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

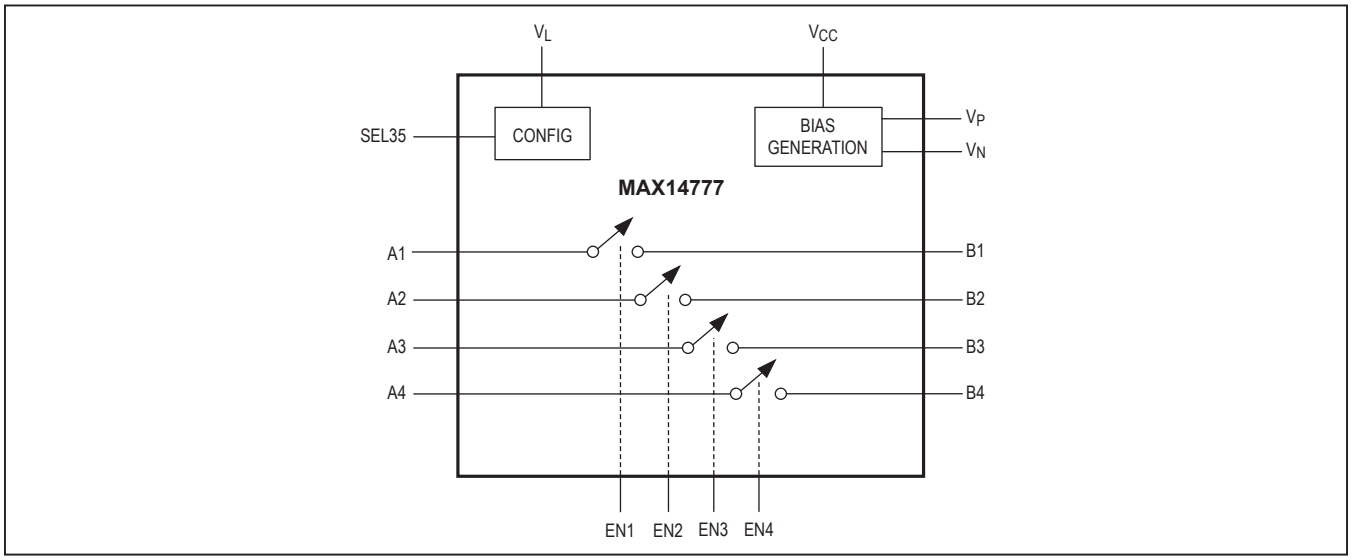
Benefits and Features

- 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°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.**

Functional Diagram



For related parts and recommended products to use with this part, refer to www.maximintegrated.com/MAX14777 related.

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Absolute Maximum Ratings

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

V_{CC} ..... -0.3V to +6V
V_L ..... -0.3V to +6V
EN1, EN2, EN3, EN4, SEL35, I.C ..... -0.3V to +6V
A1, A2, A3, A4, B1, B2, B3, B4 ..... (V_N - 0.3V) to the lesser of (V_P + 0.3V) and (V_N + 70V)
V_P
  SEL35 = High ..... -0.3V to +70V
  SEL35 = Low ..... -0.3V to +48V
V_P to V_N ..... -0.3V to +70V
V_N ..... the greater of -26V and (V_P - 70V) to +0.3V
Absolute Difference Between Switch I/Os (| A_ - B_ |) 70V
Continuous Current ..... ±80mA
Continuous Power Dissipation (T_A = +70°C) .....
  TQFN (derate 25.6mW/°C above +70°C) 2051.3mW
Operating Temperature Range ..... -40ºC to +105ºC
Junction Temperature ..... +150ºC
Storage Temperature Range ..... -65ºC 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_{JA})
  TQFN ..... 39°C/W
Junction-to-Case Thermal Resistance (θ_{JC})
  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**.

Electrical Characteristics

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

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
DC CHARACTERISTICS							
Supply Voltage Range	V_{CC}			3.0		5.5	V
V_L Supply Voltage Range	V_L			1.62		5.5	V
V_{CC} Supply Current	I_{CC}	V_{CC} = 3.3V, $V_{EN_}$ = V_L	SEL35 = low		1.8	3.4	mA
			SEL35 = high		2.2	4.3	
		V_{CC} = 5.5V, $V_{EN_}$ = V_L	SEL35 = low		0.6	1.2	
			SEL35 = high		0.8	1.65	
V_L Supply Current	I_L	SEL35, EN_ = low or high		-1		+1	µA
Analog Signal Range	$V_{A_}$, $V_{B_}$	SEL35 = low		-15		+15	V
		SEL35 = high		-15		+35	
Positive High-Voltage Charge-Pump Output (Note 3)	V_P	SEL35 = low		22.5		27.1	V
		SEL35 = high		41.7		49.8	
Negative High-Voltage Charge-Pump Output	V_N	(Note 3)		-18.2		-14.9	V
Continuous Current Through Switch	$I_{A_}$	EN_ = high		-60		+60	mA

Electrical Characteristics (continued)

