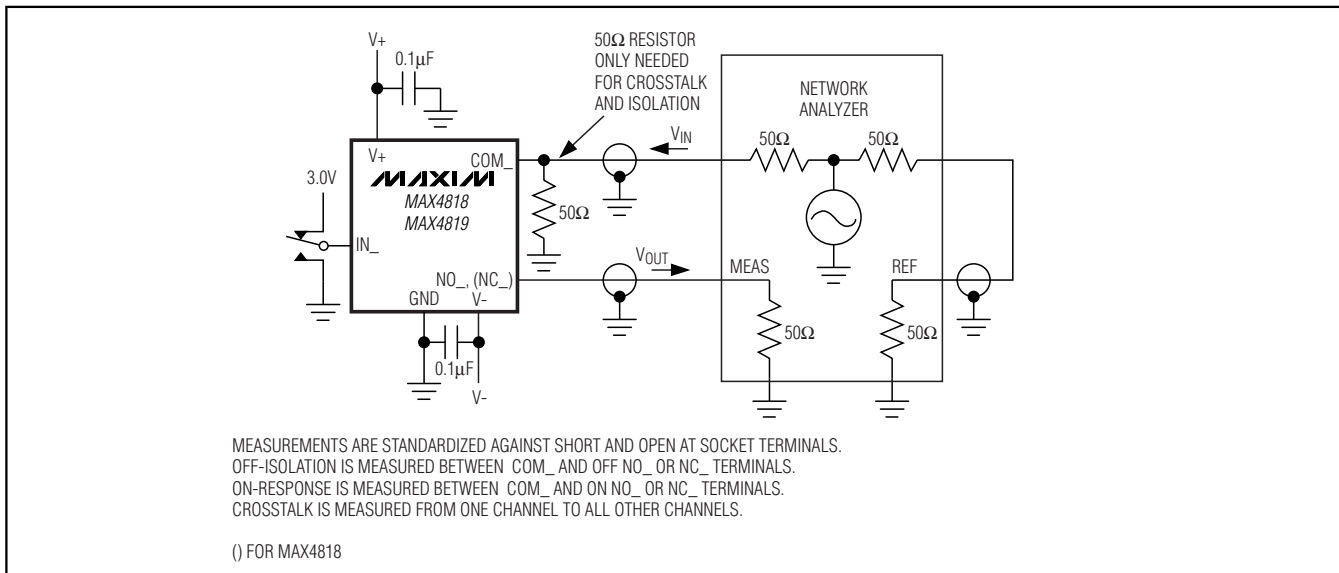


Figure 4. On-Loss, Off-Isolation, and Crosstalk

# High-Bandwidth T1/E1 Dual-SPDT Switches/ 4:1 Muxes

## Test Circuits/Timing Diagrams (continued)

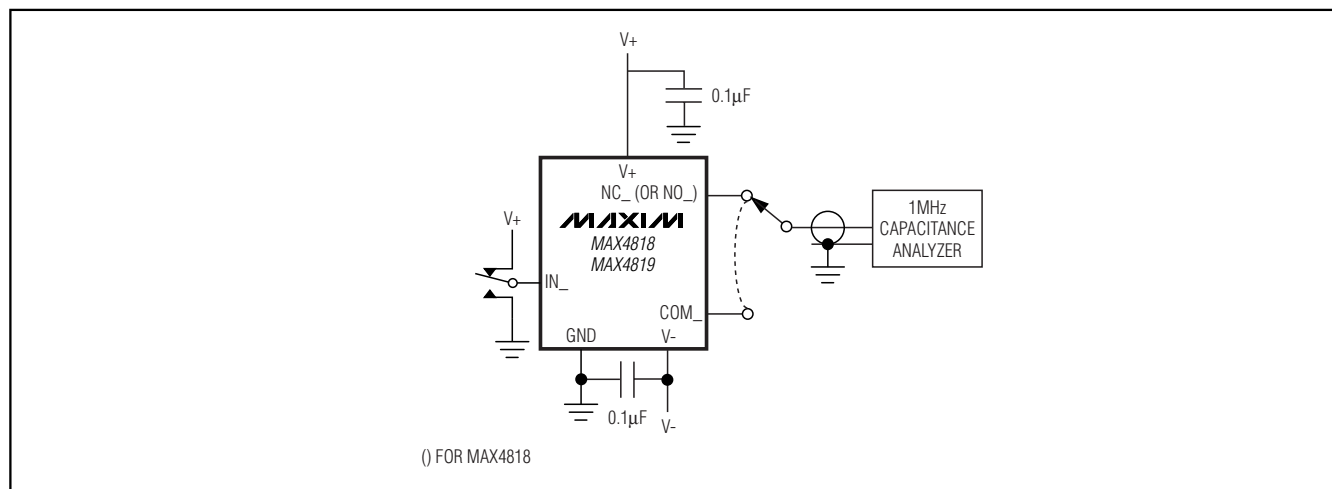


Figure 5. Channel Off-/On-Capacitance

