

# MAX14777

# Quad Beyond-the-Rails -15V to +35V Analog Switch

## General Description

The MAX14777 quad SPST switch supports analog signals above and below the rails with a single 3.0V to 5.5V supply. The device features a selectable -15V/+35V or -15V/+15V analog signal range for all switches. Each switch has a separate control input to allow independent switching, making the device an alternative to opto-relays in applications that do not need galvanic isolation.

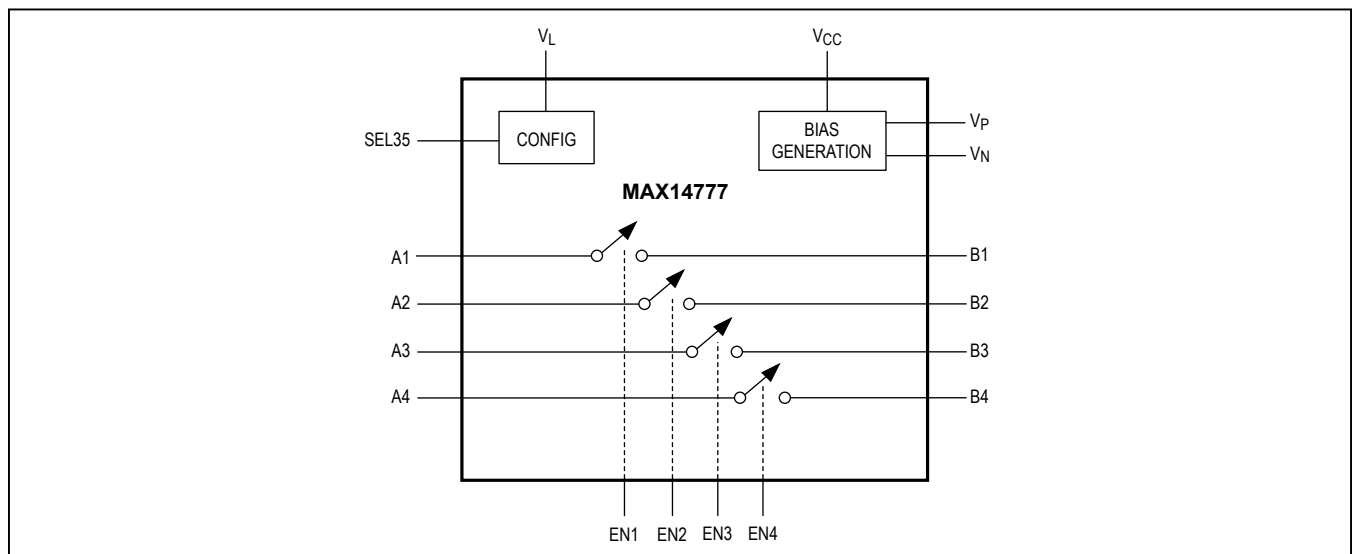
The IC features 10Ω (max) on-resistance, and 9mΩ (typ)  $R_{ON}$  flatness, along with a low 50nA (max at +85°C) on-leakage. For maximum signal integrity, the device keeps this performance over the entire common-mode voltage range. Each switch can carry up to 60mA (max) of continuous current in either direction.

The MAX14777 is available in a 20-pin (4mm x 4mm) TQFN package and is specified over the -40°C to +105°C temperature range.

## Applications

- Industrial Measurement Systems
- Instrumentation Systems
- 4–20mA Switching
- ATE Systems

## Functional Diagram



For related parts and recommended products to use with this part, refer to [www.maximintegrated.com/MAX14777\\_related](http://www.maximintegrated.com/MAX14777_related).

## Benefits and Features

- Simple, Flexible Board Design
  - -15V/+35V Beyond-the-Rails™ Signal Range from a Single 3.0V to 5.5V Supply
  - Selectable -15V/+15V Signal Range for Lower Supply Current
  - 60mA Maximum Current through Each Switch
  - 1.62V to 5.5V Logic Interface
- High-Performance 10Ω  $R_{ON}$  (max)
- 150mΩ (max)  $R_{ON}$  Flatness
- ±50nA (max) On-Leakage at  $T_A = +85^\circ\text{C}$
- Saves Board Space
  - Small 20-Pin TQFN Package (4mm x 4mm)
- -40°C to +105°C Operating Temperature Range

*Beyond-the-Rails is a registered trademark of Maxim Integrated Products, Inc.*

*Ordering Information appears at end of data sheet.*

**Absolute Maximum Ratings**

(All voltages referenced to GND, unless otherwise noted.)

V<sub>CC</sub>.....-0.3V to +6V  
 V<sub>L</sub>.....-0.3V to +6V  
 EN1, EN2, EN3, EN4, SEL35, I.C.....-0.3V to +6V  
 A1, A2, A3, A4, B1, B2, B3, B4 ..... (V<sub>N</sub> - 0.3V) to the lesser of  
 (V<sub>P</sub> + 0.3V) and (V<sub>N</sub> + 70V)  
 V<sub>P</sub>  
 SEL35 = High.....-0.3V to +70V  
 SEL35 = Low.....-0.3V to +48V  
 V<sub>P</sub> to V<sub>N</sub>.....-0.3V to +70V

V<sub>N</sub>..... the greater of -26V and (V<sub>P</sub> - 70V) to +0.3V  
 Absolute Difference Between Switch I/Os (|A<sub>-</sub> - B<sub>-</sub>|).....70V  
 Continuous Current .....±80mA  
 Continuous Power Dissipation (T<sub>A</sub> = +70°C).....  
 TQFN (derate 25.6mW/°C above +70°C).....2051.3mW  
 Operating Temperature Range.....-40°C to +105°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)**

Junction-to-Ambient Thermal Resistance (θ<sub>JA</sub>)  
 TQFN.....39°C/W  
 Junction-to-Case Thermal Resistance (θ<sub>JC</sub>)  
 TQFN.....6°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](http://www.maximintegrated.com/thermal-tutorial).

**Electrical Characteristics**

(V<sub>CC</sub> = 3.0V to 5.5V, V<sub>L</sub> = 3.3V, T<sub>A</sub> = -40°C to +105°C, unless otherwise noted. Typical values are at V<sub>CC</sub> = 5V and T<sub>A</sub> = +25°C.)  
 (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>DC CHARACTERISTICS</b>						
Supply Voltage Range	V <sub>CC</sub>		3.0		5.5	V
V <sub>L</sub> Supply Voltage Range	V <sub>L</sub>		1.62		5.5	V
V <sub>CC</sub> Supply Current	I <sub>CC</sub>	V <sub>CC</sub> = 3.3V, V <sub>EN<sub>-</sub></sub> = V <sub>L</sub>		1.8	3.4	mA
			SEL35 = low			
			SEL35 = high	2.2	4.3	
		V <sub>CC</sub> = 5.5V, V <sub>EN<sub>-</sub></sub> = V <sub>L</sub>		0.6	1.2	
		SEL35 = low		0.8	1.65	
		SEL35 = high				
V <sub>L</sub> Supply Current	I <sub>L</sub>	SEL35, EN <sub>-</sub> = low or high	-1		+1	µA
Analog Signal Range	V <sub>A<sub>-</sub></sub> , V <sub>B<sub>-</sub></sub>	SEL35 = low	-15		+15	V
		SEL35 = high	-15		+35	
Positive High-Voltage Charge-Pump Output (Note 3)	V <sub>P</sub>	SEL35 = low	22.5		27.1	V
		SEL35 = high	41.7		49.8	
Negative High-Voltage Charge-Pump Output	V <sub>N</sub>	(Note 3)	-18.2		-14.9	V
Continuous Current Through Switch	I <sub>A<sub>-</sub></sub>	EN <sub>-</sub> = high	-60		+60	mA

