MAX44290

1.8V, 15MHz, Low-Offset, Low-Power, Rail-to-Rail I/O Op Amp

General Description

The MAX44290 offers a unique combination of high-speed, precision, and low-voltage operation, making it ideally suited for a large number of signal-processing functions, such as filtering and amplification of signals in portable and industrial equipment.

This amplifier features an input offset of less than 50μV and a high-gain bandwidth product of 15MHz while maintaining a low 1.8V supply rail. The device's rail-to-rail input/outputs and low noise guarantee maximum dynamic range in demanding applications, such as 12- to 14-bit SAR ADC drivers. Unlike traditional rail-to-rail input structures, input crossover distortion is absent due to an optimized input stage with an ultra-quiet charge pump.

The device includes a fast-power-on shutdown mode for further power savings. The operational amplifier operates from a supply range of 1.8V to 5.5V over the -40°C to +125°C temperature range, and can operate down to 1.7V over the 0°C to +70°C temperature range. It is available in a tiny, 6-bump wafer-level package (WLP) with 0.4mm pitch.

Applications

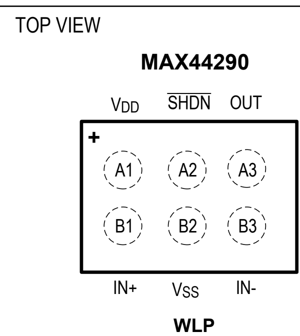
- Notebooks
- 3G/4G Handsets
- Portable Medical Instruments
- Battery-Operated Devices
- Analog-to-Digital Converter Buffers
- Transimpedance Amplifiers
- General-Purpose Signal Processing

Benefits and Features

- Low 1.8V Supply Rail over the -40°C to +125°C Range
- 1.7V Supply Rail over 0°C to +70°C Range
- 15MHz Unity-Gain Bandwidth
- Low 12.7nV/$\sqrt{Hz}$ Input Voltage-Noise Density
- Low 50μV (max) Input Offset Voltage at +25°C
- 500fA Low Input Bias Current
- 750μA Quiescent Current
- <1μA Supply Current in Shutdown
- Low 105dB Total Harmonic Distortion

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

Pin Configuration



19-8452; Rev 4; 2/21

TABLE OF CONTENTS

LIST OF FIGURES

Absolute Maximum Ratings

Supply Voltage (V_{DD} to V_{SS}) .... -0.3V to +6V
SHDN .... -0.3V to +6V
IN+, IN- Maximum Voltage .... Self Limiting*
OUT .... (V_{SS} - 0.3V) to (V_{DD} + 0.3V)
Output Short-Circuit Duration to V_{DD} or V_{SS} .... Continuous
Continuous Input Current (any pins) .... ±20mA
Differential Input Voltage .... ±6V
* Note ....Not to exceed +6V

Continuous Power Dissipation (T_A = +70°C)
(derate 10.50mW/°C above +70°C) 840mW
Junction-to-Ambient Thermal Resistance (θ_{JA}) ...... 95.15°C/W
Junction-to-Case Thermal Resistance (θ_{JC}) .... 70°C/W
Operating Temperature Range ....-40°C to +125°C
Junction Temperature .... +150ºC
Storage Temperature Range ....-65ºC to +150ºC
Lead Temperature (soldering, 10s).................................. +300ºC

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.

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.