# High-Bandwidth T1/E1 Dual-SPDT Switches/ 4:1 Muxes

MAX4818/MAX4819

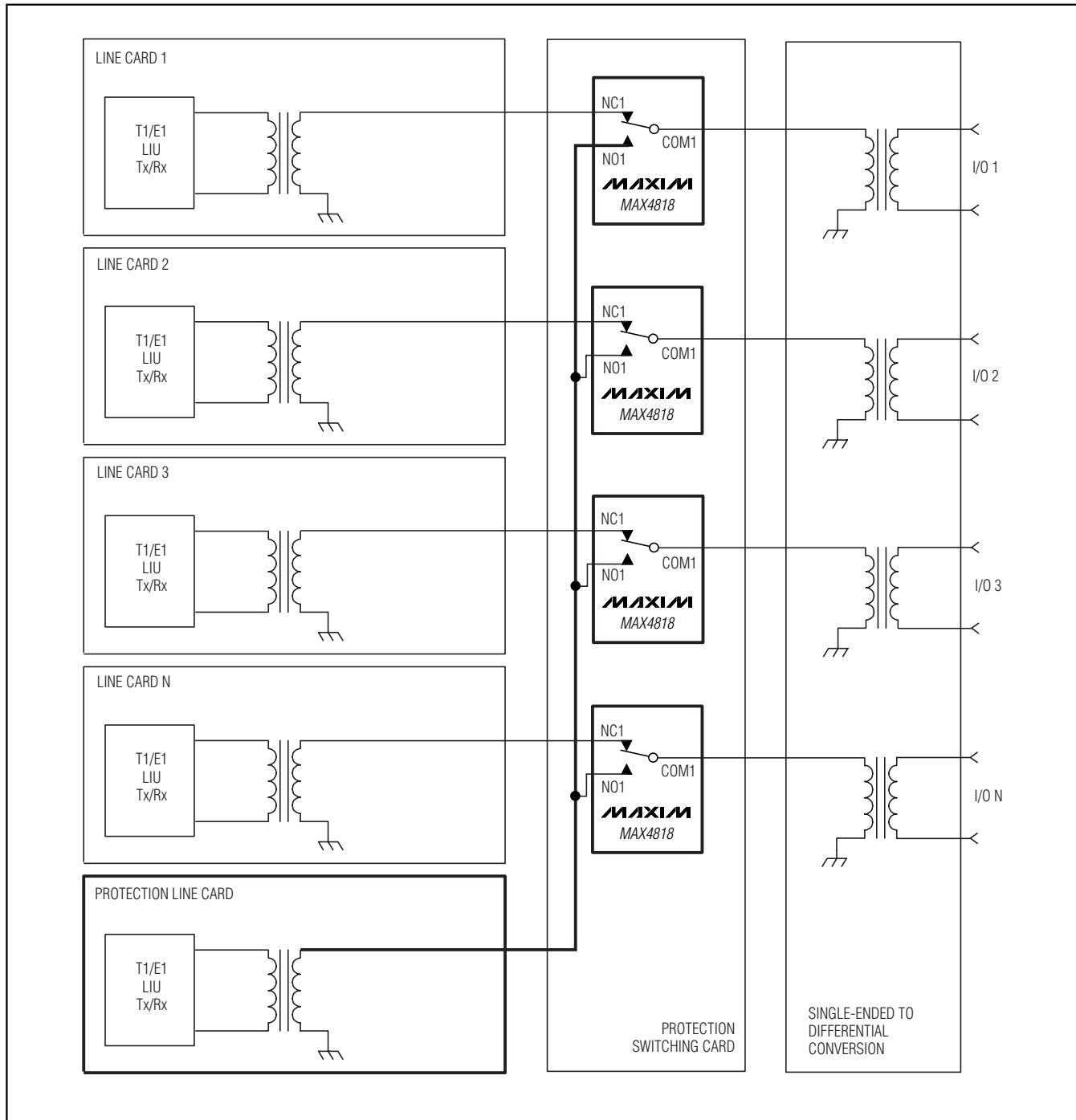


Figure 6. Switch Architecture for Twisted-Pair Cable ( $120\Omega$ , E1 or  $100\Omega$ , T1). Same figure for Coaxial Cable ( $75\Omega$ , E1) without the single-ended-to-differential conversion.