## Electrical Characteristics (continued)

( $V_{CC} = 3.0V$  to  $5.5V$ ,  $V_L = 3.3V$ ,  $T_A = -40^\circ C$  to  $+105^\circ C$ , unless otherwise noted. Typical values are at  $V_{CC} = 5V$  and  $T_A = +25^\circ C$ .)  
(Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
On-Resistance, Figure 1	$R_{ON}$	$-15V \leq V_{A\_} \leq +35V$ , SEL35 = high, $I_{IN} = \pm 60mA$ , Figure 1		4.4	10	$\Omega$
		$-15V \leq V_{A\_} \leq +15V$ , SEL35 = low, $I_{IN} = \pm 60mA$ , Figure 1		4.4	10	
On-Resistance Flatness	$\Delta R_{ON}$	$-15V \leq V_{A\_} \leq +35V$ , SEL35 = high, $I_{IN} = \pm 60mA$		9	150	m $\Omega$
		$-15V \leq V_{A\_} \leq +15V$ , SEL35 = low, $I_{IN} = \pm 60mA$		8	150	
On-Resistance Matching Between Channels	$\Delta R_{ON\_M}$	$-15V \leq V_{A\_} \leq +35V$ , SEL35 = high, $I_{IN} = \pm 60mA$ , (Note 4)			200	m $\Omega$
		$-15V \leq V_{A\_} \leq +15V$ , SEL35 = low, $I_{IN} = \pm 60mA$ , (Note 4)			200	
A_ Off-Leakage Current	$I_{L\_OFF\_A}$	$-15V \leq V_{A\_} \leq +35V$ , SEL35 = high, $V_{B\_} = 0V$ , $+40^\circ C \leq T_A \leq +85^\circ C$ , Figure 2	-20		+20	nA
		$-15V \leq V_{A\_} \leq +35V$ , SEL35 = high, $V_{B\_} = 0V$ , $+40^\circ C \leq T_A \leq +105^\circ C$ , Figure 2	-80		+80	
B_ Off-Leakage Current	$I_{L\_OFF\_B}$	$-15V \leq V_{B\_} \leq +35V$ , SEL35 = high, $V_{A\_} = 0V$ , $+40^\circ C \leq T_A \leq +85^\circ C$ , Figure 2	-20		+20	nA
		$-15V \leq V_{B\_} \leq +35V$ , SEL35 = high, $V_{A\_} = 0V$ , $+40^\circ C \leq T_A \leq +105^\circ C$ , Figure 2	-80		+80	
On-Leakage Current	$I_{L\_ON}$	$-15V \leq V_{A\_} \leq +35V$ , SEL35 = high, B_ unconnected, $+40^\circ C \leq T_A \leq +85^\circ C$ , Figure 2	-50		+50	nA
		$-15V \leq V_{A\_} \leq +35V$ , SEL35 = high, B_ unconnected, $+40^\circ C \leq T_A \leq +105^\circ C$ , Figure 2	-200		+200	
A_ Power-Off Leakage Current	$I_{L\_PWROFF\_A}$	$V_{CC\_} = 0V$ or unconnected, $ V_{A\_} - V_{B\_}  > 3V$ , current measured at A	$-15V \leq V_{A\_} \leq +35V$	-5	+5	$\mu A$
B_ Power-Off Leakage Current	$I_{L\_PWROFF\_B}$	$V_{CC\_} = 0V$ or unconnected, $ V_{A\_} - V_{B\_}  > 3V$ , current measured at B	$-15V \leq V_{A\_} \leq +35V$	-5	+5	$\mu A$
<b>DIGITAL LOGIC (EN1, EN2, EN3, EN4, SEL35)</b>						
Input Voltage Low	$V_{IL}$				$0.3 \times V_L$	V
Input Voltage High	$V_{IH}$			$0.7 \times V_L$		V
Input Leakage Current	$I_{DLKG}$	$V_{EN\_} = \text{low or high}$		-1	+1	$\mu A$

## Electrical Characteristics (continued)

( $V_{CC} = 3.0V$  to  $5.5V$ ,  $V_L = 3.3V$ ,  $T_A = -40^\circ C$  to  $+105^\circ C$ , unless otherwise noted. Typical values are at  $V_{CC} = 5V$  and  $T_A = +25^\circ C$ .)  
(Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>AC CHARACTERISTICS</b>						
Power-Up Time	$t_{PWRON}$	$C_{VP} = C_{VN} = 10nF$ (Note 6)		5		ms
Enable Turn-On Time	$t_{ON}$	$V_{A\_} = \pm 10V$ , SEL35 = low, $R_L = 10k\Omega$ , Figure 3			40	$\mu s$
		$V_{A\_} = \pm 10V$ , SEL35 = high, $R_L = 10k\Omega$ , Figure 3			40	
Enable Turn-Off Time	$t_{OFF}$	$V_{A\_} = \pm 10V$ , $R_L = 10k\Omega$ , Figure 3 (Note 5)			100	$\mu s$
Off-Isolation	$V_{ISO}$	$V_{A\_} = 1V_{RMS}$ , $f = 100kHz$ , $R_L = 50\Omega$ , $C_L = 15pF$ , Figure 4	$V_{CC} = 3V$ to $5.5V$		-88	dB
			$V_{CC} = 0V$ or unconnected		-66	
Crosstalk	$V_{CT}$	$V_{A\_} = 1V_{RMS}$ , $f = 100kHz$ , $R_S = R_L = 50\Omega$ , Figure 5	$V_{CC} = 3V$ to $5.5V$		-101	dB
			$V_{CC} = 0V$ or unconnected		-93	
-3dB Bandwidth	BW	$V_{A\_} = 1V_{P-P}$ , $R_S = R_L = 50\Omega$ , Figure 6		380		MHz
Total Harmonic Distortion	THD+N	$R_S = R_L = 1k\Omega$ , $f = 20Hz$ to $20kHz$		0.038		%
Charge Injection	Q	$V_{A\_} = GND$ , $C_L = 1nF$ , Figure 7		225		pC
Input Capacitance	$C_{ON}$	$A\_$ , $B\_$ pins, $f = 1MHz$		16		pF
	$C_{OFF}$	At $A\_$ when $B\_ = GND$ , or at $B\_$ when $A\_ = GND$ , $f = 1MHz$		12		pF
<b>THERMAL SHUTDOWN</b>						
Thermal Shutdown Threshold	$T_{SHDN}$	Temperature rising		160		$^\circ C$
Thermal Shutdown Hysteresis	$T_{HYST}$			32		$^\circ C$
<b>ESD PROTECTION</b>						
All Pins		Human Body Model		$\pm 2$		kV

**Note 2:** All units are 100% production tested at  $+85^\circ C$ . Specifications over temperature are guaranteed by design.