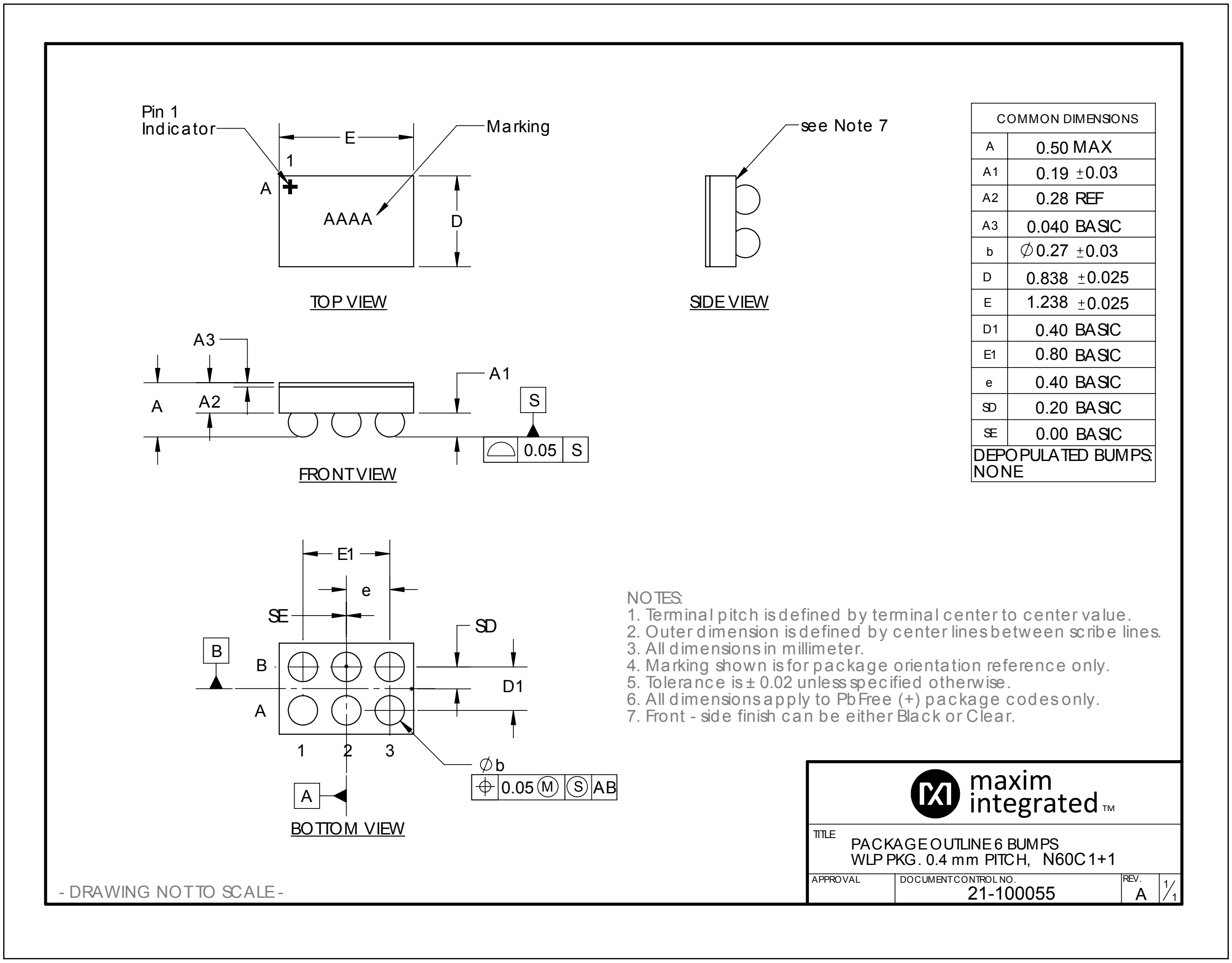
Package Information

6 WLP

Package Code	N60C1+1
Outline Number	21-100055
Land Pattern Number	Refer to *Application Note 1891*

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 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} = 3.3V, V_{SS} = 0V, V_{IN+} = V_{IN-} = V_{DD}/2, R_{LOAD} = 10kΩ to V_{DD}/2, $V_{\overline{SHDN}}$ = V_{DD}, T_A = -40°C to +125°C, unless otherwise noted. Typical values are at +25°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
POWER SUPPLY						
Supply Voltage Range	V_{DD}	Guaranteed by PSRR	1.8		5.5	V
		Over 0°C < T_A < +70°C	1.7		5.5	
Power-Supply Rejection Ratio	PSRR	V_{CM} = V_{DD}/2	82	95		dB
Quiescent Current	I_{DD}	R_{LOAD} = no load		750	1200	µA
Shutdown Supply Current	I_{SHDN}				1	µA
Shutdown Input Low	V_{IL}				0.5	V