# High-Bandwidth T1/E1 Dual-SPDT Switches/ 4:1 Muxes

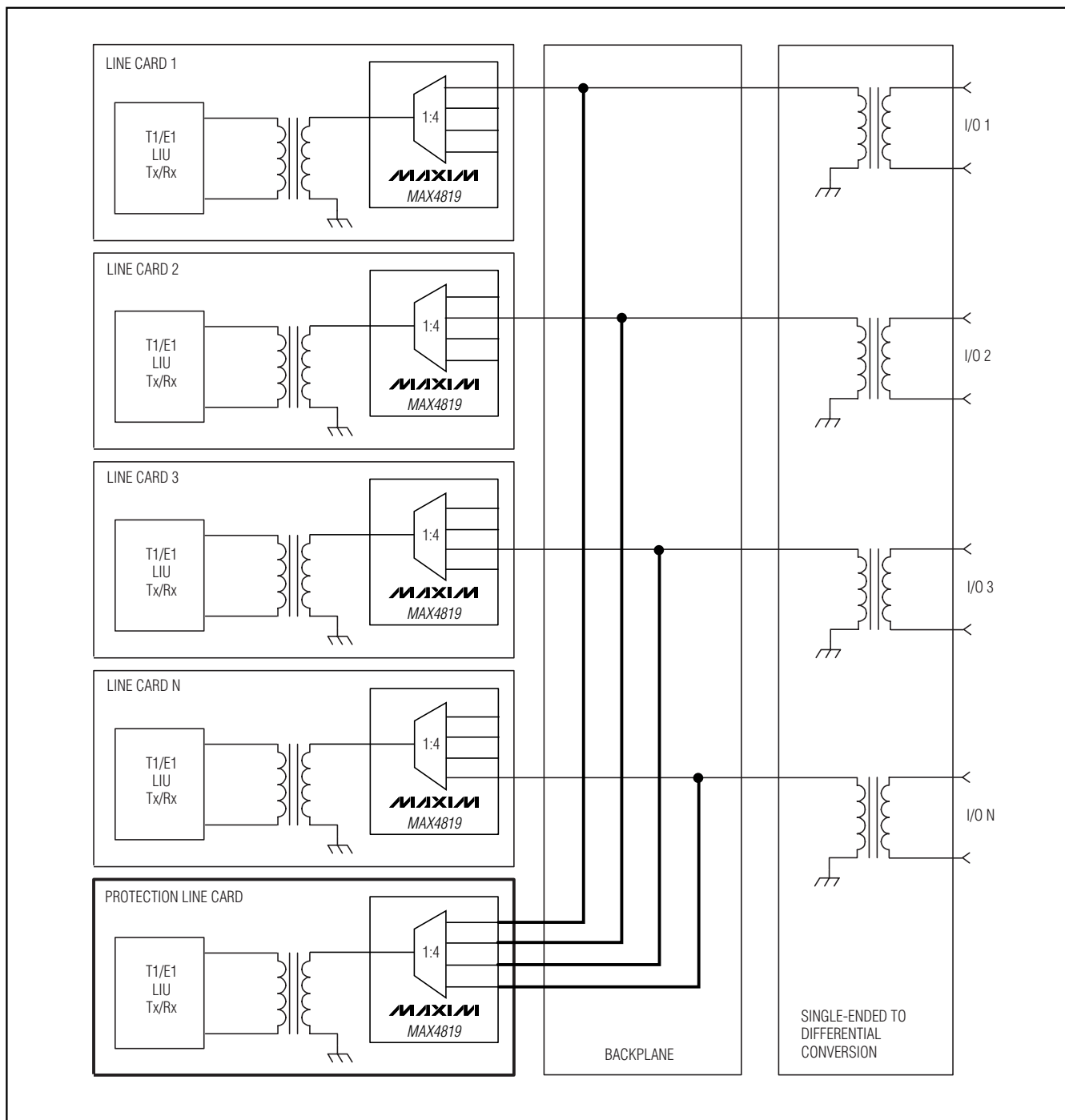


Figure 7. Multiplexed Redundancy Architecture with Multiplexer in the Line Cards for Twisted-Pair Cable (120Ω, E1 or 100Ω, T1). Same figure for coaxial cable (75Ω, E1) without the single-ended-to-differential conversion.