**Note 3:** Do not use  $V_P$  or  $V_N$  to power external circuitry.

**Note 4:** Tested at  $-1V$ , guaranteed by design for  $-15V \leq V_{A\_} \leq +35V$ .

**Note 5:** This parameter does not depend on the status of SEL35.

**Note 6:** Power-up time is the time needed of  $V_P$  and  $V_N$  to reach steady-state values.

Test Circuits/Timing Diagrams

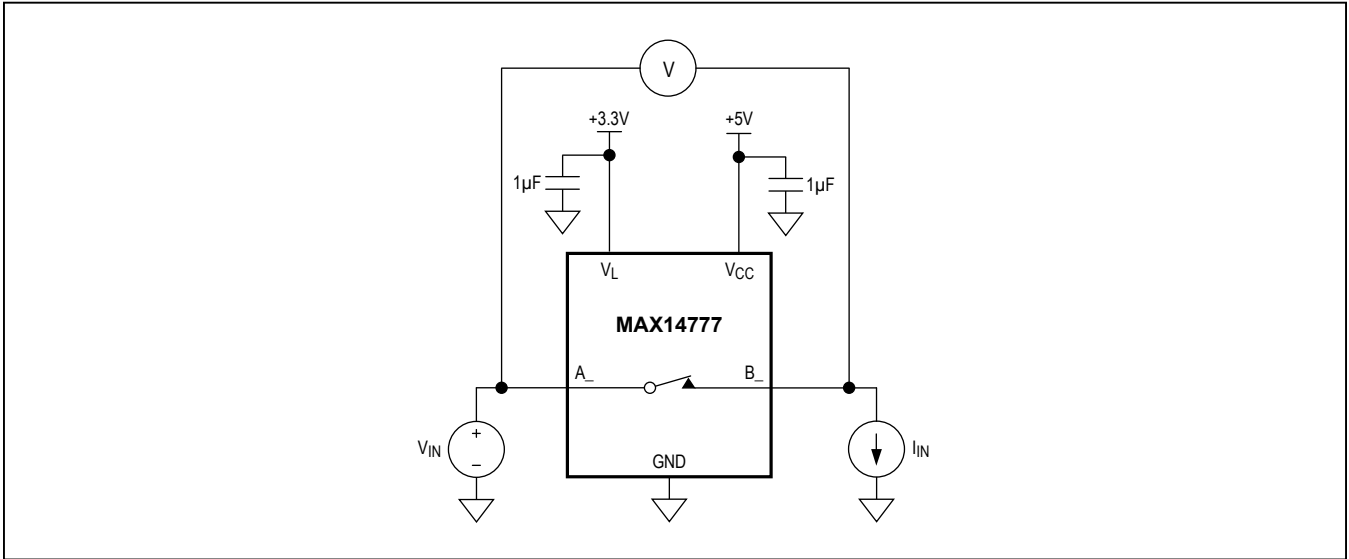


Figure 1. On-Resistance Measurement

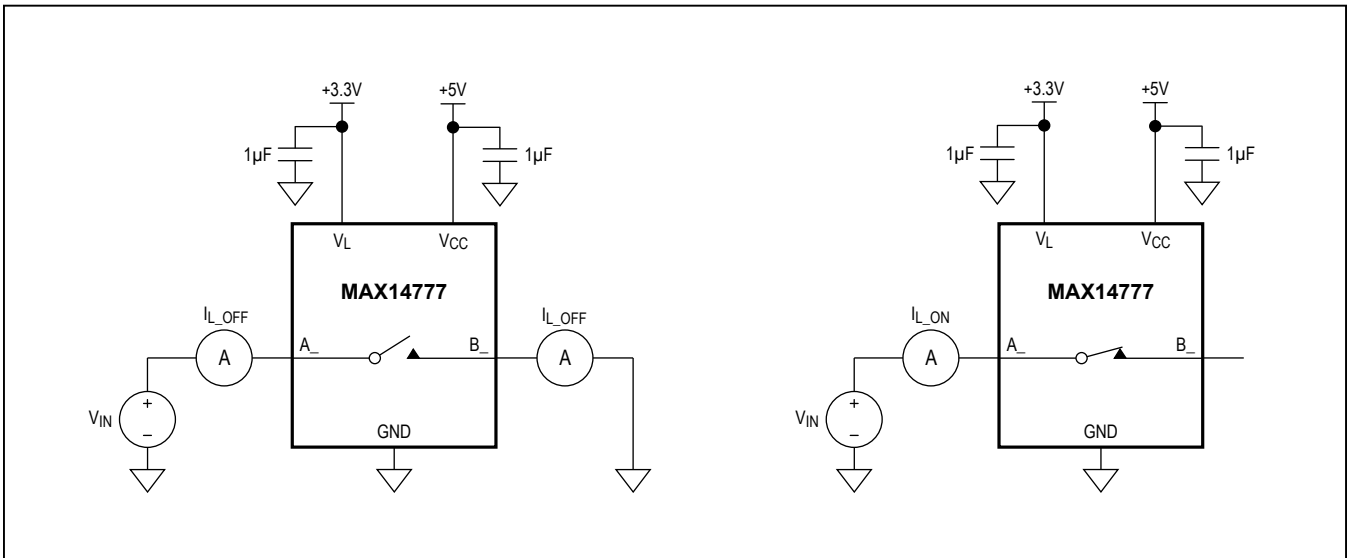


Figure 2. Leakage Current Measurements

Test Circuits/Timing Diagrams (continued)