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

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
On-Resistance, Figure 1	R_{ON}	-15V ≤ $V_{A_}$ ≤ +35V, SEL35 = high, I_{IN} = ±60mA, Figure 1			4.4	10	Ω
		-15V ≤ $V_{A_}$ ≤ +15V, SEL35 = low, I_{IN} = ±60mA, Figure 1			4.4	10	
On-Resistance Flatness	ΔR_{ON}	-15V ≤ $V_{A_}$ ≤ +35V, SEL35 = high, I_{IN} = ±60mA			9	150	mΩ
		-15V ≤ $V_{A_}$ ≤ +15V, SEL35 = low, I_{IN} = ±60mA			8	150	
On-Resistance Matching Between Channels	ΔR_{ON_M}	-15V ≤ $V_{A_}$ ≤ +35V, SEL35 = high, I_{IN} = ±60mA, (Note 4)				200	mΩ
		-15V ≤ $V_{A_}$ ≤ +15V, SEL35 = low, I_{IN} = ±60mA, (Note 4)				200	
A_ Off-Leakage Current	$I_{L_OFF_A}$	-15V ≤ $V_{A_}$ ≤ +35V, SEL35 = high, $V_{B_}$ = 0V, +40°C ≤ T_A ≤ +85°C, Figure 2		-20		+20	nA
		-15V ≤ $V_{A_}$ ≤ +35V, SEL35 = high, $V_{B_}$ = 0V, +40°C ≤ T_A ≤ +105°C, Figure 2		-80		+80	
B_ Off-Leakage Current	$I_{L_OFF_B}$	-15V ≤ $V_{B_}$ ≤ +35V, SEL35 = high, $V_{A_}$ = 0V, +40°C ≤ T_A ≤ +85°C, Figure 2		-20		+20	nA
		-15V ≤ $V_{B_}$ ≤ +35V, SEL35 = high, $V_{A_}$ = 0V, +40°C ≤ T_A ≤ +105°C, Figure 2		-80		+80	
On-Leakage Current	I_{L_ON}	-15V ≤ $V_{A_}$ ≤ +35V, SEL35 = high, B_ unconnected, +40°C ≤ T_A ≤ +85°C, Figure 2		-50		+50	nA
		-15V ≤ $V_{A_}$ ≤ +35V, SEL35 = high, B_ unconnected, +40°C ≤ T_A ≤ +105°C, Figure 2		-200		+200	
A_ Power-Off Leakage Current	$I_{L_PWROFF_A}$	$V_{CC_}$ = 0V or unconnected, $\lvert V_{A_} - V_{B_}\rvert$ > 3V, current measured at A	-15V ≤ $V_{A_}$ ≤ +35V	-5		+5	µA
B_ Power-Off Leakage Current	$I_{L_PWROFF_B}$	$V_{CC_}$ = 0V or unconnected, $\lvert V_{A_} - V_{B_}\rvert$ > 3V, current measured at B	-15V ≤ $V_{A_}$ ≤ +35V	-5		+5	µA
DIGITAL LOGIC (EN1, EN2, EN3, EN4, SEL35)							
Input Voltage Low	V_{IL}					0.3 x V_L	V
Input Voltage High	V_{IH}			0.7 x V_L			V
Input Leakage Current	I_{DLKG}	$V_{EN_}$ = low or high		-1		+1	µA

Electrical Characteristics (continued)

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

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
AC CHARACTERISTICS							
Power-Up Time	t_{PWRON}	C_{VP} = C_{VN} = 10nF (Note 6)			5		ms
Enable Turn-On Time	t_{ON}	$V_{A_}$ = ±10V, SEL35 = low, R_L = 10kΩ, Figure 3				40	µs
		$V_{A_}$ = ±10V, SEL35 = high, R_L = 10kΩ, Figure 3				40	
Enable Turn-Off Time	t_{OFF}	$V_{A_}$ = ±10V, R_L = 10kΩ, Figure 3 (Note 5)				100	µs
Off-Isolation	V_{ISO}	$V_{A_}$ = $1V_{RMS}$, f = 100kHz, R_L = 50Ω, 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 = 50Ω, 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 = 50Ω, Figure 6			380		MHz
Total Harmonic Distortion	THD+N	R_S = R_L = 1kΩ, 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
THERMAL SHUTDOWN							
Thermal Shutdown Threshold	T_{SHDN}	Temperature rising			160		°C
Thermal Shutdown Hysteresis	T_{HYST}				32		°C
ESD PROTECTION							
All Pins		Human Body Model			±2		kV

Note 2: All units are 100% production tested at +85°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 ≤ $V_{A_}$ ≤ +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

