# MAX14778

# Dual ±25V Above- and Below-the-Rails 4:1 Analog Multiplexer

## General Description

The MAX14778 dual 4:1 analog multiplexer supports analog signals up to ±25V with a single 3.0 to 5.5V supply. Each multiplexer has separate control inputs to allow independent switching, making the device ideal for multiplexing different communications signals with the same connector pins. Extended ESD protection of ±6kV (Human Body Model) enable direct interfacing to cables and connectors.

The MAX14778 features a low 1.5Ω (max) on-resistance and 3mΩ (typ) flatness to maximize signal integrity over the entire common-mode voltage range. Each multiplexer can carry up to 300mA of continuous current through the multiplexer in either direction.

The MAX14778 supports switching of full-speed USB 1.1 signals (12Mbps) and RS-485 data rates of up to 20Mbps.

The MAX14778 is available in a 20-pin (5mm x 5mm) TQFN package and is specified over the -40°C to +85°C extended temperature range.

## Applications

RS-485/RS-232/USB 1.1 Multiplexing

POS Peripherals

Handheld Industrial Devices

Communication Systems

Audio/Data Multiplexing

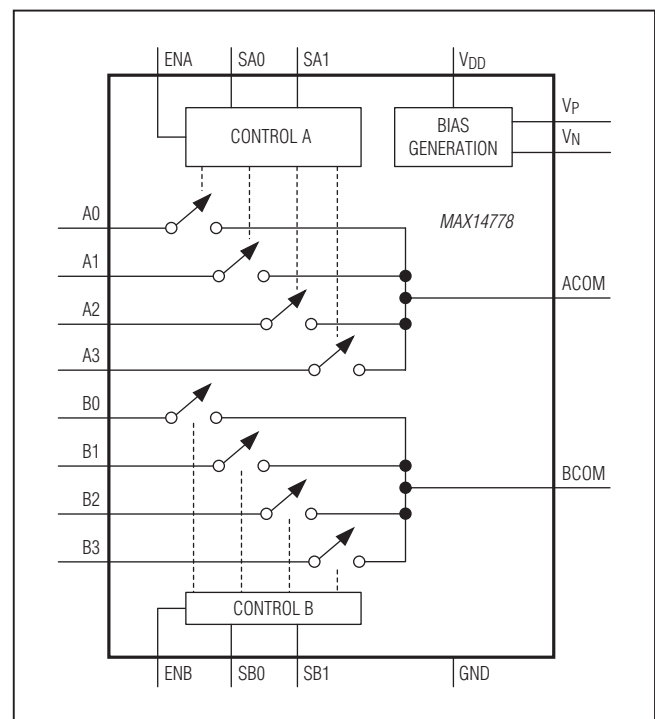Connector Sharing

Gaming Machines

## Features

♦ **±25V Signal Range**

♦ **Single 3.0V to 5.5V Supply**

♦ **Two Independent Multiplexers**

♦ **1.5Ω $R_{ON}$ (max)**

♦ **3mΩ $R_{ON}$ Flatness (typ)**

♦ **300mA Maximum Current Through Multiplexer**

♦ **78pF Input Capacitance**

♦ **75MHz Large-Signal Bandwidth**

♦ **Break-Before-Make Operation**

♦ **Extended ESD Protection on A_ and B_ Pins**
  ✧ **±6kV Human Body Model (HBM)**

*Ordering Information* **appears at end of data sheet.**

*For related parts and recommended products to use with this part, refer to* **www.maximintegrated.com/MAX14778.related**.

## Functional Diagram



**For pricing, delivery, and ordering information, please contact Maxim Direct at 1-888-629-4642, or visit Maxim Integrated's website at www.maximintegrated.com.**

*19-5929; Rev 1; 6/12*

# Dual ±25V Above- and Below-the-Rails 4:1 Analog Multiplexer

## ABSOLUTE MAXIMUM RATINGS

(All voltages referenced to GND.)

$V_{DD}$ ..........................................................-0.3V to +6V
$V_P$ ...........................-0.3V to the lesser of +52V and ($V_N$ + 70V)
$V_N$ ...............The lesser of ($V_{DD}$ - 40V) and ($V_P$ - 70V) to +0.3V
$V_P$ to $V_N$................................................-0.3V to +70V
ENA, ENB, SA_, SB_ ............................... -0.3V to ($V_{DD}$ + 0.3V)
A_, ACOM, B_,
  BCOM .. ($V_N$ - 0.3V) to the lesser of ($V_P$ + 0.3V) and ($V_N$ + 52V)

Continuous Current Through Switch ............................. ±500mA
Continuous Power Dissipation ($T_A$ = +70°C)
  TQFN (derate 33.3mW/°C above +70°C)..............2666.7mW
Operating Temperature Range ......................... -40°C to +85°C
Junction Temperature ....................................................+150°C
Storage Temperature Range........................... -65°C to +150°C
Lead Temperature (soldering, 10s) .............................+300°C
Soldering Temperature (reflow) .......................................+260°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.*

## PACKAGE THERMAL CHARACTERISTICS (Note 1)

TQFN
  Junction-to-Ambient Thermal Resistance ($\theta_{JA}$) ..........30°C/W
  Junction-to-Case Thermal Resistance ($\theta_{JC}$) .................2°C/W

**Note 1:** Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to **www.maximintegrated.com/thermal-tutorial**.

## ELECTRICAL CHARACTERISTICS

($V_{DD}$ = 3.0V to 5.5V, $T_A$ = -40°C to +85°C, unless otherwise noted. Typical values are at $V_{DD}$ = 5V, $T_A$ = +25°C.) (Note 2)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| **DC CHARACTERISTICS** | | | | | | | |
| Supply Voltage Range | $V_{DD}$ | | | 3.0 | | 5.5 | V |
| Supply Current | $I_{DD}$ | ENA = ENB = high | $V_{DD} \leq V_{DDTH}$ | | 4.27 | 10 | mA |
| | | | $V_{DD} > V_{DDTH}$ | | 2.54 | 6 | |
| | | $V_{ENA} = V_{ENB} = V_{DD}/2$ | $V_{DD} \leq V_{DDTH}$ | | 4.31 | 10 | |
| | | | $V_{DD} > V_{DDTH}$ | | 2.59 | 6 | |
| Charge-Pump Threshold | $V_{DDTH}$ | (Note 3) | | | 4.64 | | V |
| Analog Signal Range | $V_{IN}$ | Figure 1, switch open or closed | | -25 | | +25 | V |
| Continuous Current Through Switch | $I_{COM}$ | | | -300 | | +300 | mA |
| On-Resistance | $R_{ON}$ | Figure 1, $I_{COM}$ = ±300mA, $V_{IN}$ = ±25V | | | 0.84 | 1.5 | Ω |
| On-Resistance Flatness | $R_{FLAT(ON)}$ | Figure 1, -25V ≤ $V_{IN}$ ≤ +25V, $I_{COM}$ = ±300mA | | | 3 | | mΩ |
| A_, B_ Off-Leakage Current | $I_{A(OFF)}$, $I_{B(OFF)}$ | Figure 2, $V_{IN}$ = 25V, $V_{OUT}$ = 0V | | -200 | | +200 | nA |
| ACOM, BCOM Off-Leakage Current | $I_{ACOM(OFF)}$, $I_{BCOM(OFF)}$ | Figure 2, $V_{OUT}$ = 15V, $V_{IN}$ = 0V | | -1 | | +1 | µA |
| A_, B_ On-Leakage Current | $I_{A(ON)}$, $I_{B(ON)}$ | Figure 2, $V_{IN}$ = ±25V, ACOM or BCOM is unconnected | | -1 | | +1 | µA |