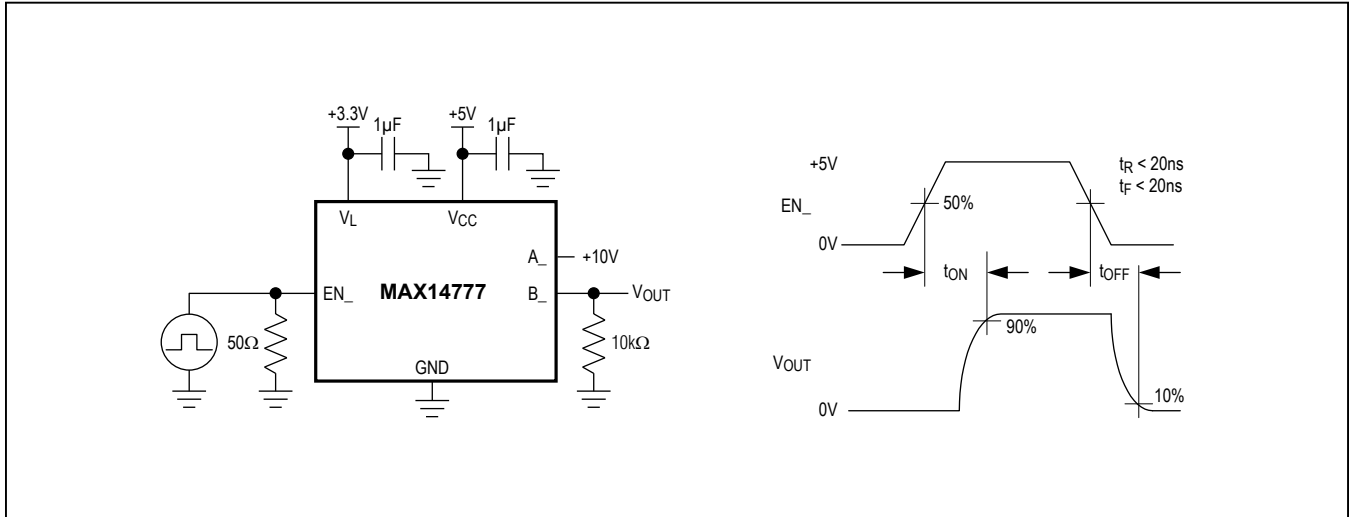


Figure 3. Enable Switching Time

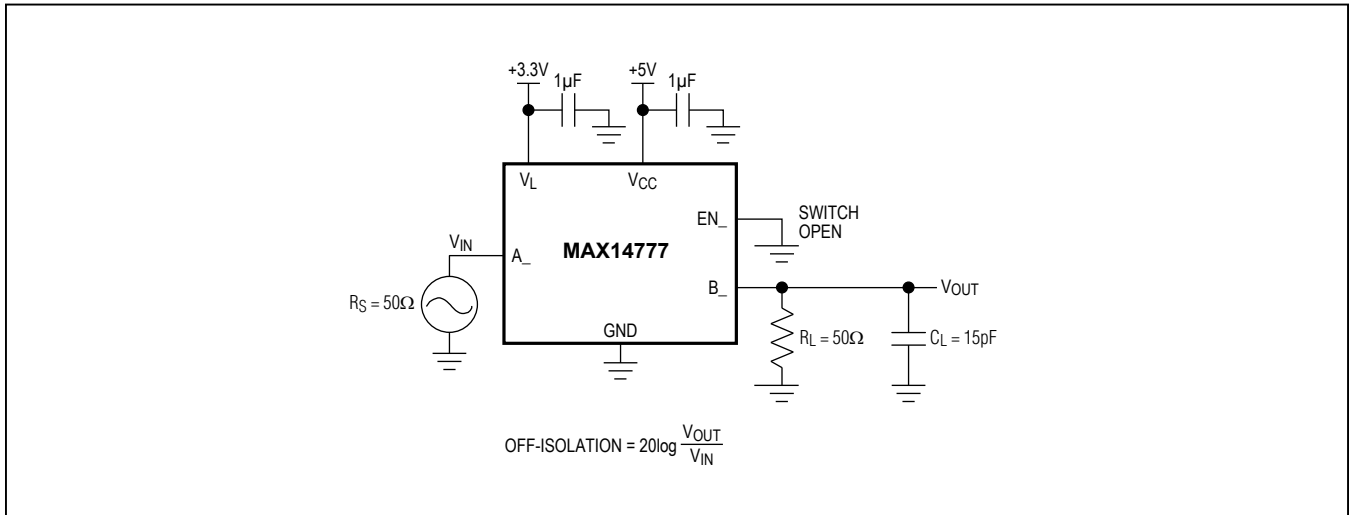


Figure 4. Off-Isolation

Test Circuits/Timing Diagrams (continued)

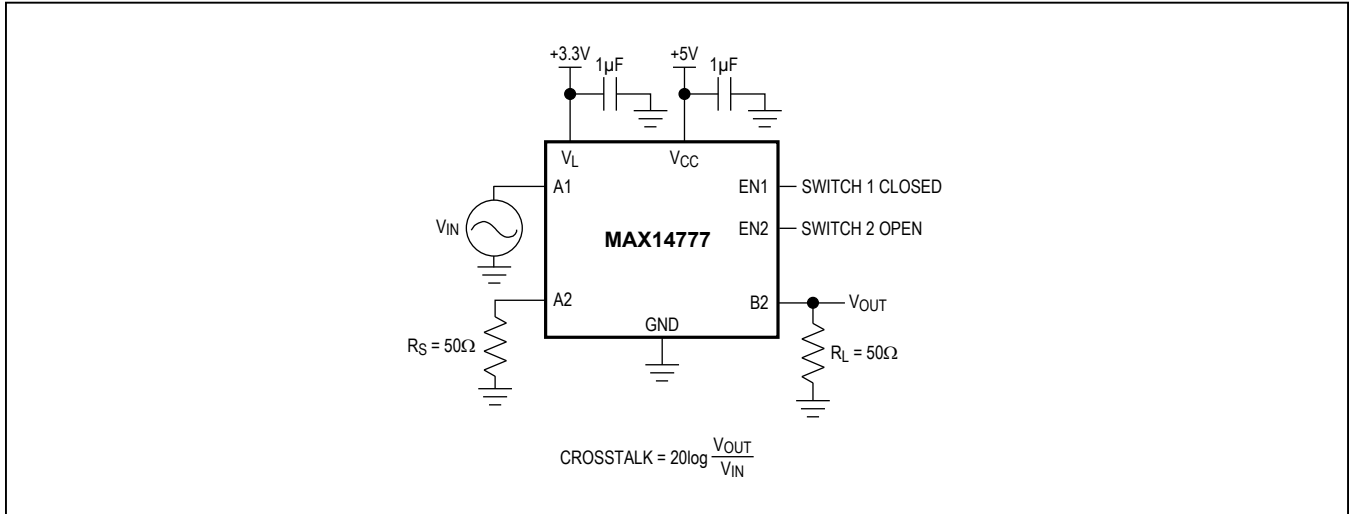


Figure 5. Crosstalk

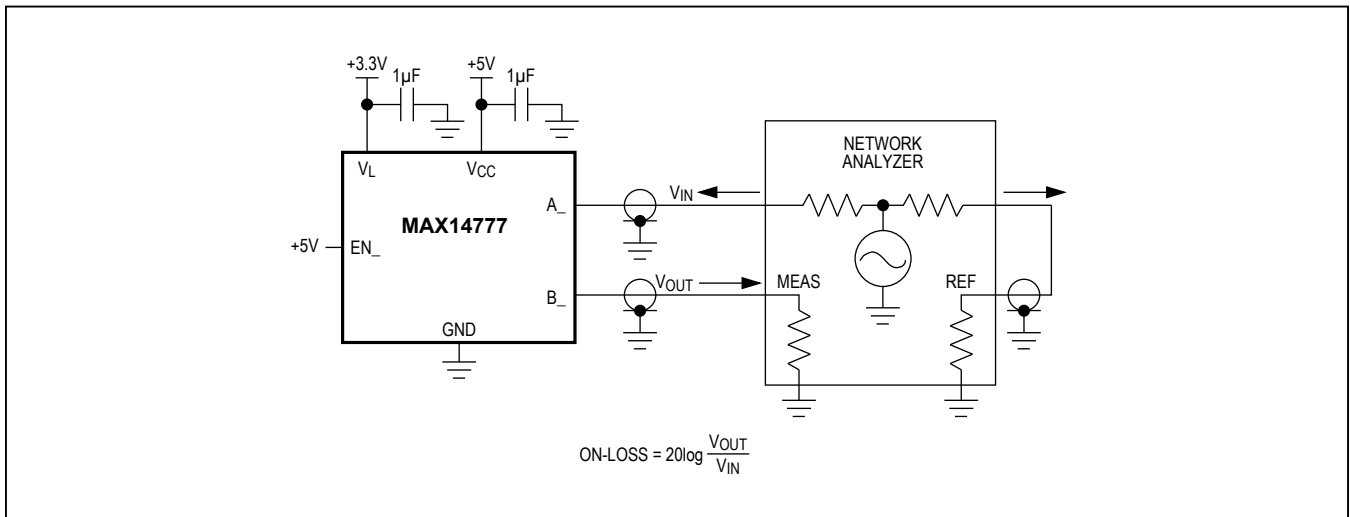


Figure 6. Frequency Response

Test Circuits/Timing Diagrams (continued)