# High-Bandwidth T1/E1 Dual-SPDT Switches/ 4:1 Muxes

**MAX4818/MAX4819**

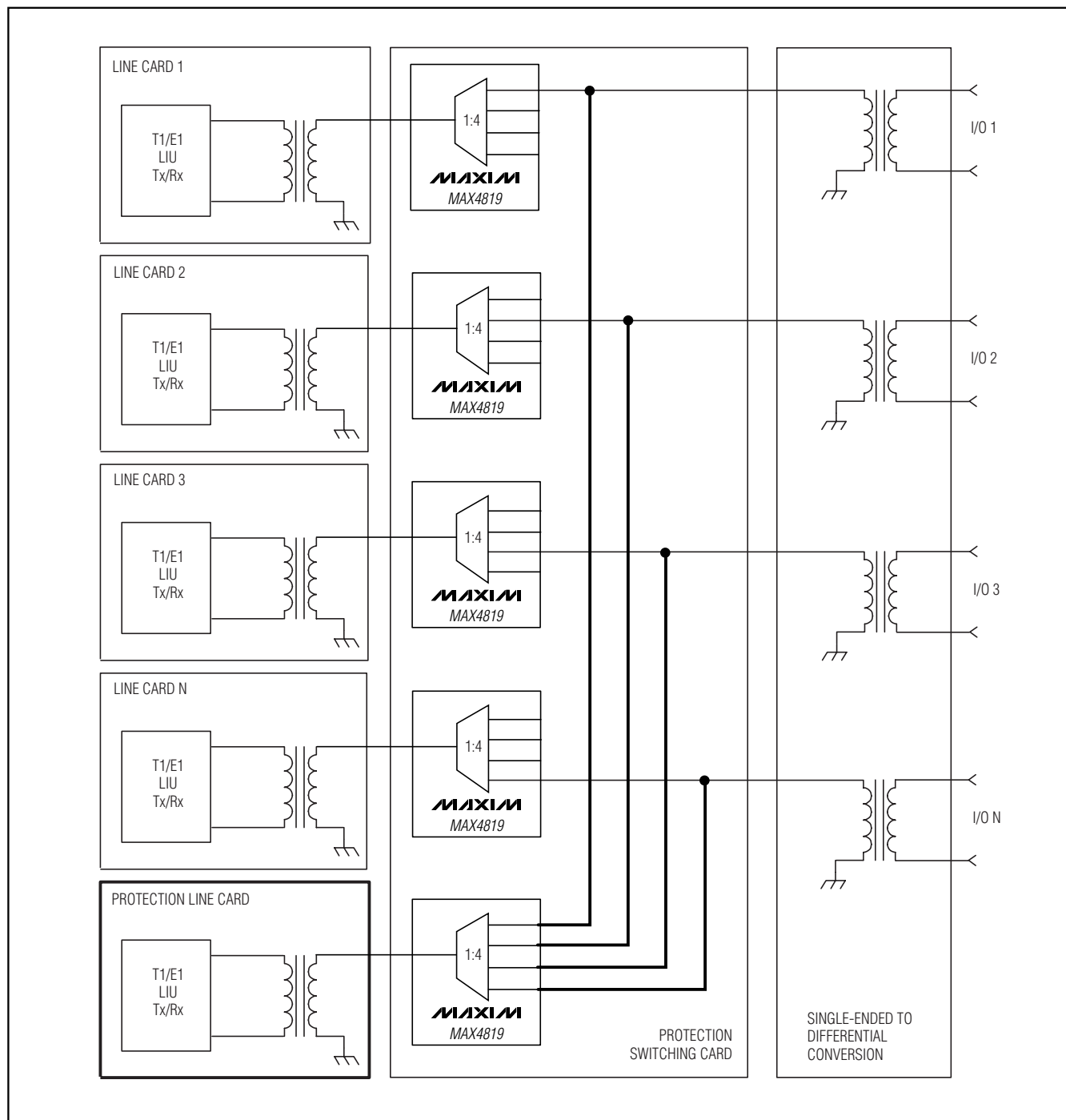
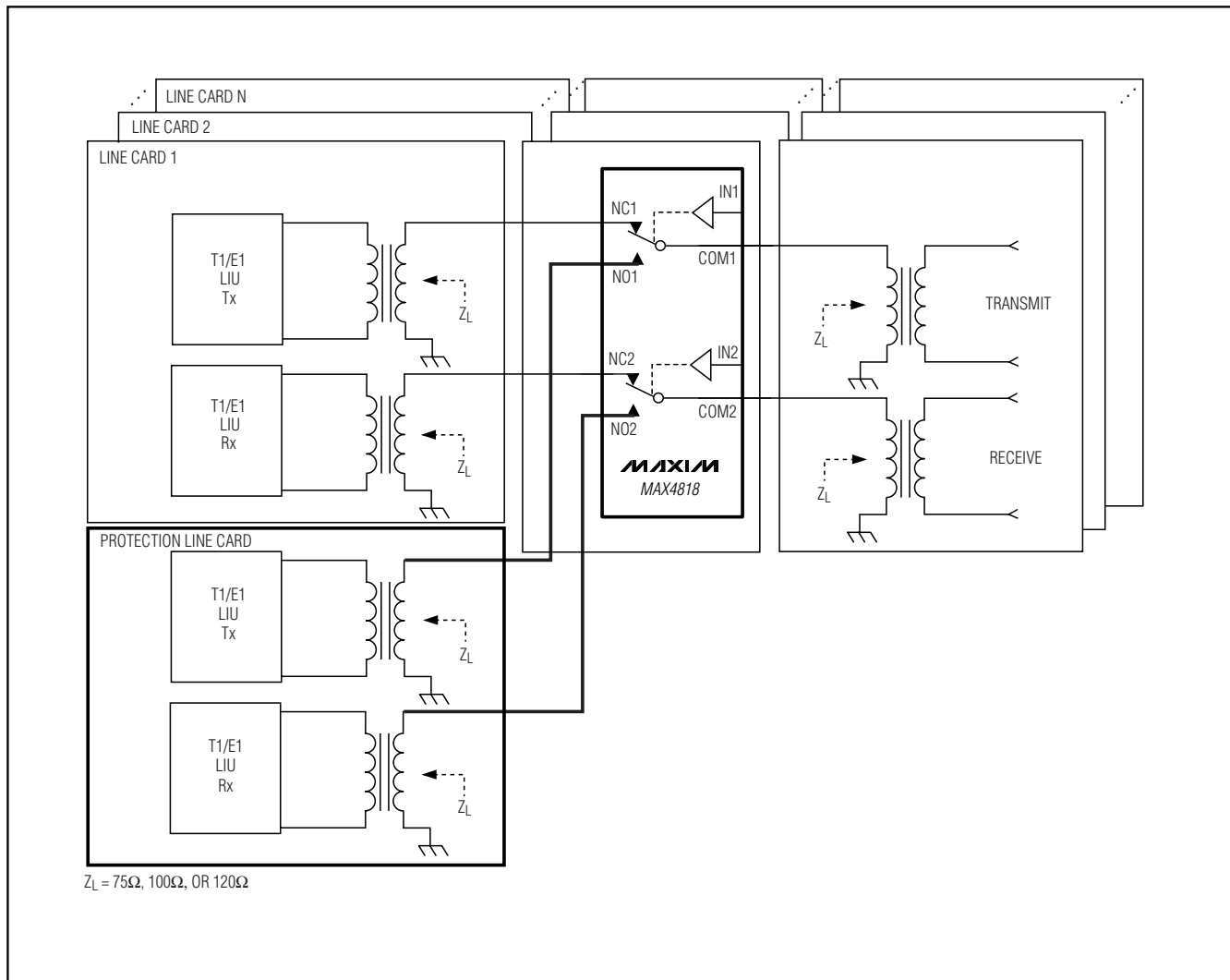


Figure 8. Multiplexed Redundancy Architecture with Multiplexer Out of the Line Cards for Twisted-Pair Cable ( $120\Omega$ , E1 or  $100\Omega$ , T1). Same figure for coaxial cable ( $75\Omega$ , E1) without the single-ended-to-differential conversion.