## ELECTRICAL CHARACTERISTICS (continued)

($V_{DD}$ = 3.0V to 5.5V, $T_A$ = -40°C to +85°C, unless otherwise noted. Typical values are at $V_{DD}$ = 5V, $T_A$ = +25°C.) (Note 2)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| **LOGIC INPUTS (ENA, ENB, SA_, SB_)** | | | | | | |
| Input Logic-Low Voltage | $V_{IL}$ | $V_{DD}$ = 5.5V | | | 0.8 | V |
| | | $V_{DD}$ = 4.5V | | | 0.8 | |
| | | $V_{DD}$ = 3.6V | | | 0.7 | |
| | | $V_{DD}$ = 3.0V | | | 0.7 | |
| Input Logic-High Voltage | $V_{IH}$ | $V_{DD}$ = 5.5V | 2.1 | | | V |
| | | $V_{DD}$ = 4.5V | 2.0 | | | |
| | | $V_{DD}$ = 3.6V | 1.9 | | | |
| | | $V_{DD}$ = 3.0V | 1.7 | | | |
| **AC CHARACTERISTICS** | | | | | | |
| Power-Up Time | $t_{POR}$ | | | 404 | | ms |
| Enable Turn-On Time | $t_{ON}$ | Figure 3, $V_{IN}$ = ±10V, $R_L$ = 10kΩ, $C_L$ = 15pF | | | 2 | ms |
| Enable Turn-Off Time | $t_{OFF}$ | Figure 3, $V_{IN}$ = ±10V, $R_L$ = 10kΩ, $C_L$ = 15pF | | | 1.5 | ms |
| Break-Before-Make Interval | $t_{BBM}$ | Figure 4, $V_{IN}$ = ±10V, $R_L$ = 10kΩ, $C_L$ = 15pF | | 840 | | µs |
| Charge Injection | Q | Figure 5, $V_{A\_}$ = 0V, $C_L$ = 1nF | | 1720 | | pC |
| Off-Isolation | $V_{ISO}$ | Figure 6, $V_{A\_}$ = 1$V_{RMS}$, f = 100kHz, $R_L$ = 50Ω, $C_L$ = 15pF | | -80 | | dB |
| Crosstalk | $V_{CT}$ | Figure 6, f = 100kHz, $R_S$ = $R_L$ = 50Ω | | -103 | | dB |
| -3dB Bandwidth | BW | Figure 6, $R_S$ = 50Ω, $R_L$ = 50Ω | | 75 | | MHz |
| Total Harmonic Distortion Plus Noise | THD+N | $R_S$ = $R_L$ = 1kΩ, f = 20Hz to 20kHz | | 0.003 | | % |
| Input Capacitance | $C_{IN}$ | A_, B_ pins | | 78 | | pF |
| **THERMAL PROTECTION** | | | | | | |
| Thermal-Shutdown Threshold | $T_{SHUT}$ | | | 145 | | °C |
| Thermal-Shutdown Hysteresis | $T_{HYST}$ | | | 25 | | °C |
| **ESD PROTECTION** | | | | | | |
| A_, B_ Pins (Note 4) | | Human Body Model | | ±6 | | kV |
| All Other Pins | | Human Body Model | | ±2 | | kV |

**Note 2:** All units are production tested at $T_A$ = +25°C. Specifications over temperature are guaranteed by design.
**Note 3:** When $V_{DD}$ is higher than the charge-pump threshold, the internal 5V regulated charge pump is turned off and the input to the high-voltage charge pumps is provided by $V_{DD}$.
**Note 4:** The MAX14778 requires a 100nF capacitor on both $V_P$ and $V_N$ to GND to guarantee full ESD protection. See the *Applications Information* section for details on ESD test conditions.