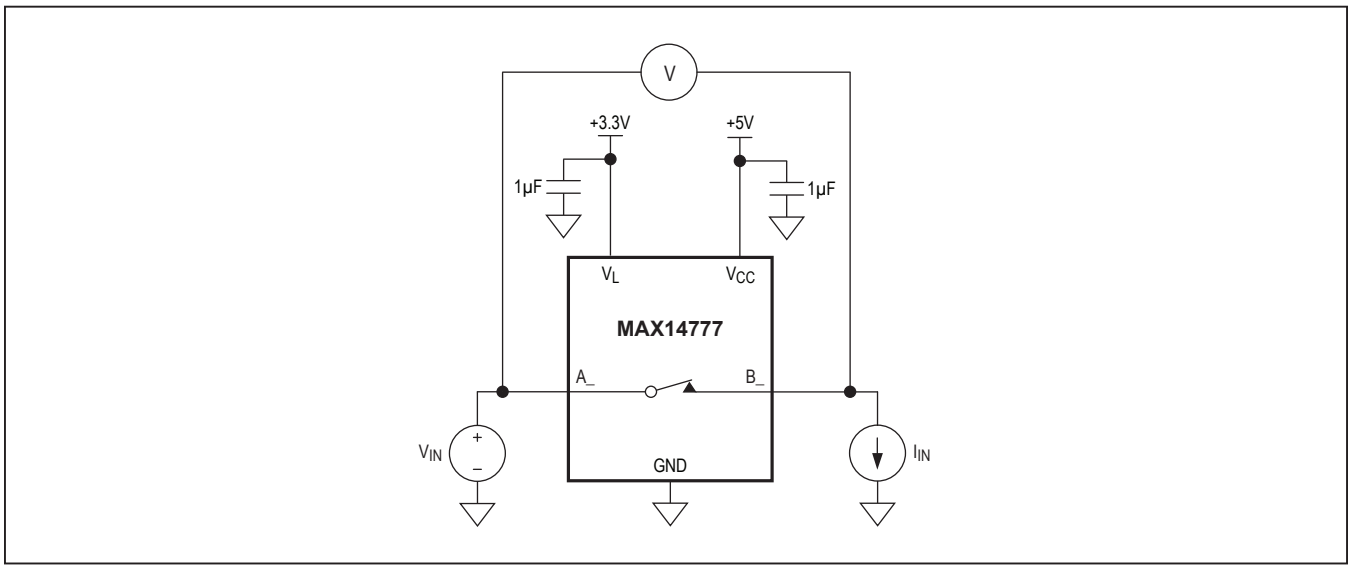


Figure 1. On-Resistance Measurement

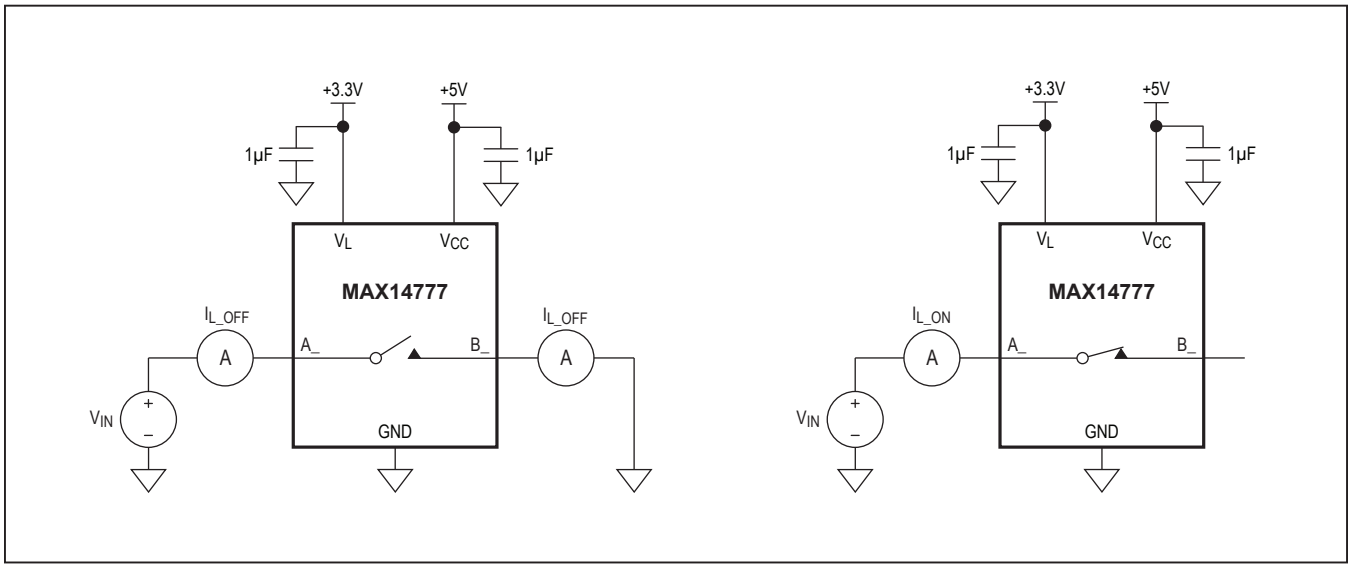


Figure 2. Leakage Current Measurements

Test Circuits/Timing Diagrams (continued)