# High-Bandwidth T1/E1 Dual-SPDT Switches/ 4:1 Muxes

## Typical Operating Circuits

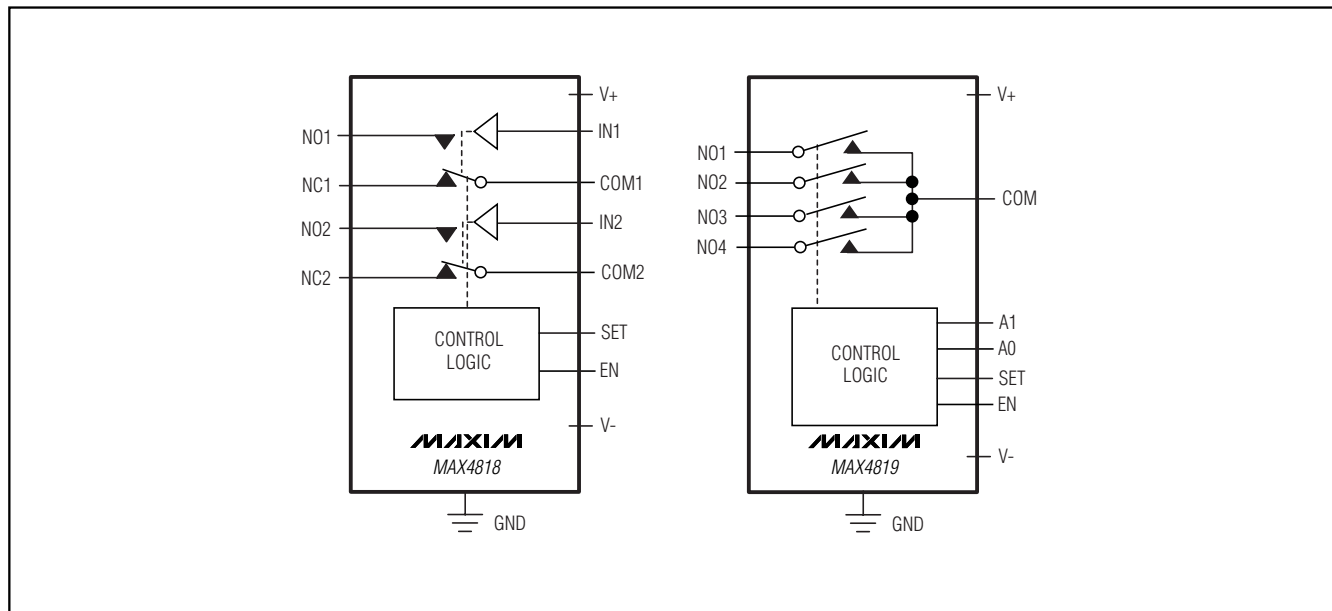


**MAX4818/MAX4819**

The diagram illustrates a 4-line card architecture. It consists of three line cards (LINE CARD N, LINE CARD 2, LINE CARD 1) and a PROTECTION LINE CARD, all connected to a central BACKPLANE. Each line card contains two T1/E1 LIU (Tx/Rx) blocks. The BACKPLANE contains three MAX4819 transceivers. The diagram shows the connection of the LIU blocks to the transceivers and the backplane, including the use of  $Z_L$  (75Ω, 100Ω, or 120Ω) terminators.