*Test Circuits/Timing Diagrams*
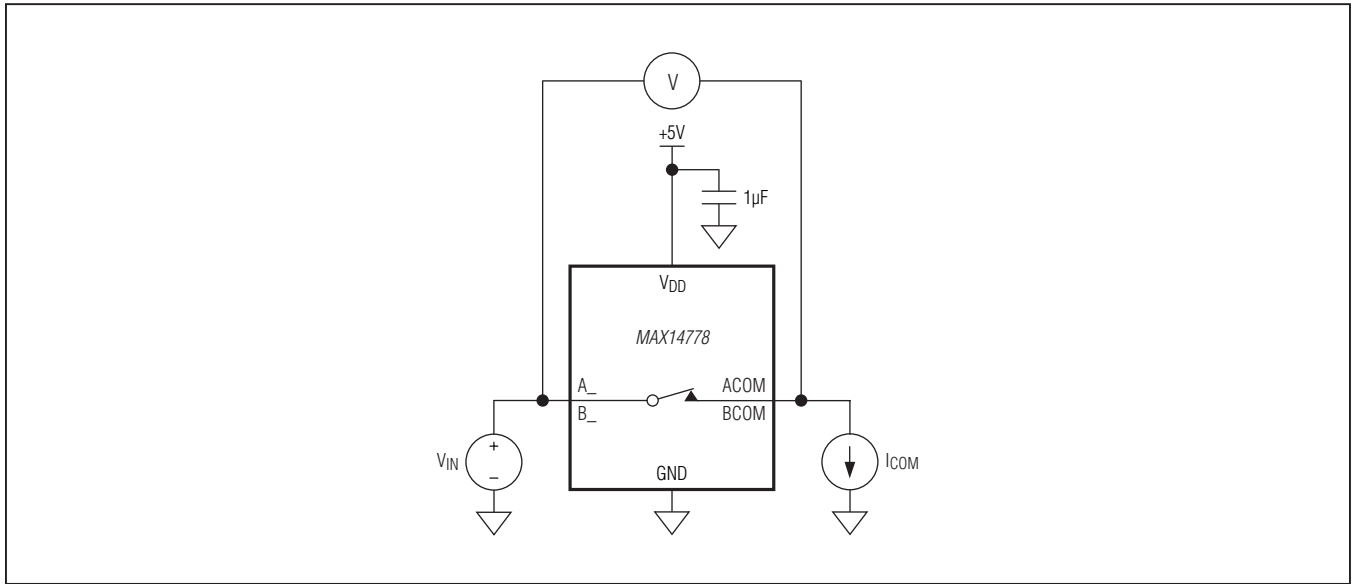


*Figure 1. On-Resistance Measurement*
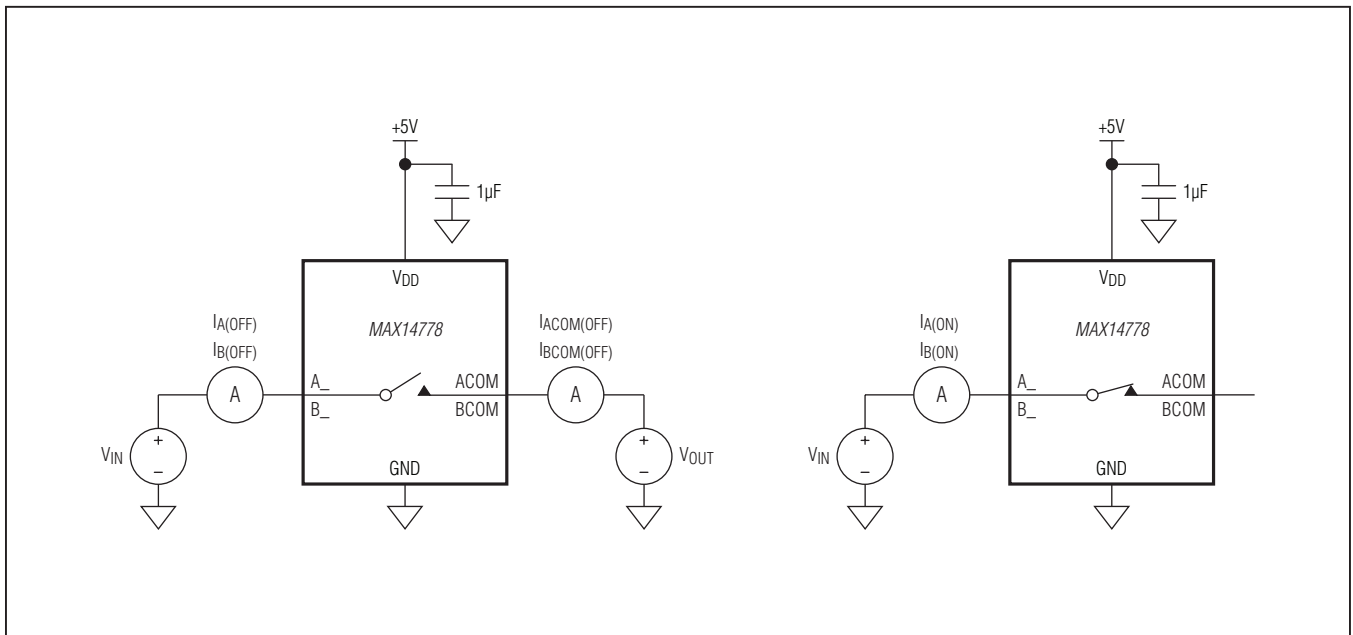


*Figure 2. Leakage Current Measurement*

### Test Circuits/Timing Diagrams (continued)
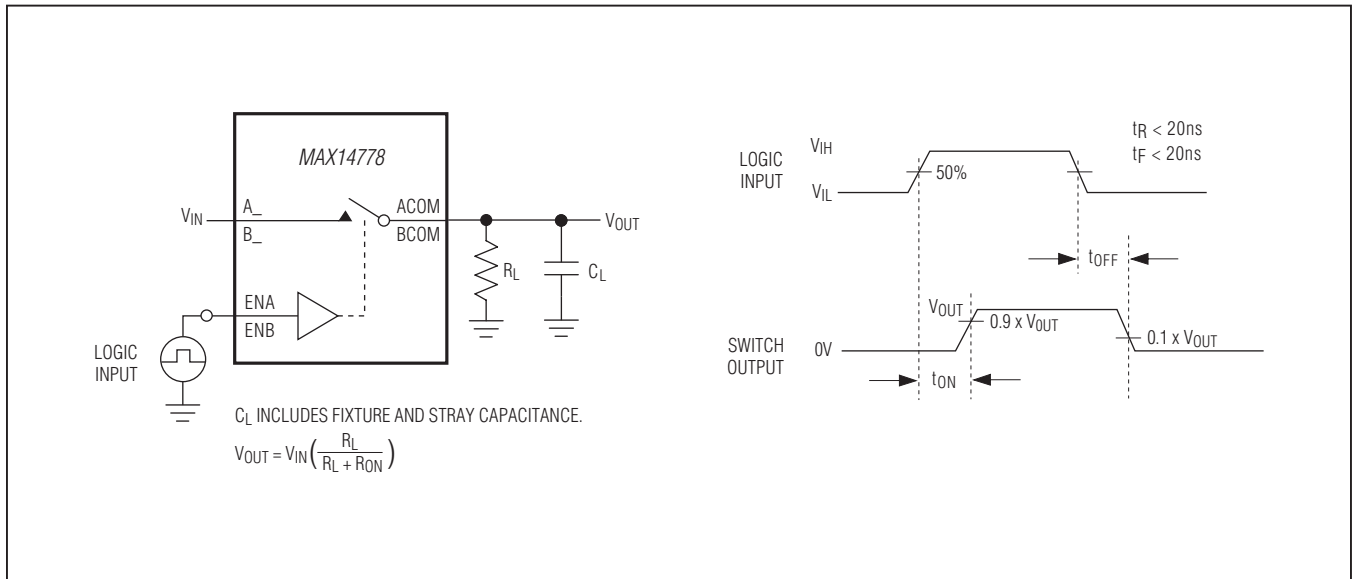


Figure 3. Turn-On/Turn-Off Timing
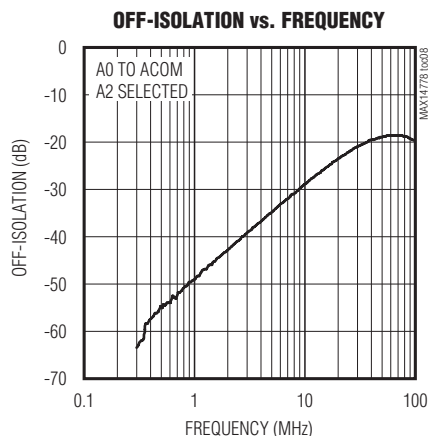
$C_L$ INCLUDES FIXTURE AND STRAY CAPACITANCE.

$$V_{OUT} = V_{IN} \left( \frac{R_L}{R_L + R_{ON}} \right)$$
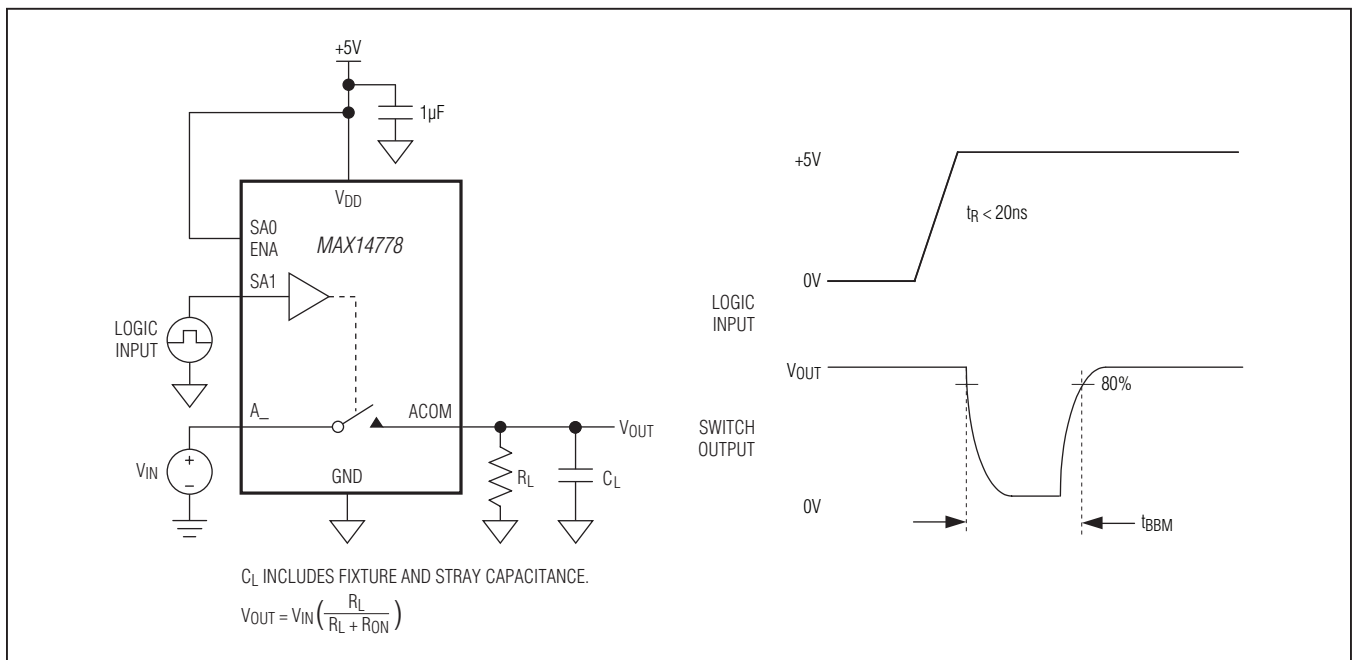