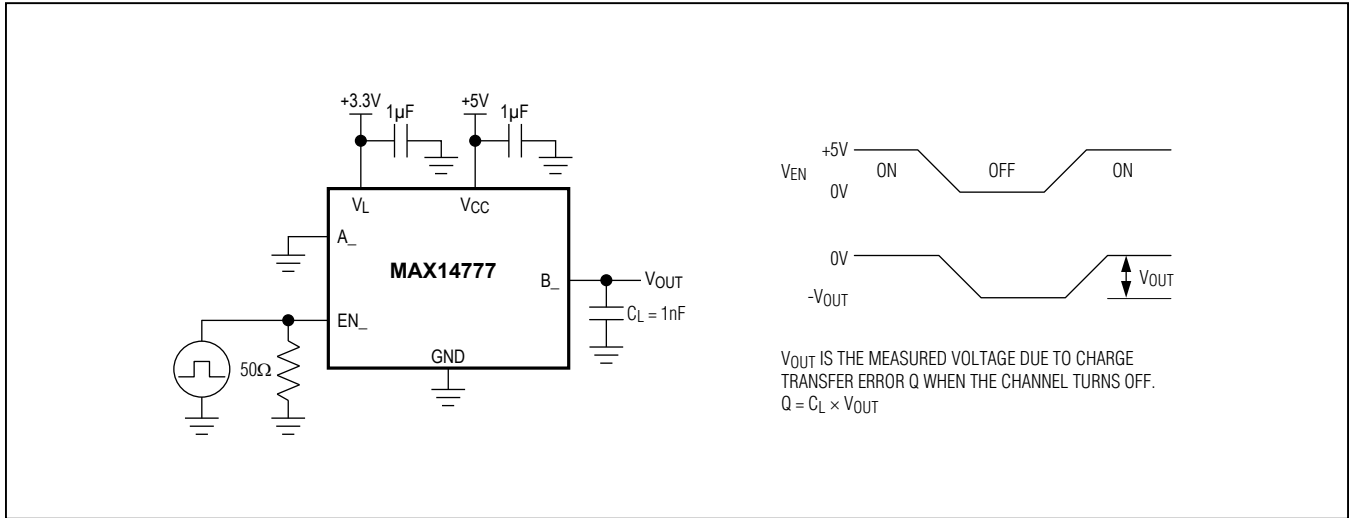
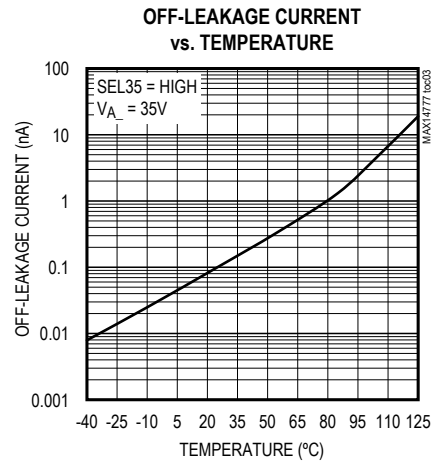
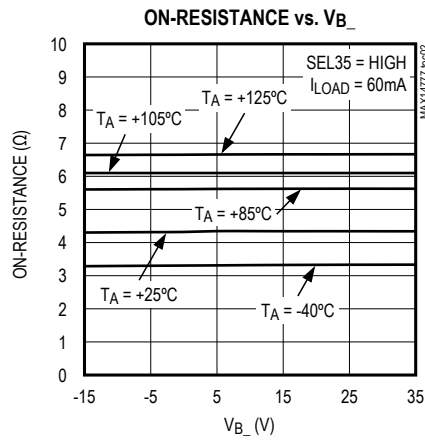
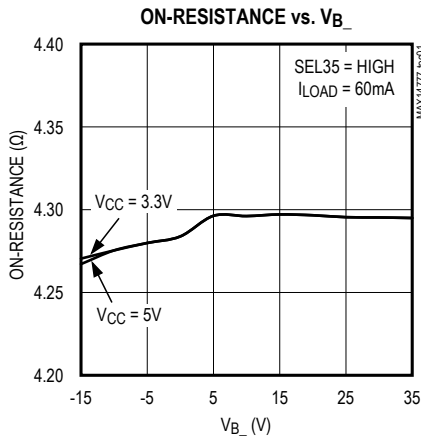


Figure 7. Charge Injection

Typical Operating Characteristics

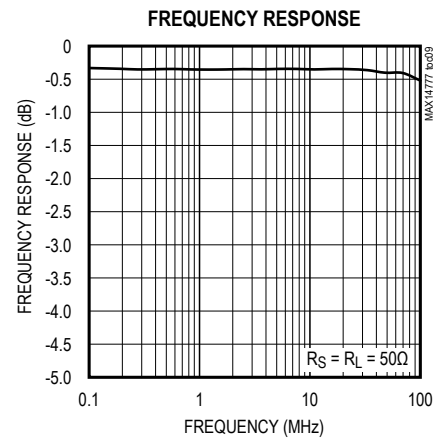
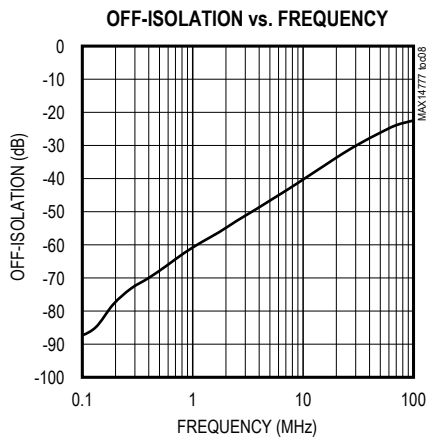
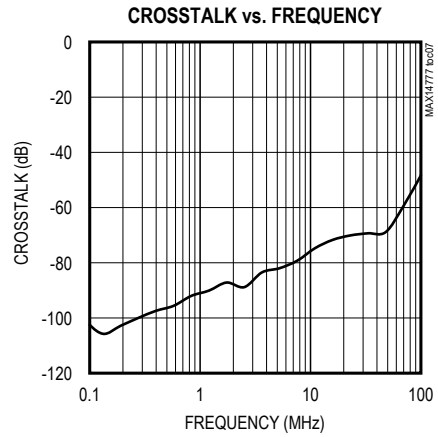
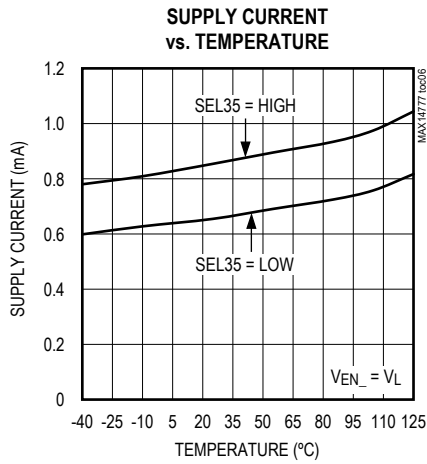
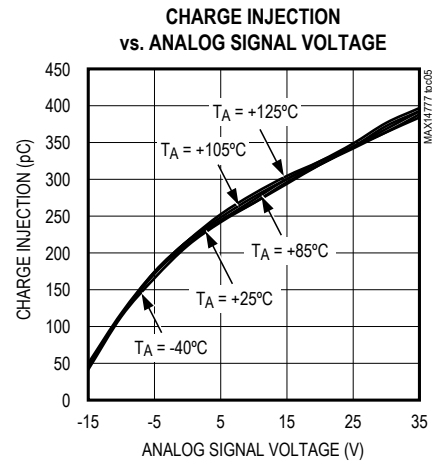
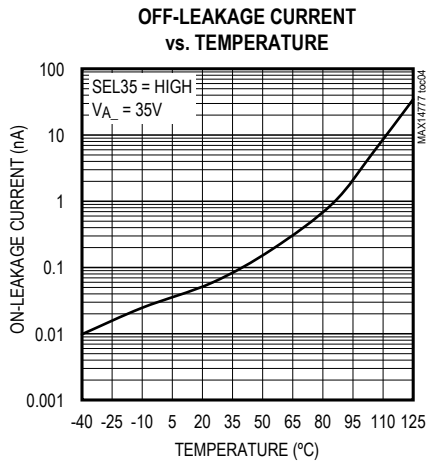
( $V_{CC} = 5V$ ,  $V_L = 3.3V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)