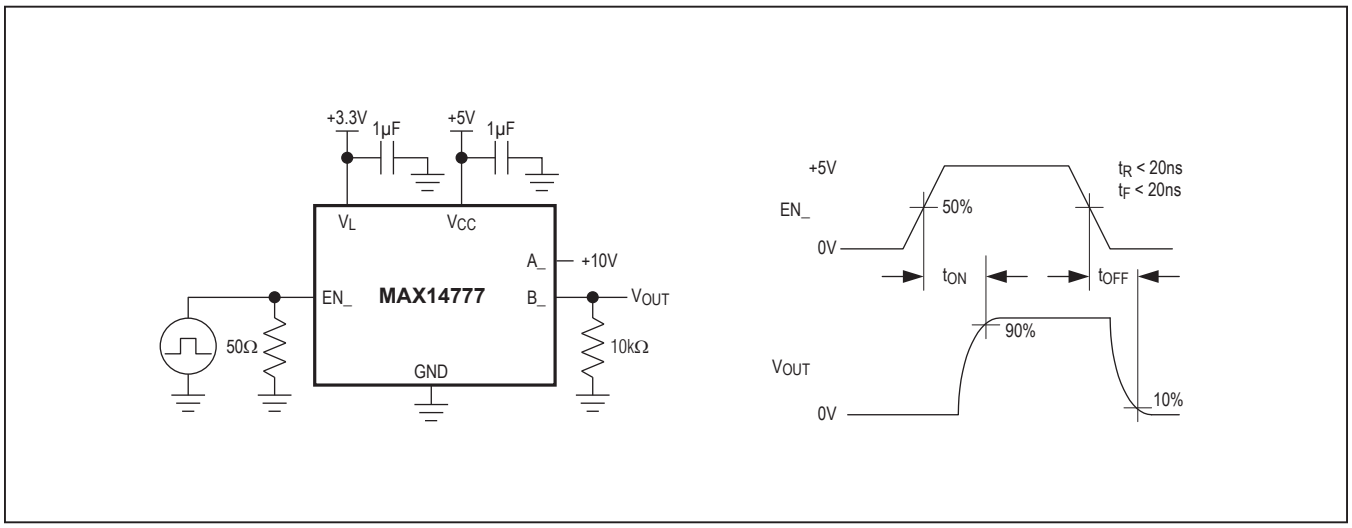


Figure 3. Enable Switching Time

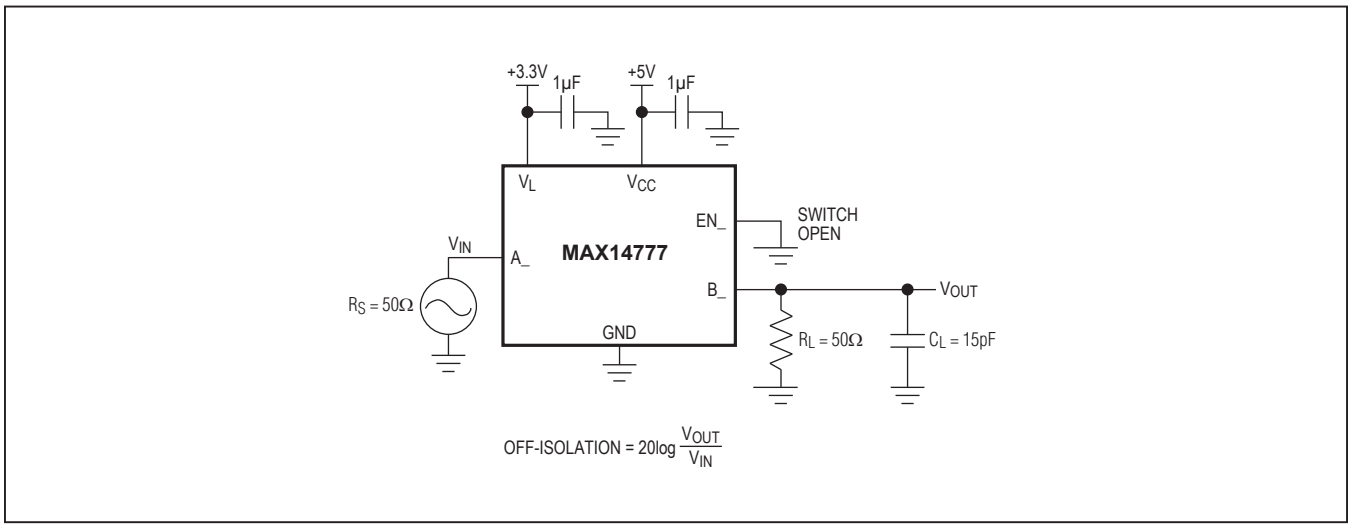


Figure 4. Off-Isolation

Test Circuits/Timing Diagrams (continued)