Figure 4. Break-Before-Make Timing

$C_L$ INCLUDES FIXTURE AND STRAY CAPACITANCE.

$$V_{OUT} = V_{IN} \left( \frac{R_L}{R_L + R_{ON}} \right)$$

**Test Circuits/Timing Diagrams (continued)**
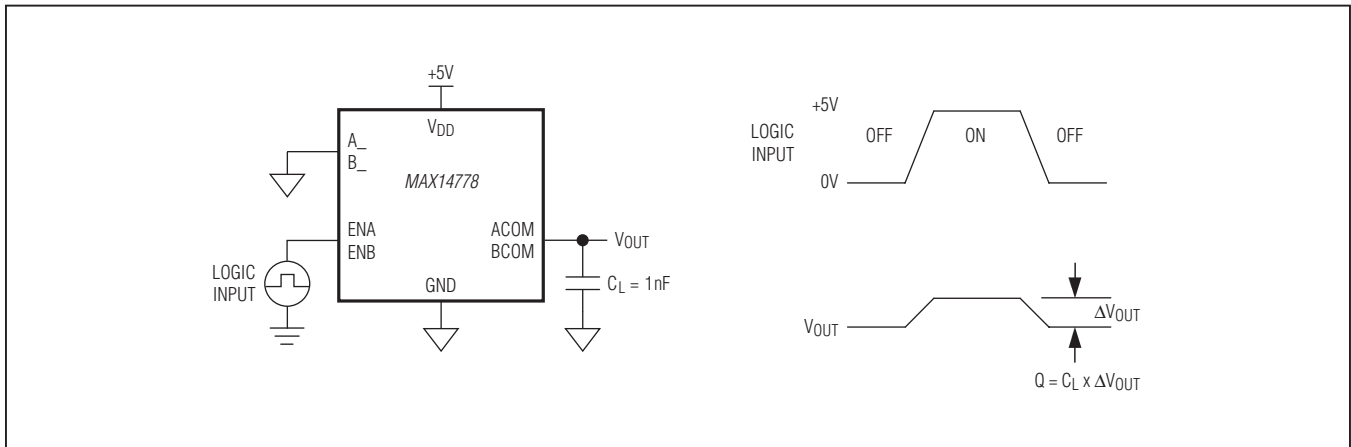


*Figure 5. Charge Injection*



MEASUREMENTS ARE STANDARDIZED AGAINST SHORTS AT IC TERMINALS.
OFF-ISOLATION IS MEASURED BETWEEN ACOM AND "OFF" A_ TERMINAL ON EACH MULTIPLEXER.
-3dBW IS MEASURED BETWEEN ACOM AND "ON" A_ TERMINAL ON EACH MULTIPLEXER.
CROSSTALK IS MEASURED FROM ONE CHANNEL TO ALL OTHER CHANNELS.
SIGNAL DIRECTION THROUGH MULTIPLEXER IS REVERSED; WORST VALUES ARE RECORDED.
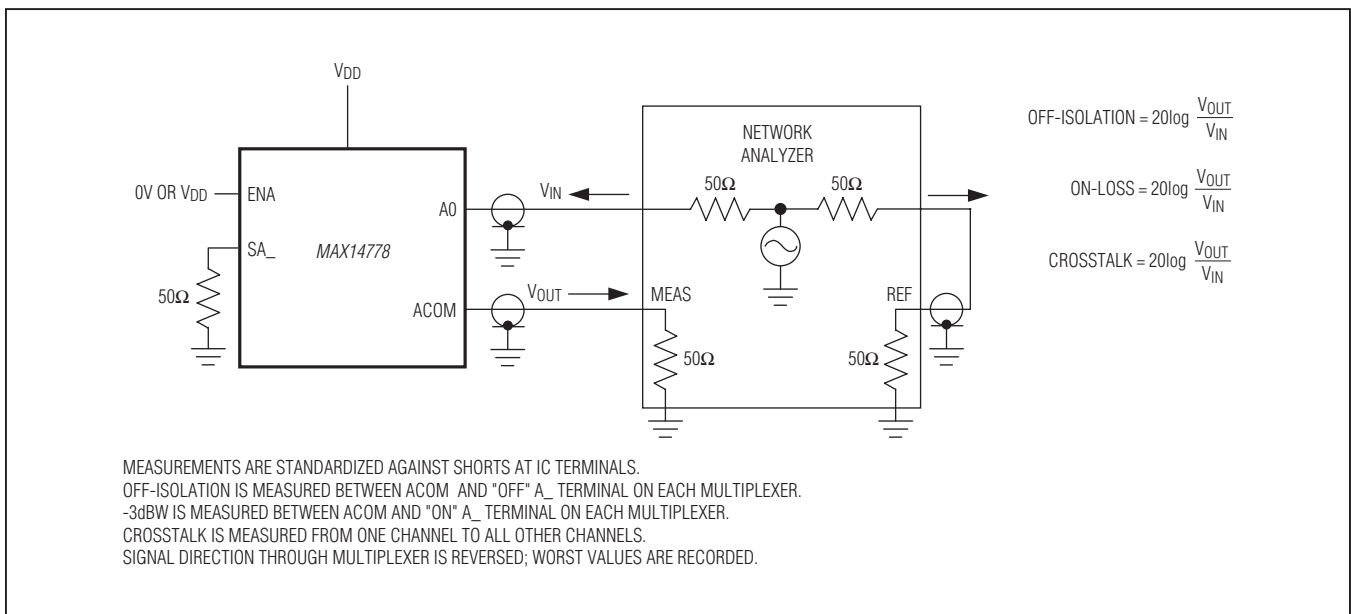
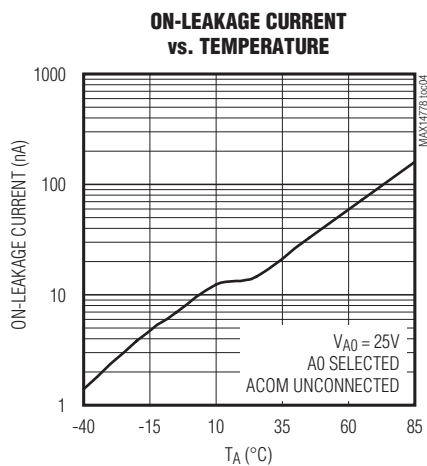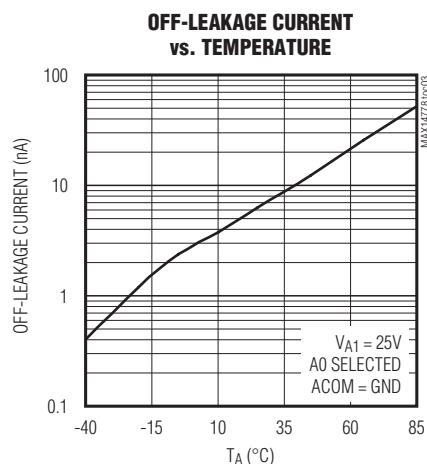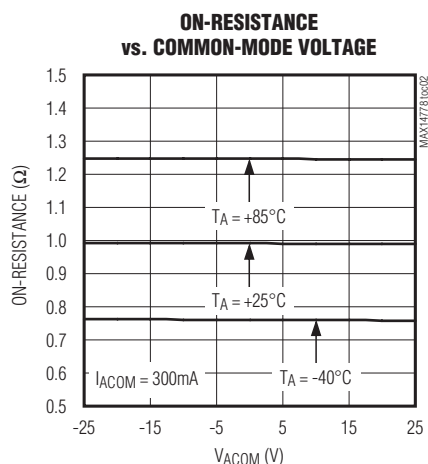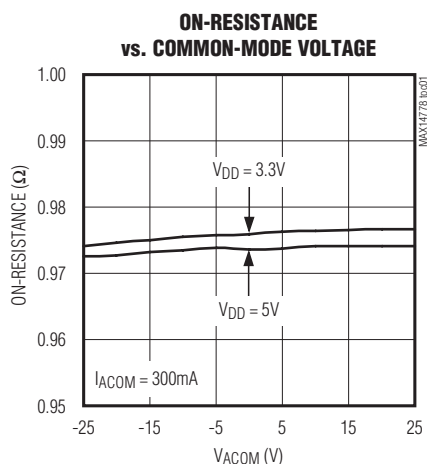*Figure 6. Off-Isolation, -3dB Bandwidth, and Crosstalk*