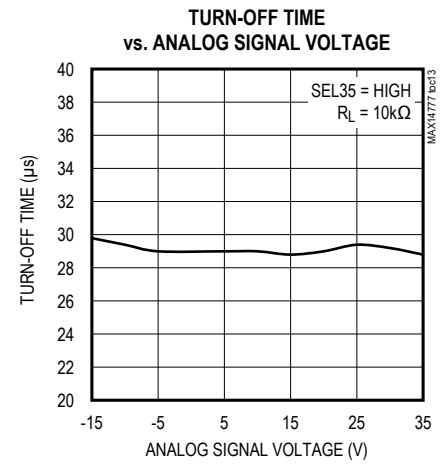
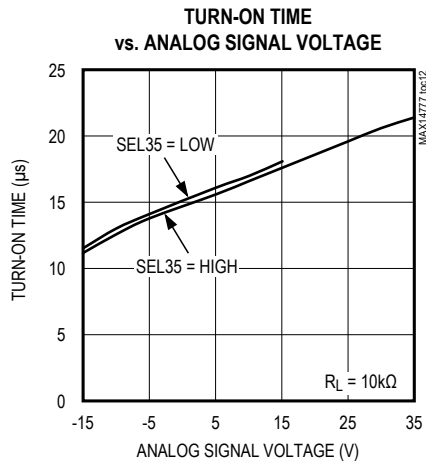
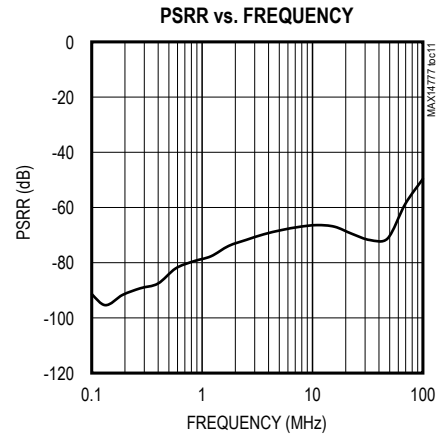
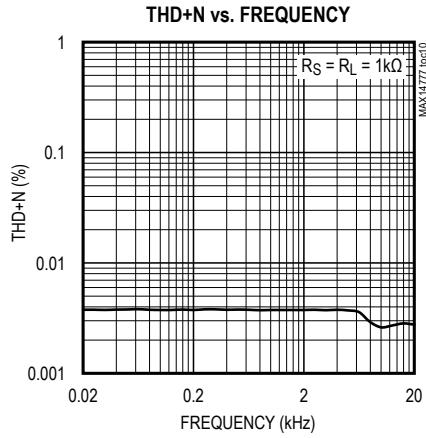
Typical Operating Characteristics (continued)

( $V_{CC} = 5V$ ,  $V_L = 3.3V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

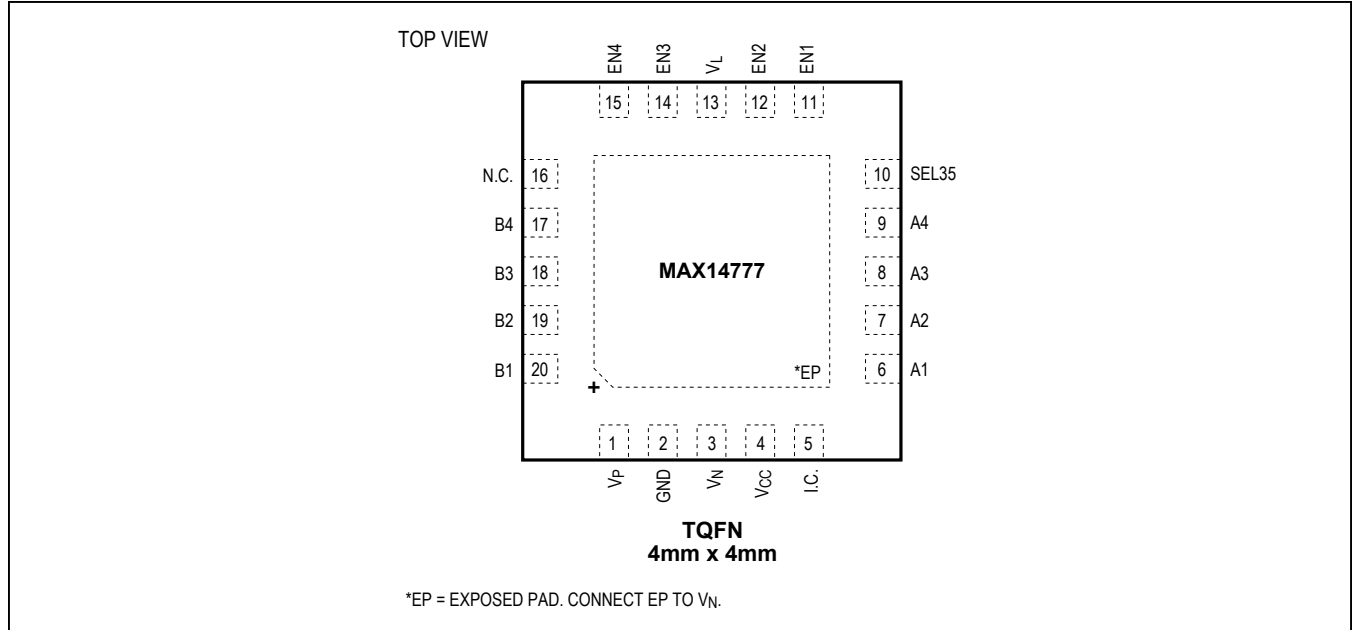


Typical Operating Characteristics (continued)

(V<sub>CC</sub> = 5V, V<sub>L</sub> = 3.3V, T<sub>A</sub> = +25°C, unless otherwise noted.)