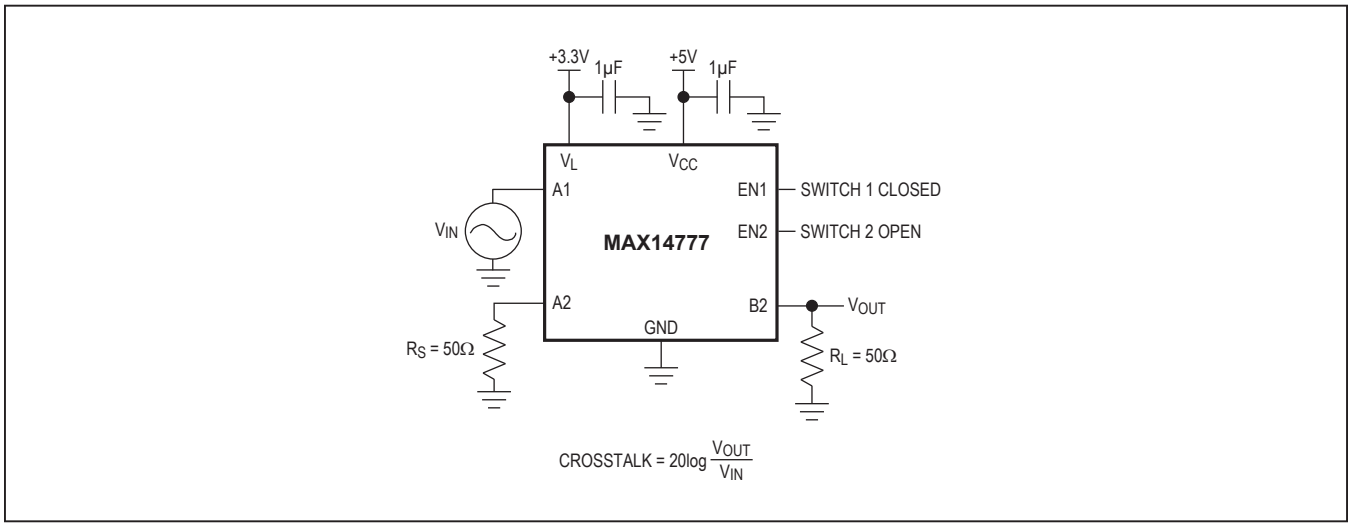


Figure 5. Crosstalk

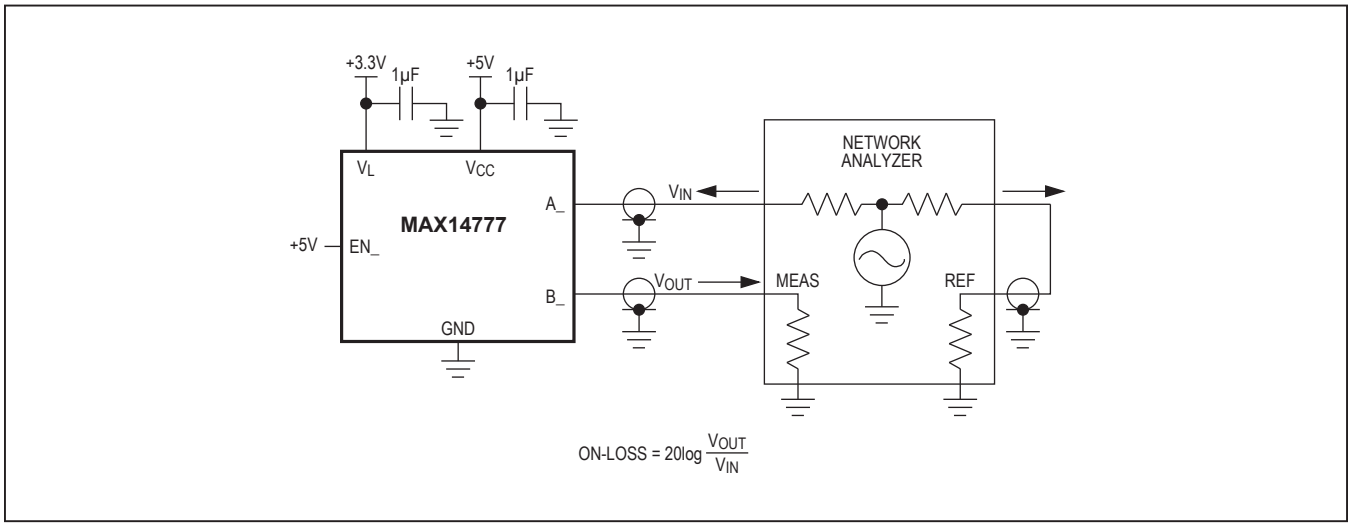


Figure 6. Frequency Response

Test Circuits/Timing Diagrams (continued)

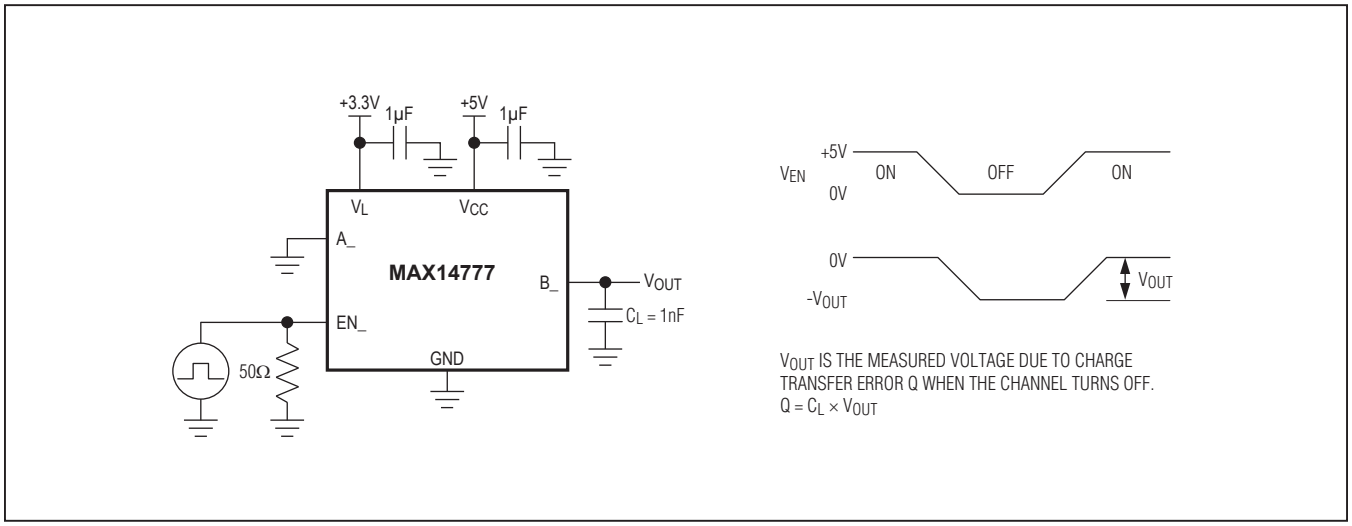
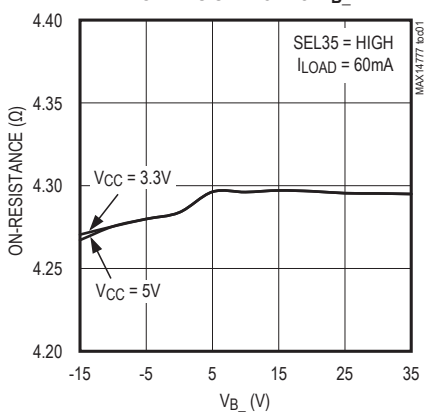
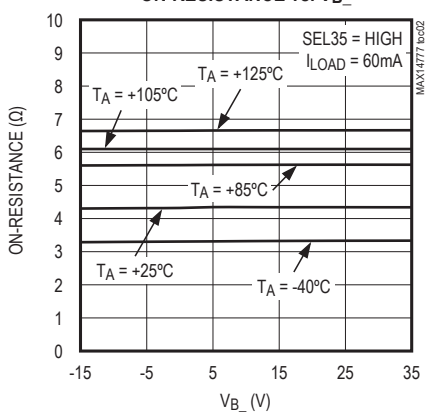