# High-Bandwidth T1/E1 Dual-SPDT Switches/ 4:1 Muxes

## Functional Diagram

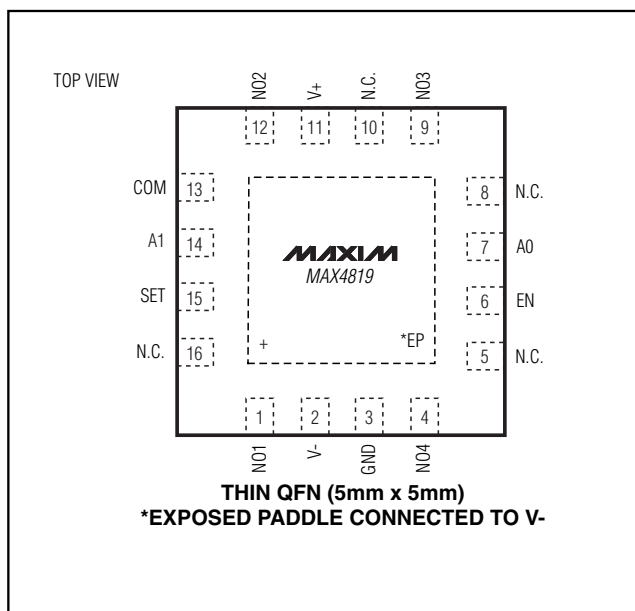


## Chip Information

PROCESS: BiCMOS

CONNECT EXPOSED PADDLE TO V-.

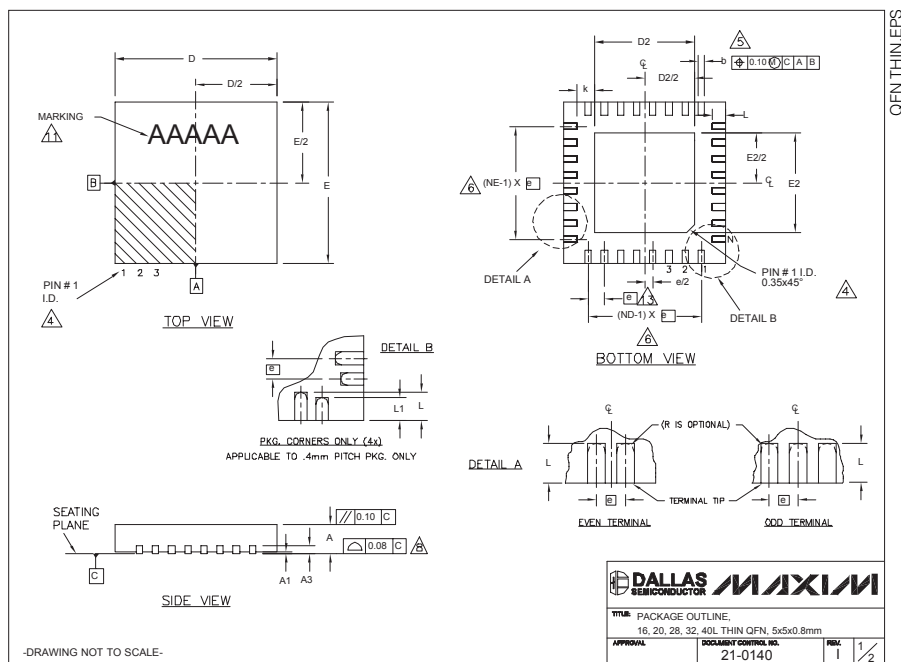
## Pin Configurations (continued)