Electrical Characteristics (continued)

(V_{DD} = 3.3V, V_{SS} = 0V, V_{IN+} = V_{IN-} = V_{DD}/2, R_{LOAD} = 10kΩ to V_{DD}/2, $V_{\overline{SHDN}}$ = V_{DD}, T_A = -40°C to +125°C, unless otherwise noted. Typical values are at +25°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Shutdown Input High	V_{IH}			1.3			V
Output Leakage Current in Shutdown					100		pA
Shutdown Input Bias Current	I_{IL}/I_{IH}					1	µA
Shutdown Turn-On Time	$t_{\overline{SHDN}}$	T_A = +25°C (Note 3)			14.4	18.9	µs
		-40°C < T_A < +125°C (Note 3)				26.7	
Power-Up Time	t_{ON}	T_A = +25°C (Note 3)			9.7	15.2	ms
		-40°C < T_A < +125°C (Note 3)				18.4	
DC CHARACTERISTICS							
Input Common-Mode Range	V_{CM}	Guaranteed by CMRR test		V_{SS} - 0.1		V_{DD} + 0.1	V
Common-Mode Rejection Ratio	CMRR	V_{CM} = V_{SS} - 0.1V to V_{DD} + 0.1V		75	90		dB
Input Offset Voltage (Note 3)	V_{OS}	T_A = +25°C (Note 4)			10	50	µV
		-40°C ≤ T_A ≤ +125°C (Note 5)				100	
		-40°C ≤ T_A ≤ +125°C (Note 6)				500	
Input Offset Voltage Drift (Note 3)	TC V_{OS}				0.8	5	µV/°C
Input Bias Current (Note 3)	I_B	T_A = +25°C			0.01	0.5	pA
		-40°C < T_A < +85°C				10	
		-40°C < T_A < +125°C				100	
Open-Loop Gain	A_{VOL}	400mV ≤ V_{OUT} ≤ V_{DD} - 400mV, R_{LOAD} = 10kΩ		100	115		dB
		400mV ≤ V_{OUT} ≤ V_{DD} - 400mV, R_{LOAD} = 600Ω		91	100		
		400mV ≤ V_{OUT} ≤ V_{DD} - 400mV, R_{LOAD} = 32Ω			80		
Output Short-Circuit Current		To V_{DD} or V_{SS}			50		mA
Output Voltage Low	V_{OL}	V_{OUT} – V_{SS}	R_{LOAD} = 10kΩ to V_{DD}/2			20	mV
			R_{LOAD} = 600Ω to V_{DD}/2			50	
			R_{LOAD} = 32Ω to V_{DD}/2		400	700	

Electrical Characteristics (continued)

(V_{DD} = 3.3V, V_{SS} = 0V, V_{IN+} = V_{IN-} = V_{DD}/2, R_{LOAD} = 10kΩ to V_{DD}/2, $V_{\overline{SHDN}}$ = V_{DD}, T_A = -40°C to +125°C, unless otherwise noted. Typical values are at +25°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Output Voltage High	V_{OH}	V_{DD} – V_{OUT}	R_{LOAD} = 10kΩ to V_{DD}/2			10	mV
			R_{LOAD} = 600Ω to V_{DD}/2			40	
			R_{LOAD} = 32Ω to V_{DD}/2		400	800	
AC CHARACTERISTICS							
Input Voltage Noise Density	e_n	f = 10kHz			12.7		nV/√Hz
Input Voltage Noise		0.1Hz ≤ f ≤ 10Hz			10		µV_{P-P}
Input Capacitance	C_{IN}				2.5		pF
Gain-Bandwidth Product	GBW				15		MHz
Slew Rate	SR	A_V = 1V/V, V_{OUT} = 2V_{P-P}, 10% to 90%			7		V/µs
Capacitive Loading	C_{LOAD}	No sustained oscillation, A_V = 1V/V			300		pF
Total Harmonic Distortion + Noise	THD+N	V_{OUT} = 2V_{P-P}, AV = 1V/V, R_{LOAD} = 10kΩ	f = 10kHz		-105		dB
Settling Time		To 0.01%, V_{OUT} = 2V_{P-P}, A_V = 1V/V, C_{LOAD} = 30pF			1.7		µs
Output Transient Recovery Time		ΔV_{OUT} = 0.2V, V_{DD} = 3.3V, A_V = 1V/V, R_S = 20Ω, C_{LOAD} = 1nF			1		µs