# Dual ±25V Above- and Below-the-Rails
# 4:1 Analog Multiplexer

## *Typical Operating Characteristics*

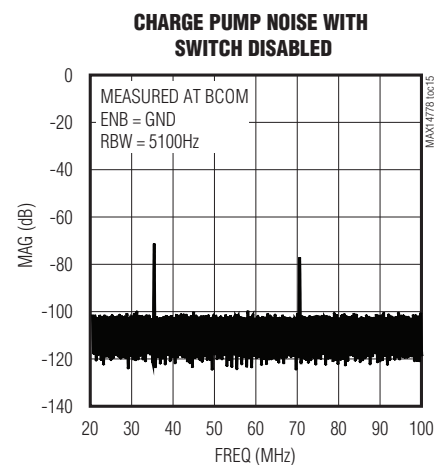(V$_{DD}$ = 5.0V, T$_A$ = +25°C, unless otherwise noted.)
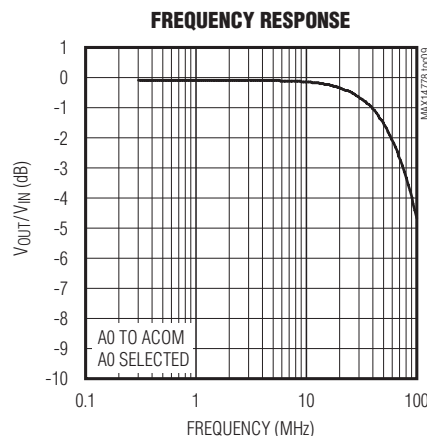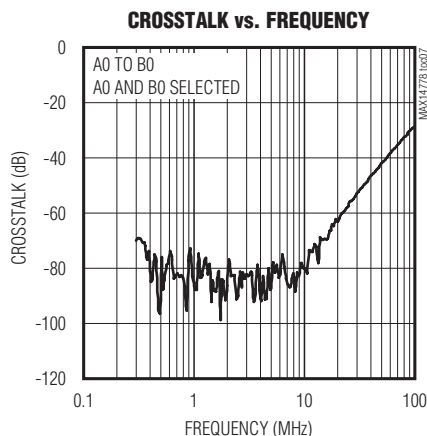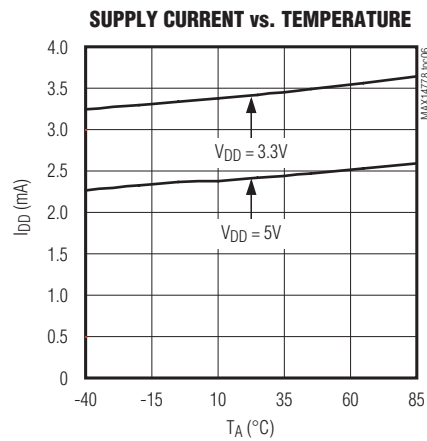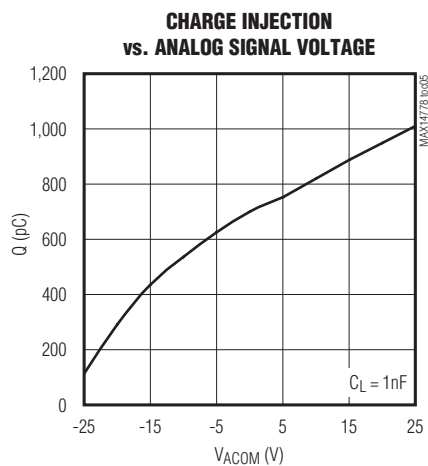
**ON-RESISTANCE**
**vs. COMMON-MODE VOLTAGE**

**ON-RESISTANCE**
**vs. COMMON-MODE VOLTAGE**

**OFF-LEAKAGE CURRENT**
**vs. TEMPERATURE**

**ON-LEAKAGE CURRENT**
**vs. TEMPERATURE**

**CHARGE INJECTION**
**vs. ANALOG SIGNAL VOLTAGE**

**SUPPLY CURRENT vs. TEMPERATURE**

**CROSSTALK vs. FREQUENCY**

**OFF-ISOLATION vs. FREQUENCY**

**FREQUENCY RESPONSE**

# Dual ±25V Above- and Below-the-Rails
# 4:1 Analog Multiplexer

## *Typical Operating Characteristics (continued)*
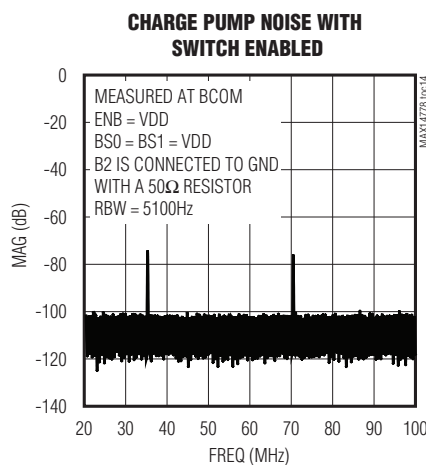
($V_{DD}$ = 5.0V, $T_A$ = +25°C, unless otherwise noted.)

**THD+N vs. FREQUENCY**

A0 TO ACOM
$R_S$ = 600Ω
$R_L$ = 1kΩ

MAX14778 toc10

THD+N (%)

FREQUENCY (kHz)

**PSRR vs. FREQUENCY**

$V_{DD}$ TO ACOM

MAX14778 toc11

PSRR (dB)

FREQUENCY (kHz)

**TURN-ON TIME
vs. ANALOG-SIGNAL VOLTAGE**

MAX14778 toc12

$t_{ON}$ (ms)

$V_{ACOM}$ (V)

**TURN-OFF TIME
vs. ANALOG-SIGNAL VOLTAGE**

MAX14778 toc13

$t_{OFF}$ (ms)

$V_{ACOM}$ (V)

**CHARGE PUMP NOISE WITH
SWITCH ENABLED**

MEASURED AT BCOM
ENB = VDD
BS0 = BS1 = VDD
B2 IS CONNECTED TO GND
WITH A 50Ω RESISTOR
RBW = 5100Hz

MAX14778 toc14

MAG (dB)

FREQ (MHz)