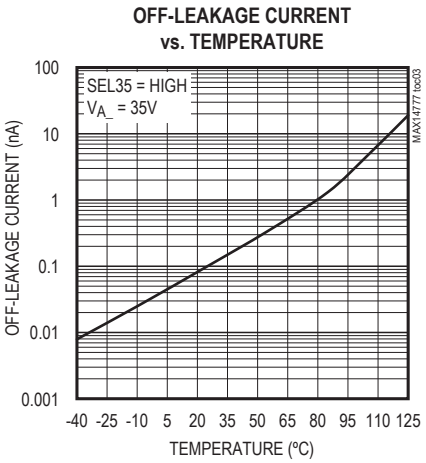
Figure 7. Charge Injection

Typical Operating Characteristics

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



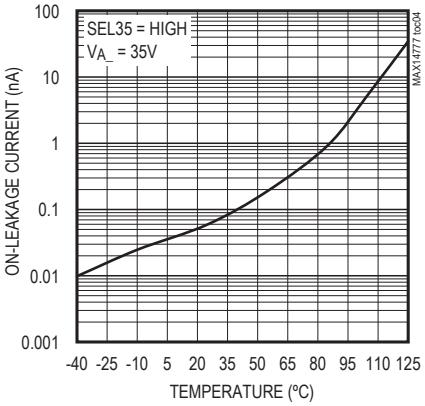




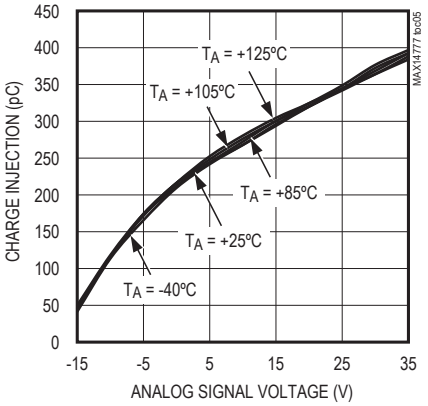
Typical Operating Characteristics (continued)

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

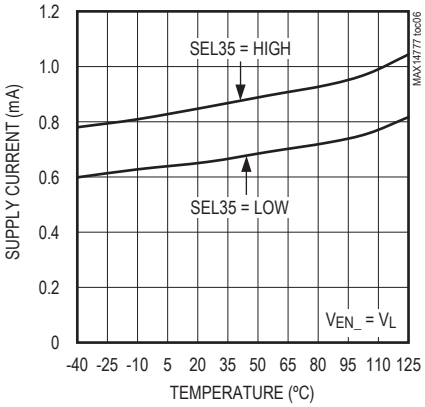
OFF-LEAKAGE CURRENT vs. TEMPERATURE



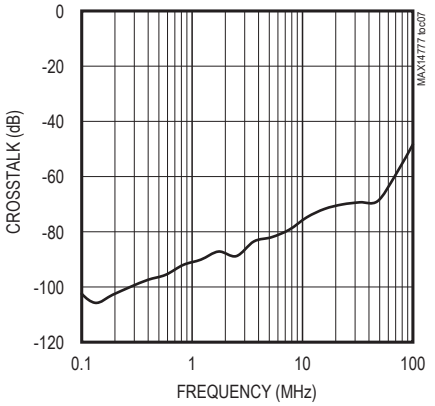
CHARGE INJECTION vs. ANALOG SIGNAL VOLTAGE



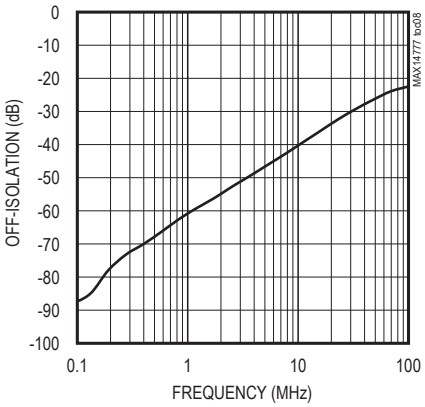
SUPPLY CURRENT vs. TEMPERATURE



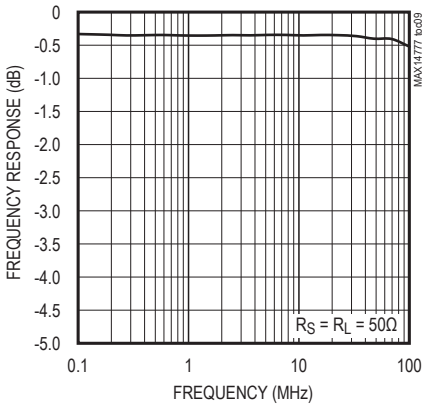
CROSSTALK vs. FREQUENCY



OFF-ISOLATION vs. FREQUENCY



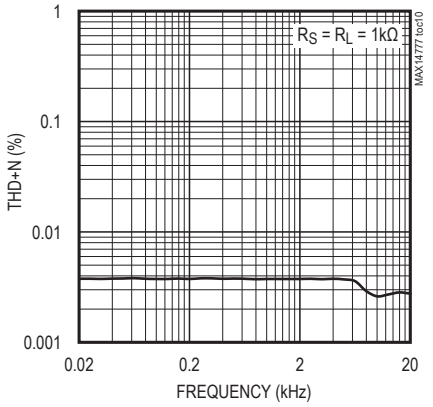
FREQUENCY RESPONSE



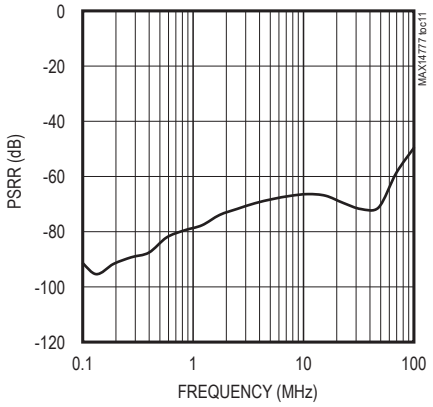
Typical Operating Characteristics (continued)