Pin Configuration



PIN	NAME	FUNCTION
1	$V_P$	Positive Charge-Pump Output. Bypass $V_P$ to GND with a 10nF, 50V capacitor for applications with an input range of $\pm 15V$ (SEL35 = low) or a 100V capacitor for applications with an input range of $-15V/+35V$ (SEL35 = high). Place the capacitor as close as possible to the device.
2	GND	Ground
3	$V_N$	Negative Charge-Pump Output. Bypass $V_N$ to GND with a 50V, 10nF ceramic capacitor placed as close as possible to the device.
4	$V_{CC}$	Power-Supply Input. Bypass $V_{CC}$ to GND with a 1 $\mu$ F ceramic capacitor placed as close as possible to the device.
5	I.C.	Internally Connected. Connect to GND.
6	A1	Analog Switch 1 Terminal A. Switch 1 is open when EN1 is low.
7	A2	Analog Switch 2 Terminal A. Switch 2 is open when EN2 is low.
8	A3	Analog Switch 3 Terminal A. Switch 3 is open when EN3 is low.
9	A4	Analog Switch 4 Terminal A. Switch 4 is open when EN4 is low.
10	SEL35	Analog-Signal Range Select Input. Drive SEL35 low to enable the $-15V/+15V$ analog signal range. Drive SEL35 high to enable the $-15V/+35V$ analog signal range.
11	EN1	Switch 1 Control Input. Drive EN1 high to close switch 1. Drive EN1 low to open switch 1.

### Pin Description (continued)

PIN	NAME	FUNCTION
12	EN2	Switch 2 Control Input. Drive EN2 high to close switch 2. Drive EN2 low to open switch 2.
13	$V_L$	Logic Interface Reference Supply Input. Bypass $V_L$ to GND with a 1 $\mu$ F ceramic capacitor.
14	EN3	Switch 3 Control Input. Drive EN3 high to close switch 3. Drive EN3 low to open switch 3.
15	EN4	Switch 4 Control Input. Drive EN4 high to close switch 4. Drive EN4 low to open switch 4.
16	N.C.	No Connection. Not internally connected.
17	B4	Analog Switch 4 Terminal B. Switch 4 is open when EN4 is low.
18	B3	Analog Switch 3 Terminal B. Switch 3 is open when EN3 is low.
19	B2	Analog Switch 2 Terminal B. Switch 2 is open when EN2 is low.
20	B1	Analog Switch 1 Terminal B. Switch 1 is open when EN1 is low.
—	EP	Exposed Pad. Connect EP to $V_N$ . Do not connect to ground. EP is not intended as an electrical connection point.

### Detailed Description

The MAX14777 quad SPST switch supports analog signals above and below the rails with a single 3.0V to 5.5V supply. The device features up to -15V/+35V analog signal range for all switches when pin SEL35 is high. When pin SEL35 is low, the analog signal range reduces to -15V/+15V signal range, also resulting in a lower  $V_{CC}$  supply current. SEL35 trades off high-side analog signal range for supply current. Each switch has a separate control input to allow independent switching.

The MAX14777 features 10 $\Omega$  (max) on-resistance, and 9m $\Omega$  (typ)  $R_{ON}$  flatness, along with a 50nA (max at +85°C) on-leakage. For maximum signal integrity, the IC keeps this performance over the entire common-mode voltage range. Each switch can carry up to 60mA (max) of continuous current in either direction.

### Integrated Bias Generation

The MAX14777 contains a total of three charge pumps to generate bias voltages for the internal switches: a 5V regulated charge pump, a positive high-voltage charge pump ( $V_P$ ), and a negative high-voltage charge pump ( $V_N$ ). When  $V_{CC}$  is above 4.75V (typ), the 5V charge pump is bypassed and  $V_{CC}$  provides the input for the high-voltage charge pumps, reducing overall supply current.

The voltage at  $V_N$  is always -16V (typ); however, the MAX14777 features a pin-selectable (SEL35) voltage-high range for the analog signal. When the SEL35 input is low, the voltage on  $V_P$  is +26V (typ) and the analog signal range is -15V/+15V. When the SEL35 input is high, the voltage on  $V_P$  is +46V (typ) and the analog signal range is extended to -15V/+35V.

An external 10nF capacitor is required for each high-voltage charge pump between  $V_P/V_N$  and GND. Use a 50V-rated capacitor on  $V_N$ . On  $V_P$  use a 50V capacitor if SEL35 = low or use a 100V capacitor if SEL35 = high. Never use  $V_P$  or  $V_N$  to power external circuitry.

### Analog Signal Levels

The MAX14777 transmits signals above and below the rails with a single 3.0V to 5.5V supply due to its integrated bias circuitry. The analog signal range is pin selectable using the SEL35 input. Drive SEL35 low to switch signals between -15V and +15V. Drive SEL35 high to switch signals between -15V and +35V.

Setting SEL35 low reduces both turn-on delay and  $V_{CC}$  supply current.

The MAX14777 features 10 $\Omega$  (max) on-resistance and 9m $\Omega$  (typ)  $R_{ON}$  flatness for analog signals between -15V and +35V. The current flow through the switches can be bidirectional.

**V<sub>L</sub> Supply Logic Input**

The MAX14777 features a separate logic supply input (V<sub>L</sub>) that sets the high and low thresholds for the logic inputs (EN<sub>n</sub> and SEL35). This feature allows flexibility in interfacing to controllers that have a different logic level than V<sub>CC</sub>. Connect V<sub>L</sub> to a voltage between 1.62V and 5.5V for normal operation.

**Applications Information**

**Non-Powered Condition**

To understand the behavior of the MAX14777 when not powered (i.e. V<sub>CC</sub> = 0V), both the transient and DC signal conditions should be considered. Every A<sub>n</sub> and B<sub>n</sub> pin has internal diodes to V<sub>P</sub> and V<sub>N</sub>, as shown in Figure 8. Applying a positive voltage on A<sub>n</sub> or B<sub>n</sub> charges the V<sub>P</sub> capacitor through the diode to V<sub>P</sub>. Applying a negative voltage on A<sub>n</sub> or B<sub>n</sub> charges the V<sub>N</sub> capacitor negative through the diode to V<sub>N</sub>. Switch terminals A<sub>n</sub>, B<sub>n</sub> are tolerant to high-voltage signals ranging from -15V to +35V when device is unpowered; i.e., V<sub>CC</sub> = 0 or V<sub>CC</sub> floating.

Once the capacitor is charged to a DC voltage, the I<sub>L\_IO\_OFF</sub> current flows. Thus, under transient conditions, applying a changing voltage to an A<sub>n</sub> or B<sub>n</sub> pin results in flow into or out of the pin due to a charge movement at the external capacitors on V<sub>P</sub> and V<sub>N</sub>.

Under DC conditions, when a voltage is applied to an A<sub>n</sub> or B<sub>n</sub> pin, with V<sub>CC</sub> unpowered, the switch is open when the voltage difference between the A<sub>n</sub> and B<sub>n</sub> pin is larger than 3V. Under these conditions, DC leakage current flows into the pin. When |V<sub>A</sub> - V<sub>B</sub>| < 3V DC, the switch is not fully open, and currents up to a few mA can flow between A<sub>n</sub> and B<sub>n</sub>.