Note 2: All devices are 100% production tested at T_A = +25°C. Specifications over temperature are guaranteed by design.

Note 3: Guaranteed by design.

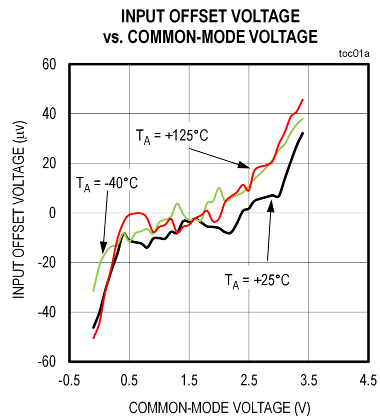
Note 4: At +25°C, upon power up and after calibration.

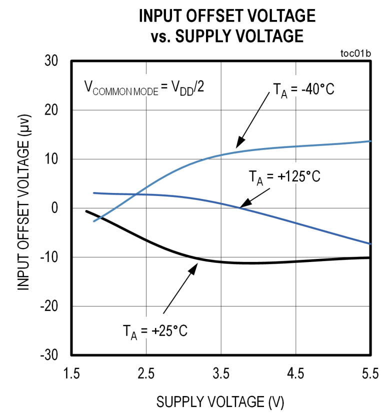
Note 5: For any temperature values between -40°C to +125°C, upon power up and after calibration.

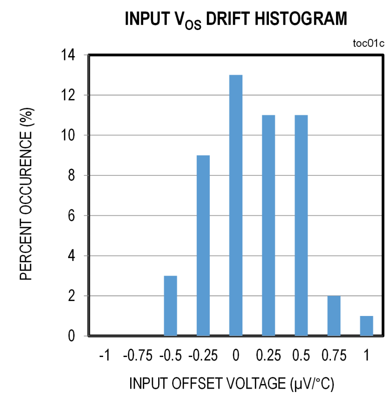
Note 6: For any temperature values between -40°C and +125°C it indicates the maximum drift from power up, initial calibrated value.

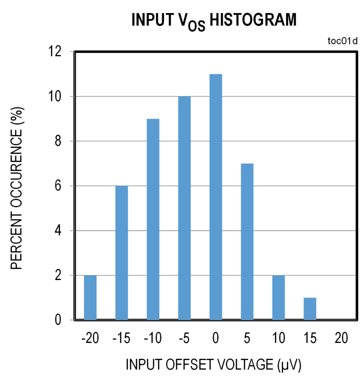
Typical Operating Characteristics

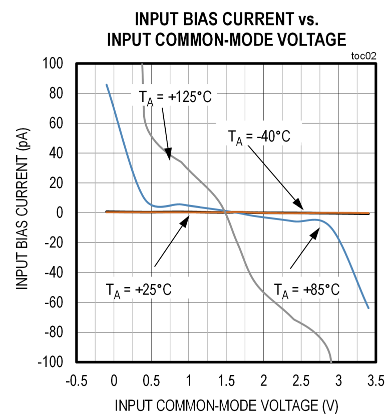
(T_A = +25°C, unless otherwise noted.)