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

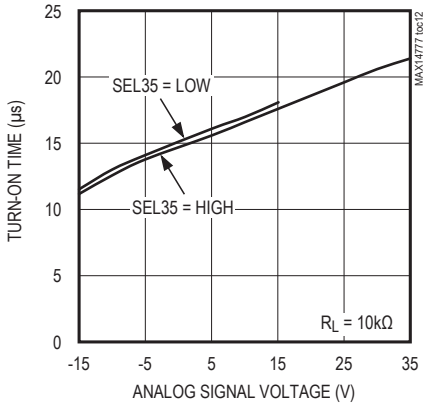
THD+N vs. FREQUENCY



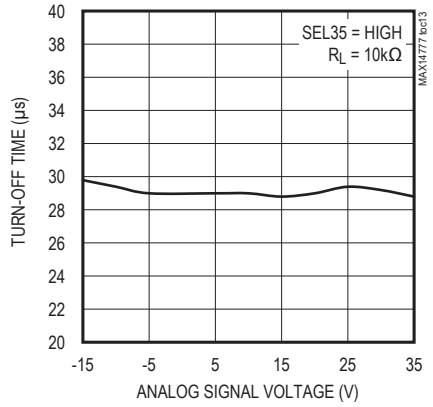
PSRR vs. FREQUENCY



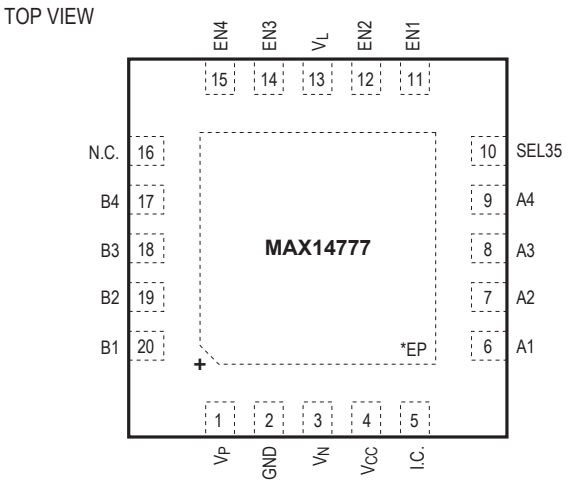
TURN-ON TIME vs. ANALOG SIGNAL VOLTAGE



TURN-OFF TIME vs. ANALOG SIGNAL VOLTAGE



Pin Configuration



TQFN
4mm x 4mm

*EP = EXPOSED PAD. CONNECT EP TO V_N.

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 ±15V (SEL35 = low) or a 100V capacitor for applications with an input range of -15V/+35V (SEL 35 = 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 1µF 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 1µF 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 10Ω (max) on-resistance, and 9mΩ (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 10Ω (max) on-resistance and 9mΩ (typ) R_{ON} flatness for analog signals between -15V and +35V. The current flow through the switches can be bidirectional.

V_L Supply Logic Input

The MAX14777 features a separate logic supply input (V_L) that sets the high and low thresholds for the logic inputs (EN_ and SEL35). This feature allows flexibility in interfacing to controllers that have a different logic level than V_{CC}. Connect V_L 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_{CC} = 0V), both the transient and DC signal conditions should be considered. Every A_ and B_ pin has internal diodes to V_P and V_N, as shown in Figure 8. Applying a positive voltage on A_ or B_ charges the V_P capacitor through the diode to V_P. Applying a negative voltage on A_ or B_ charges the V_N capacitor negative through the diode to V_N. Switch terminals A_, B_ are tolerant to high-voltage signals ranging from -15V to +35V when device is unpowered; i.e, V_{CC} = 0 or V_{CC} floating.

Once the capacitor is charged to a DC voltage, the $I_{L_IO_OFF}$ current flows. Thus, under transient conditions, applying a changing voltage to an A_ or B_ pin results in flow into or out of the pin due to a charge movement at the external capacitors on V_P and V_N.

Under DC conditions, when a voltage is applied to an A_ or B_ pin, with V_{CC} unpowered, the switch is open when the voltage difference between the A_and B_ pin is larger than 3V. Under these conditions, DC leakage current flows into the pin. When $|V_A - V_B| < 3V$ DC, the switch is not fully open, and currents up to a few mA can flow between A_ and B_.

If SEL35 is connected low, the V_P capacitor charges to about 25V. Applying a positive voltage above about 25V on A_ or B_ charges the V_P capacitor through the diode to V_P. Once the V_P capacitor is charged to this increased voltage, current flow from A_ or B_ ceases. Thus, even when SEL35 is low, any of A_ or B_ tolerate voltages up to 35V.