If SEL35 is connected low, the V<sub>P</sub> capacitor charges to about 25V. Applying a positive voltage above about 25V on A<sub>n</sub> or B<sub>n</sub> charges the V<sub>P</sub> capacitor through the diode to V<sub>P</sub>. Once the V<sub>P</sub> capacitor is charged to this increased voltage, current flow from A<sub>n</sub> or B<sub>n</sub> ceases. Thus, even when SEL35 is low, any of A<sub>n</sub> or B<sub>n</sub> tolerate voltages up to 35V.

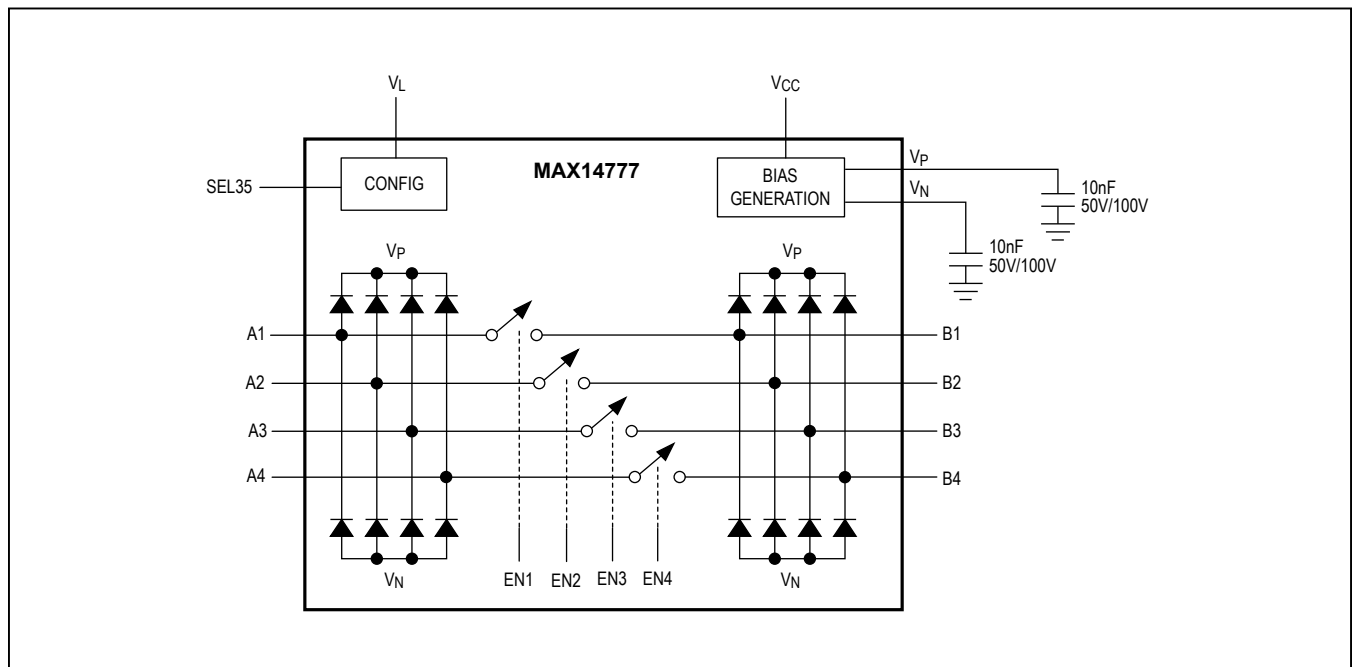


Figure 8. Typical Application Circuit

**Application Example**

The MAX14777 can be used for designing an industrial single-supply analog input module that supports both  $\pm 15\text{V}$  voltages and  $4\text{mA}$ – $20\text{mA}$  current measurements. In this scheme, the MAX14777 switches in a  $250\Omega$  resistor, typically used for translating the current-loop current to a voltage for analog measurement, as shown in Figure 9. By using three of the four MAX14777 switches, which provide accurate current and voltage measurement, the device handles voltages up to  $36\text{V}$ , as maximally found in current-loop power supplies. In voltage measurement

mode, with switch positions as shown in Figure 9, analog input voltages in the  $\pm 15\text{V}$  range are switched to the amplifier input. Invert all switch positions for current loop measurement operation.

When the analog input module is not powered, the MAX14777 tolerates and protects the resistor and PGA against voltages mistakenly connected to the AIN terminal.

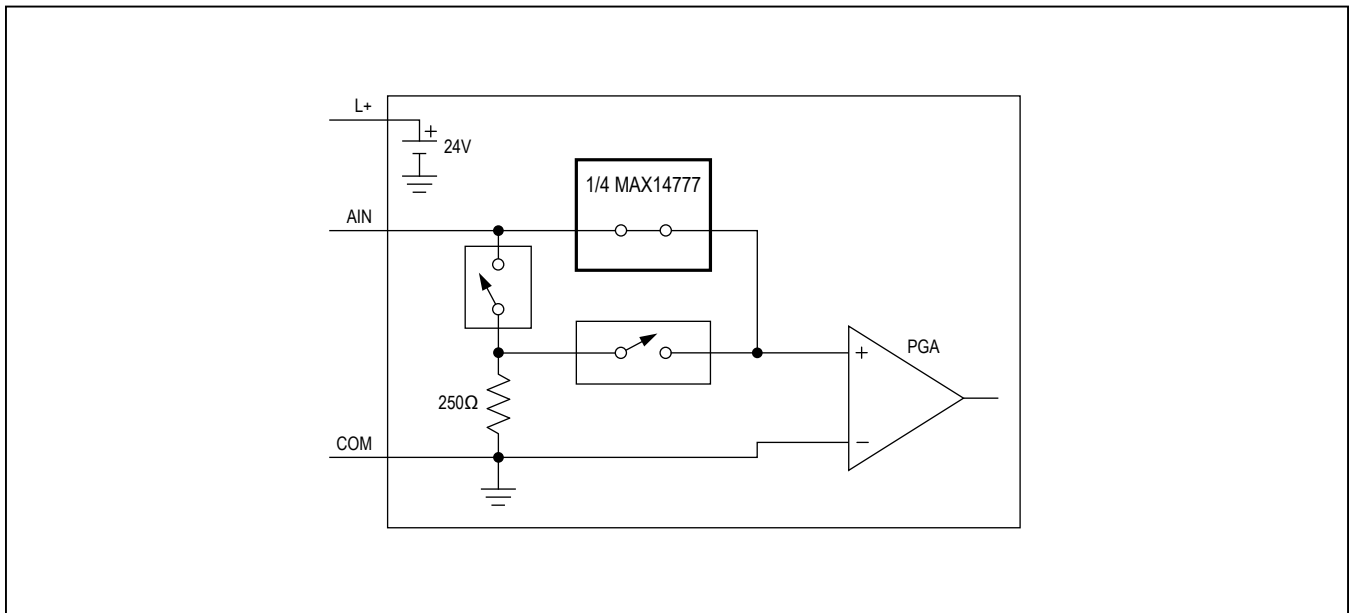


Figure 9. Analog Input Module for Voltage and Current Loop Measurement

MAX14777

Quad Beyond-the-Rails -15V to +35V  
Analog Switch

### Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX14777GTP+	-40°C to +105°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](http://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	T2044+4	<a href="#">21-0139</a>	<a href="#">90-0409</a>

## Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	6/13	Initial release	—
1	10/13	Removed reference to prereleased op amp	14

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](http://www.maximintegrated.com).

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