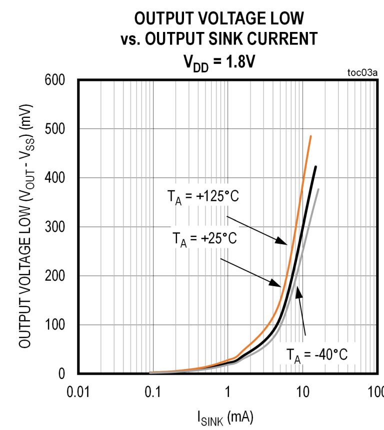


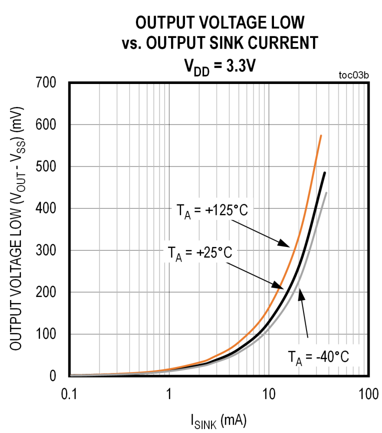


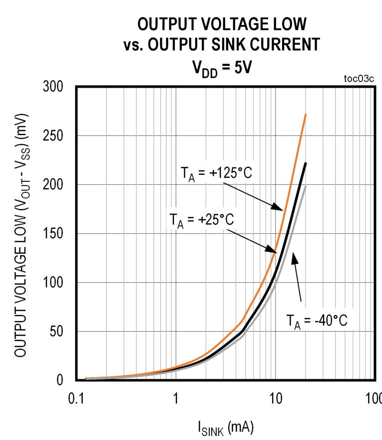


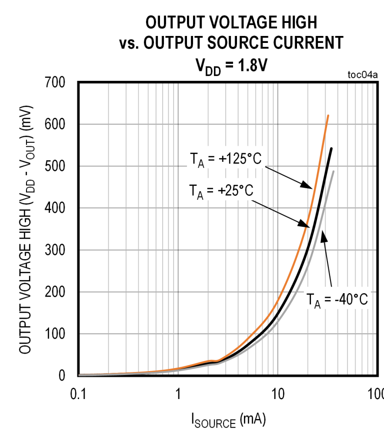






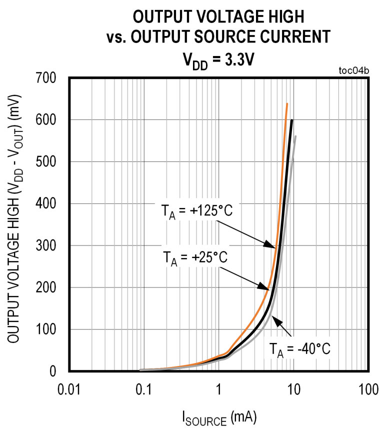


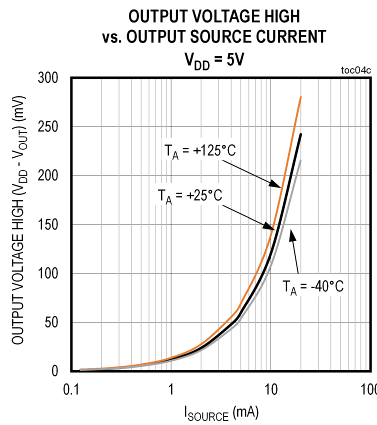


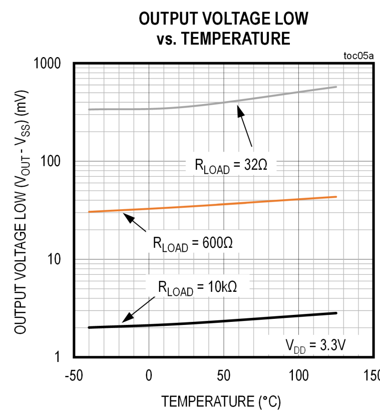


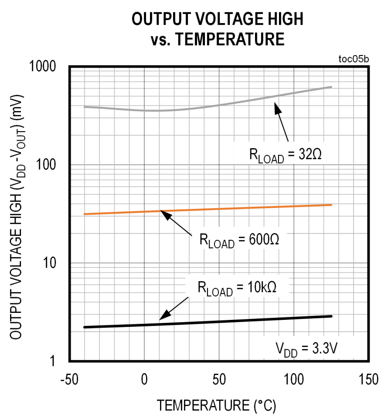
Typical Operating Characteristics (continued)