**CHARGE PUMP NOISE WITH
SWITCH DISABLED**
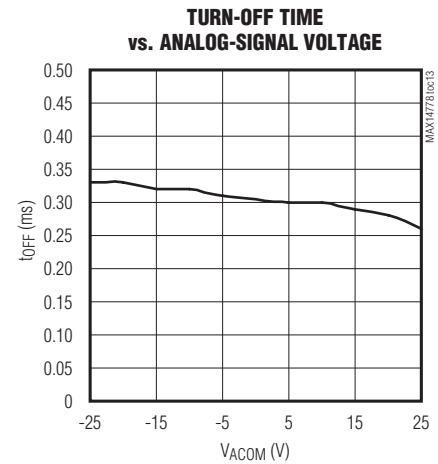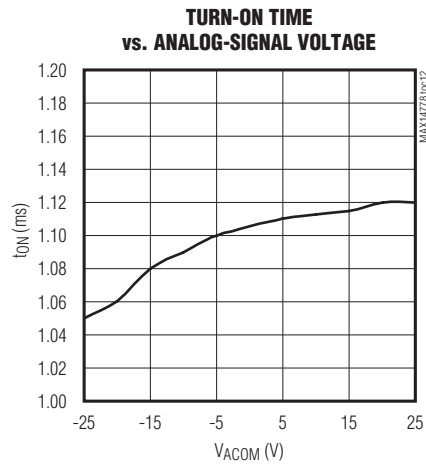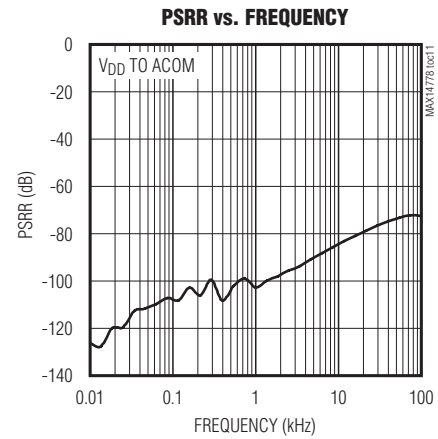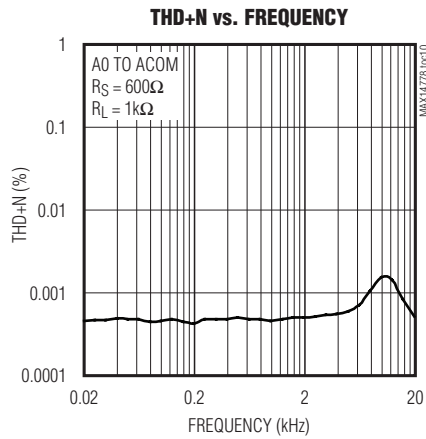
MEASURED AT BCOM
ENB = GND
RBW = 5100Hz

MAX14778 toc15

MAG (dB)

FREQ (MHz)

# Dual ±25V Above- and Below-the-Rails 4:1 Analog Multiplexer

## Pin Configuration

TOP VIEW

MAX14778

**TQFN**
**5mm x 5mm**

*CONNECT EXPOSED PAD TO $V_N$.
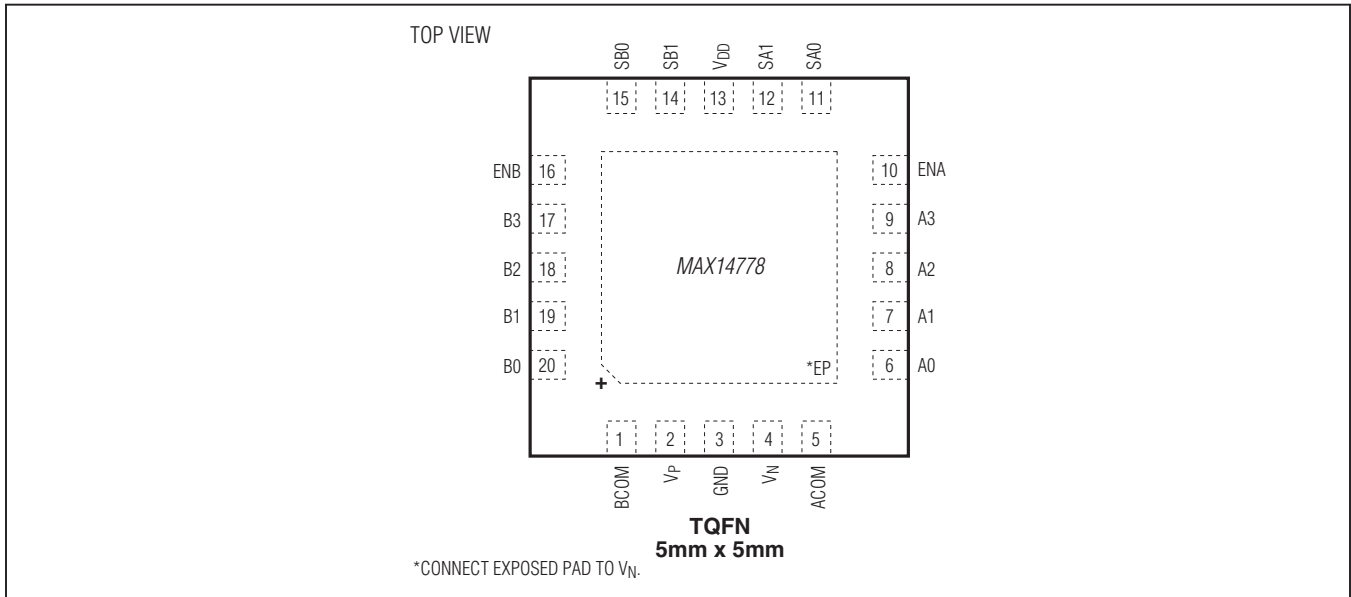
## Pin Description

| PIN | NAME | FUNCTION |
|---|---|---|
| 1 | BCOM | MUX B Common Terminal |
| 2 | $V_P$ | Positive Charge-Pump Output. Bypass $V_P$ to GND with a 100nF 50V ceramic capacitor. |
| 3 | GND | Ground |
| 4 | $V_N$ | Negative Charge-Pump Output. Bypass $V_N$ to GND with a 100nF 50V ceramic capacitor. |
| 5 | ACOM | MUX A Common Terminal |
| 6 | A0 | MUX A Bidirectional Analog Input/Output 0 |
| 7 | A1 | MUX A Bidirectional Analog Input/Output 1 |
| 8 | A2 | MUX A Bidirectional Analog Input/Output 2 |
| 9 | A3 | MUX A Bidirectional Analog Input/Output 3 |
| 10 | ENA | MUX A Enable Input |
| 11 | SA0 | MUX A Channel Select Input 0 |
| 12 | SA1 | MUX A Channel Select Input 1 |
| 13 | $V_{DD}$ | Power-Supply Input. Bypass $V_{DD}$ to GND with a 1µF ceramic capacitor. |
| 14 | SB1 | MUX B Channel Select Input 1 |
| 15 | SB0 | MUX B Channel Select Input 0 |
| 16 | ENB | MUX B Enable Input |
| 17 | B3 | MUX B Bidirectional Analog Input/Output 3 |
| 18 | B2 | MUX B Bidirectional Analog Input/Output 2 |
| 19 | B1 | MUX B Bidirectional Analog Input/Output 1 |
| 20 | B0 | MUX B Bidirectional Analog Input/Output 0 |
| — | EP | Exposed Pad. **Connect EP to $V_N$.** EP is not intended as an electrical connection point. |

*Truth Tables*

## Table 1. MUX A Channel Selection

| ENA | SA1 | SA0 | ACOM CONNECTED TO |
|-----|-----|-----|-------------------|
| 0 | X | X | Open |
| 1 | 0 | 0 | A0 |
| 1 | 0 | 1 | A1 |
| 1 | 1 | 0 | A2 |
| 1 | 1 | 1 | A3 |

*X = Don't care*

## Table 2. MUX B Channel Selection

| ENB | SB1 | SB0 | BCOM CONNECTED TO |
|-----|-----|-----|-------------------|
| 0 | X | X | Open |
| 1 | 0 | 0 | B0 |
| 1 | 0 | 1 | B1 |
| 1 | 1 | 0 | B2 |
| 1 | 1 | 1 | B3 |

*X = Don't care*

## *Detailed Description*

The MAX14778 dual 4:1 analog multiplexer integrates bias circuitry to provide a ±25V analog voltage range with a single 3.0 to 5.5V supply. This extended input range allows multiplexing different communications signals such as RS-232, RS-485, audio and USB 1.1 onto the same connector.