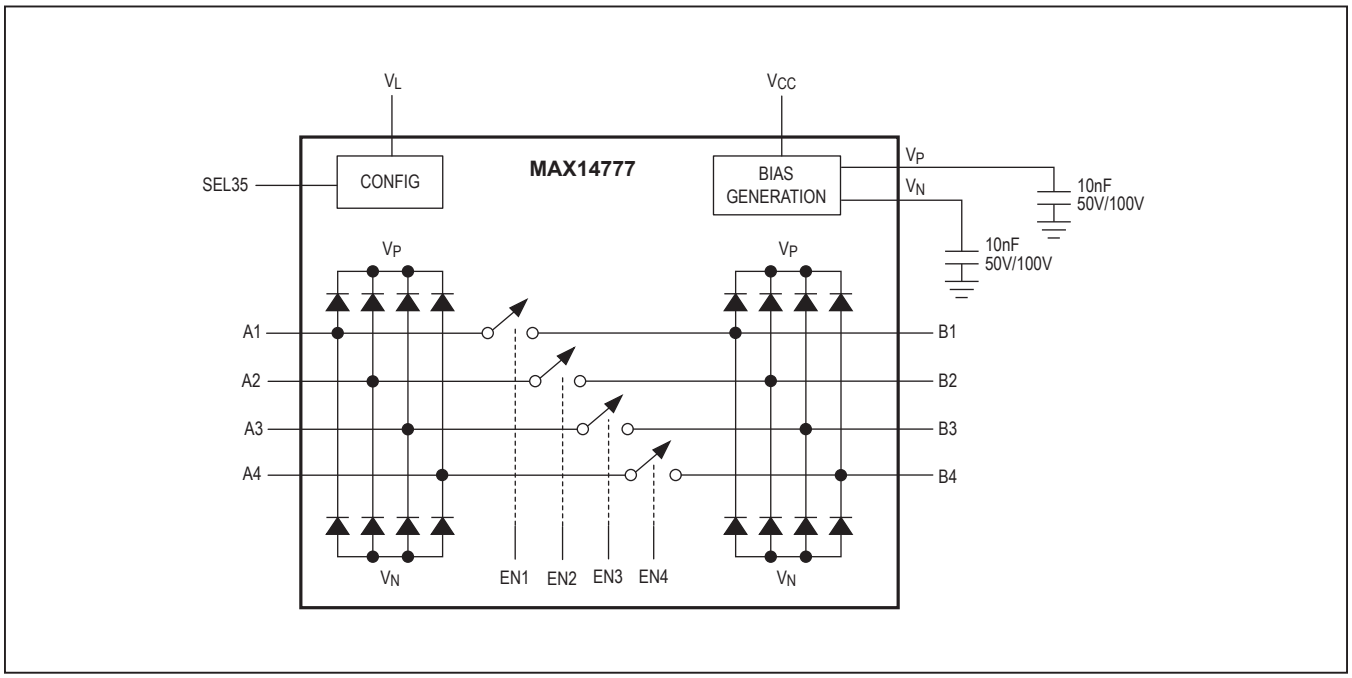


Figure 8. Typical Application Circuit

Application Example

The MAX14777 can be used for designing an industrial single-supply analog input module that supports both ±15V voltages and 4mA–20mA current measurements. In this scheme, the MAX14777 switches in a 250Ω 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 36V, 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 ±15V 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.

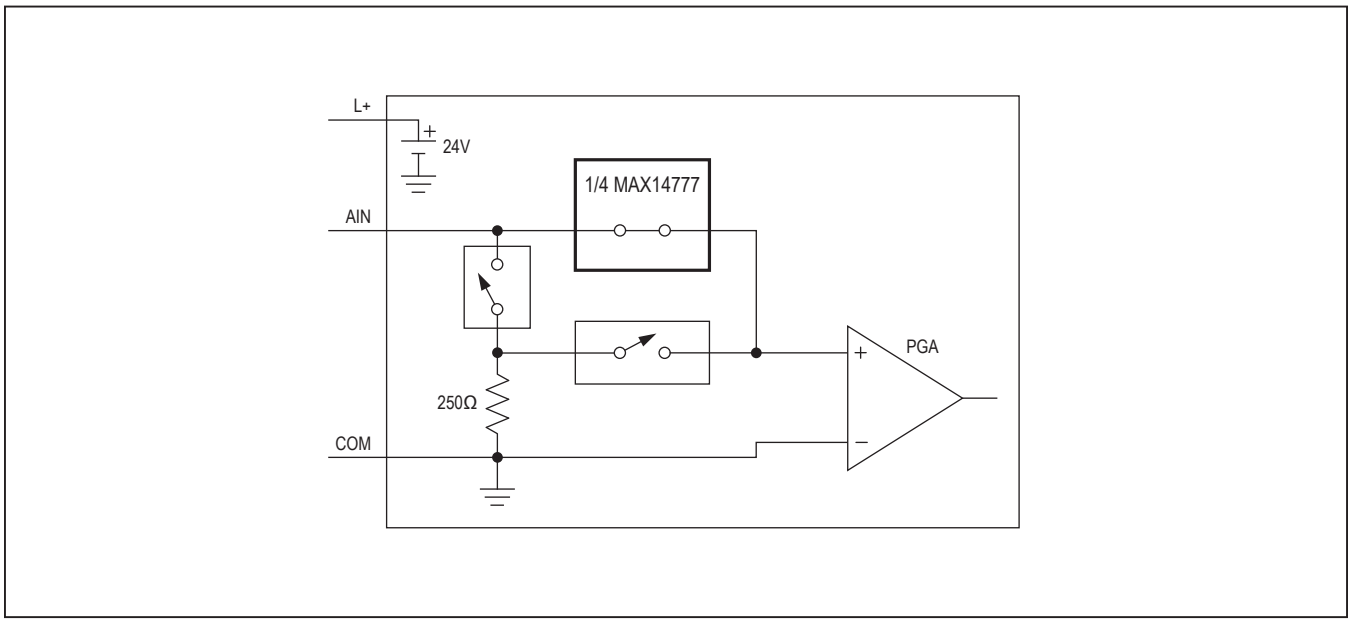


Figure 9. Analog Input Module for Voltage and Current Loop Measurement

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**. 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	**21-0139**	**90-0409**

Revision History

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

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