# High-Bandwidth T1/E1 Dual-SPDT Switches/ 4:1 Muxes

## 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](http://www.maxim-ic.com/packages).)



| COMMON DIMENSIONS |           |      |      |           |      |      |           |      |      |           |      |      |           |      |      |
|-------------------|-----------|------|------|-----------|------|------|-----------|------|------|-----------|------|------|-----------|------|------|
| PKG. SYMBOL       | 16L 5x5   |      |      | 20L 5x5   |      |      | 28L 5x5   |      |      | 32L 5x5   |      |      | 40L 5x5   |      |      |
|                   | MIN.      | NOM. | MAX. | MIN.      | NOM. | MAX. | MIN.      | NOM. | MAX. | MIN.      | NOM. | MAX. | MIN.      | NOM. | MAX. |
| A                 | 0.70      | 0.75 | 0.80 | 0.70      | 0.75 | 0.80 | 0.70      | 0.75 | 0.80 | 0.70      | 0.75 | 0.80 | 0.70      | 0.75 | 0.80 |
| A1                | 0         | 0.02 | 0.05 | 0         | 0.02 | 0.05 | 0         | 0.02 | 0.05 | 0         | 0.02 | 0.05 | 0         | 0.02 | 0.05 |
| A3                | 0.20 REF. |      |      | 0.20 REF. |      |      | 0.20 REF. |      |      | 0.20 REF. |      |      | 0.20 REF. |      |      |
| b                 | 0.25      | 0.30 | 0.35 | 0.25      | 0.30 | 0.35 | 0.20      | 0.25 | 0.30 | 0.20      | 0.25 | 0.30 | 0.15      | 0.20 | 0.25 |
| D                 | 4.90      | 5.00 | 5.10 | 4.90      | 5.00 | 5.10 | 4.90      | 5.00 | 5.10 | 4.90      | 5.00 | 5.10 | 4.90      | 5.00 | 5.10 |
| E                 | 4.90      | 5.00 | 5.10 | 4.90      | 5.00 | 5.10 | 4.90      | 5.00 | 5.10 | 4.90      | 5.00 | 5.10 | 4.90      | 5.00 | 5.10 |
| e                 | 0.80 BSC. |      |      | 0.65 BSC. |      |      | 0.50 BSC. |      |      | 0.50 BSC. |      |      | 0.40 BSC. |      |      |
| k                 | 0.25      | -    | -    | 0.25      | -    | -    | 0.25      | -    | -    | 0.25      | -    | -    | 0.25      | 0.35 | 0.45 |
| L                 | 0.30      | 0.40 | 0.50 | 0.45      | 0.55 | 0.65 | 0.45      | 0.55 | 0.65 | 0.30      | 0.40 | 0.50 | 0.40      | 0.50 | 0.60 |
| L1                | -         | -    | -    | -         | -    | -    | -         | -    | -    | -         | -    | -    | 0.30      | 0.40 | 0.50 |
| N                 | 16        |      |      | 20        |      |      | 28        |      |      | 32        |      |      | 40        |      |      |
| ND                | 4         |      |      | 5         |      |      | 7         |      |      | 8         |      |      | 10        |      |      |
| NE                | 4         |      |      | 5         |      |      | 7         |      |      | 8         |      |      | 10        |      |      |
| JEDEC             | WHHB      |      |      | WHHC      |      |      | WHHD-1    |      |      | WHHD-2    |      |      | -----     |      |      |

NOTES:

1. DIMENSIONING & TOLERANCING CONFORM TO ASME Y14.5M-1994.

2. ALL DIMENSIONS ARE IN MILLIMETERS; ANGLES ARE IN DEGREES.

3. N IS THE TOTAL NUMBER OF TERMINALS.

4. THE TERMINAL #1 IDENTIFIER AND TERMINAL NUMBERING CONVENTION SHALL CONFORM TO JEDEC 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.

5. DIMENSION b APPLIES TO METALLIZED TERMINAL AND IS MEASURED BETWEEN 0.25 mm AND 0.30 mm FROM TERMINAL TIP.

6. ND AND NE REFER TO THE NUMBER OF TERMINALS ON EACH D AND E SIDE RESPECTIVELY.

7. DEPOPULATION IS POSSIBLE IN A SYMMETRICAL FASHION.

8. COPLANARITY APPLIES TO THE EXPOSED HEAT SINK SLUG AS WELL AS THE TERMINALS.

9. DRAWING CONFORMS TO JEDEC MO220, EXCEPT EXPOSED PAD DIMENSION FOR T2855-3 AND T2855-6.

10. WARPAGE SHALL NOT EXCEED 0.10 mm.

11. MARKING IS FOR PACKAGE ORIENTATION REFERENCE ONLY.

12. NUMBER OF LEADS SHOWN ARE FOR REFERENCE ONLY.

13. LEAD CENTERLINES TO BE AT TRUE POSITION AS DEFINED BY BASIC DIMENSION "e", ±0.05.

DRAWING NOT TO SCALE.

DALLAS  
SEMICONDUCTOR

MAXIM

TEMP. PACKAGE OUTLINE,  
16, 20, 28, 32, 40L THIN QFN, 5x5x0.8mm

21-0140

APPROVAL

DOCUMENT CONTROL

REV. 1

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