### *Integrated Bias Generation*

The MAX14778 contains a total of three charge pumps to generate bias voltages for the internal switches: a 5V regulated charge pump, a positive high-voltage (+35V) charge pump, and a negative high-voltage (-27V) charge pump. When $V_{DD}$ is above 4.7V (typ), the 5V regulated charge pump is bypassed and $V_{DD}$ provides the input for the high-voltage charge pumps, reducing overall supply current.

An external 100nF capacitor is required for each high-voltage charge pump between $V_P/V_N$ and GND.

### *Analog Signal Levels*

The MAX14778 transmits signals of up to ±25V with a single 3.0 to 5.5V supply due to integrated bias circuitry. The device features 1.5Ω (max) on-resistance and 3mΩ (typ) flatness for analog signals between -25V and +25V (see the *Typical Operating Characteristics*). The current flow through the multiplexers can be bidirectional, allowing operation either as a multiplexer or demultiplexer.

### *Digital Interface*

The MAX14778 has two digital select inputs for each MUX: SA1 and SA0 control MUX A; SB1 and SB0 control MUX B. Drive the digital select inputs high or low to select which input (A_, B_) is connected to the common terminal (ACOM, BCOM) for each MUX. See the *Truth Tables* for more information.

Each MUX features an independent enable input (ENA and ENB). Drive ENA or ENB low to disconnect all inputs from the common terminal for that MUX, regardless of the status of the select inputs or the other enable input.

## *Applications Information*

### *Connector Sharing*

The MAX14778 supports a ±25V analog signal range independently for each input/output, allowing physical connector sharing between interface types that have differing signal ranges.

The multiprotocol connector-sharing application in the *Typical Operating Circuits* shows an application with RS-232, half-duplex RS-485, full-speed USB 1.1, and audio signals sharing the same connector. The device allows signals to pass over the entire signal range specified by each standard while safely isolating the unused transceivers.

# Dual ±25V Above- and Below-the-Rails 4:1 Analog Multiplexer

## Non-Powered Condition

The MAX14778 can tolerate input voltages on the A_, B_, ACOM, and BCOM pins in the ±25V range when it is not powered.

When VDD = 0V, the DC input leakage current into the A_, B_, ACOM or BCOM pins will typically be below 1µA. Some devices can have a larger leakage current up to mA range due to technology spread.

With VDD not powered, internal diodes between the analog pins and the VP and VN will charge up the external capacitors on VP and VN when positive and/or negative voltages are applied to these pins. This causes transient input current flow.

Large dv/dt on the inputs causes large capacitive charging currents, which have to be limited to the 300mA Absolute Maximum Ratings in order to not destroy the internal diodes. With 100nF capacitors on VP and VN, the dv/dt must be limited to 3V/µs once the capacitors reach their final voltage; the input current decays to the leakage current levels mentioned above.

## High-ESD Protection

Electrostatic discharge (ESD)-protection structures are incorporated on all pins to protect against electrostatic discharges up to ±2kV Human Body Model (HBM) encountered during handling and assembly. A_ and B_ are further protected against ESD up to ±6kV (HBM) without damage. The ESD structures withstand high ESD both in normal operation and when the device is powered down. After an ESD event, the MAX14778 continues to function without latchup.

## ESD Test Conditions

ESD performance depends on a variety of conditions. Contact Maxim for a reliability report that documents test setup, test methodology, and test results.

The MAX14778 requires a 100nF capacitor on both $V_P$ and $V_N$ to GND to guarantee full ESD protection.

## Human Body Model

Figure 7 shows the Human Body Model. Figure 8 shows the current waveform it generates when discharged into a low impedance. This model consists of a 100pF capacitor charged to the ESD voltage of interest that is then discharged into the device through a 1.5kΩ resistor.
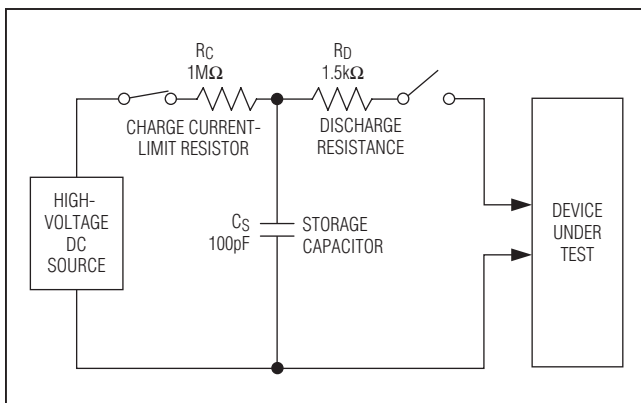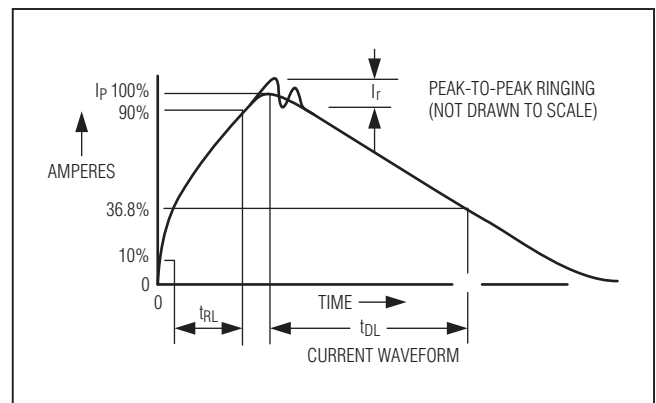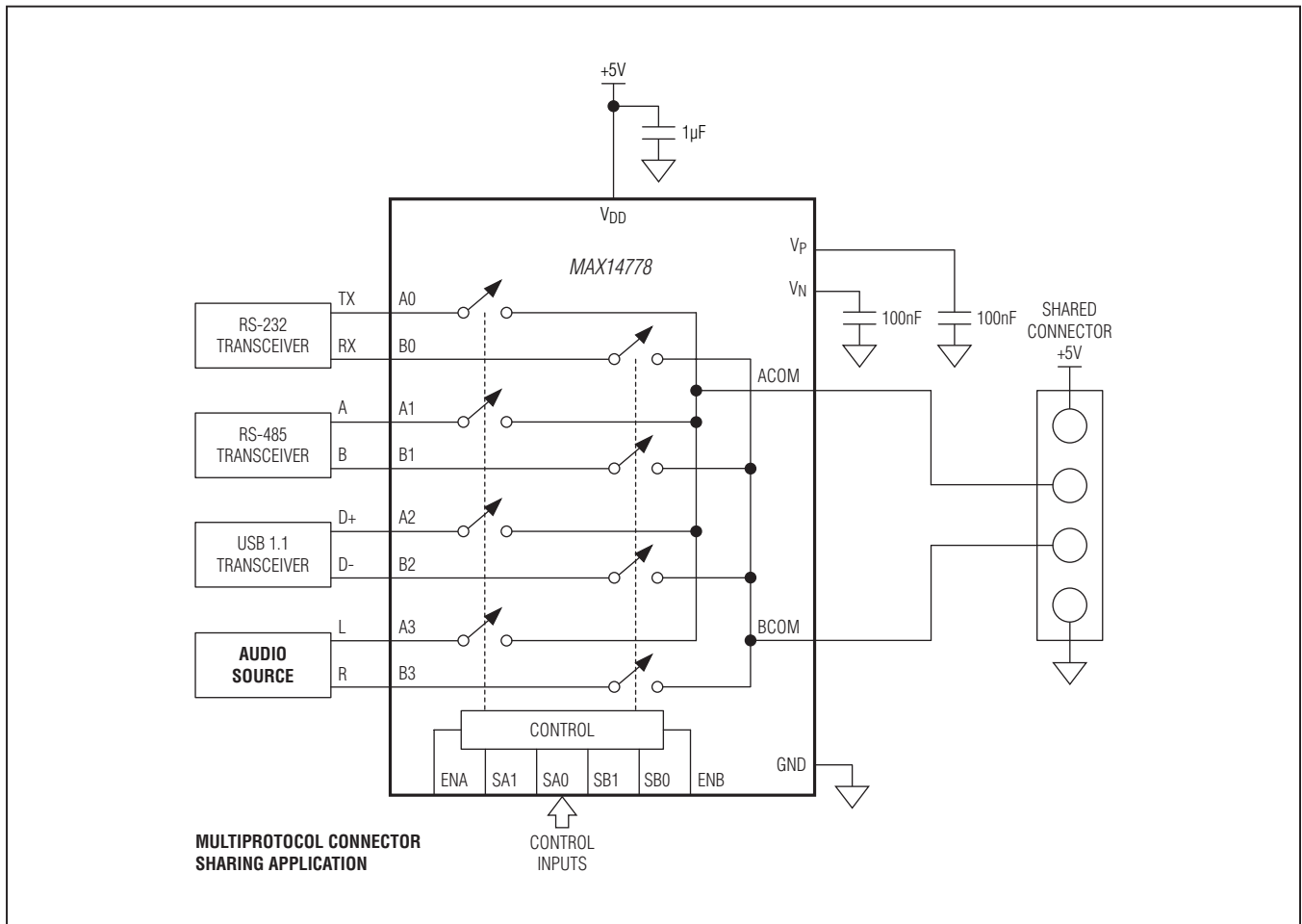


Figure 7. Human Body ESD Test Model



Figure 8. Human Body Current Waveform

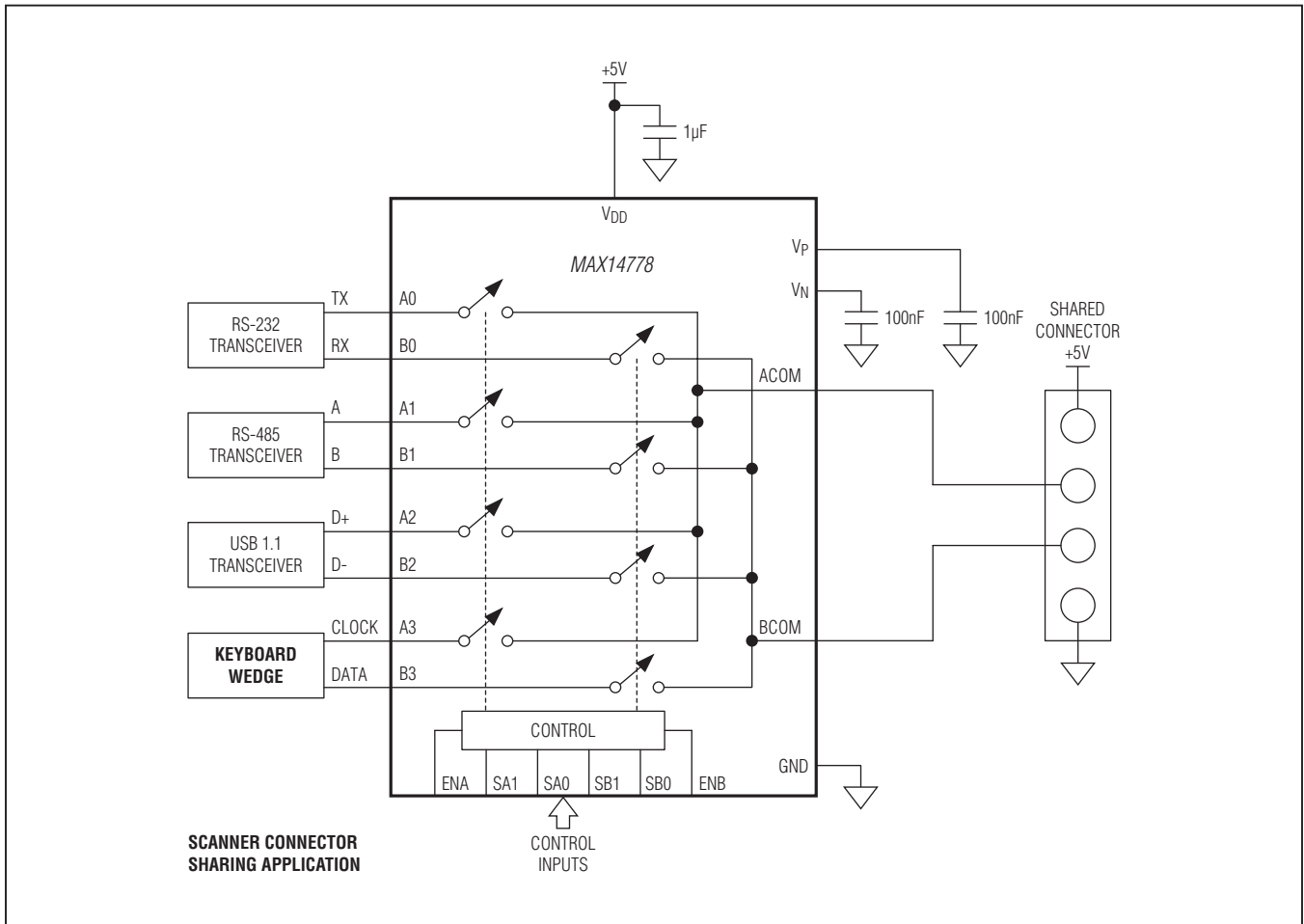# Dual ±25V Above- and Below-the-Rails 4:1 Analog Multiplexer

## *Typical Operating Circuits*



**MULTIPROTOCOL CONNECTOR SHARING APPLICATION**

# Dual ±25V Above- and Below-the-Rails
# 4:1 Analog Multiplexer

## *Typical Operating Circuits (continued)*

# Dual ±25V Above- and Below-the-Rails
# 4:1 Analog Multiplexer

## *Ordering Information*

| PART | TEMP RANGE | PIN-PACKAGE |
|------|-----------|-------------|
| MAX14778ETP+ | -40°C to +85°C | 20 TQFN-EP* |

*+Denotes a lead(Pb)-free/RoHS-compliant package.*
*\*EP = Exposed pad.*

## *Chip Information*

PROCESS: BiCMOS

## *Package Information*

For the latest package outline information and land patterns (footprints), go to **www.maximintegrated.com/packages**. Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

| PACKAGE TYPE | PACKAGE CODE | OUTLINE NO. | LAND PATTERN NO. |
|--------------|--------------|-------------|------------------|
| 20 TQFN-EP | T2055+4 | **21-0140** | **90-0009** |

## *Revision History*

| REVISION NUMBER | REVISION DATE | DESCRIPTION | PAGES CHANGED |
|---|---|---|---|
| 0 | 6/11 | Initial release | — |
| 1 | 6/12 | Added new TOCs 14 and 15, updated *Non-Powered Condition* section, updated Note 4, *Pin Description*, *ESD Test Conditions*, *Typical Operating Circuits*, updated capacitor values | 3, 8, 9, 10, 11, 12, 13 |