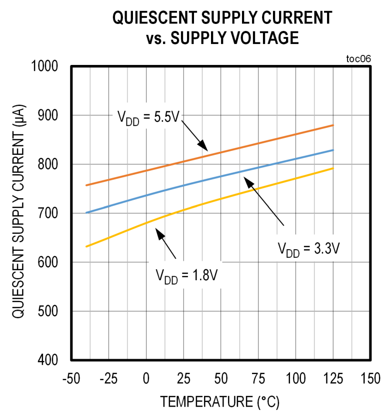
(T_A = +25°C, unless otherwise noted.)

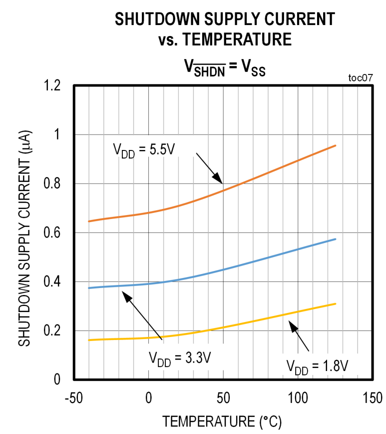


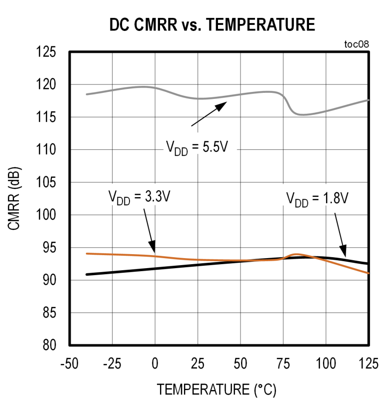


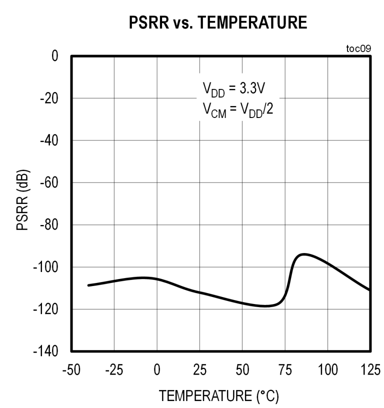


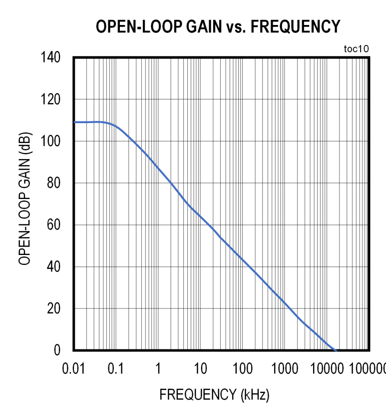








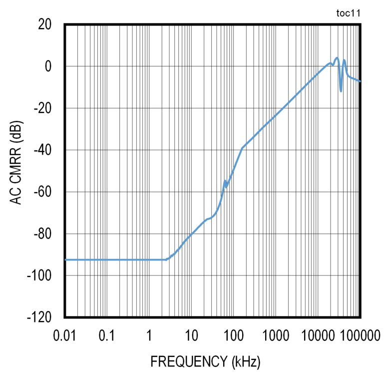




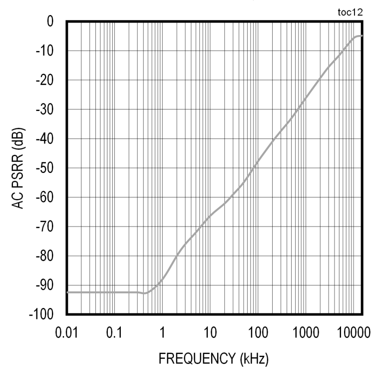
Typical Operating Characteristics (continued)

(T_A = +25°C, unless otherwise noted.)

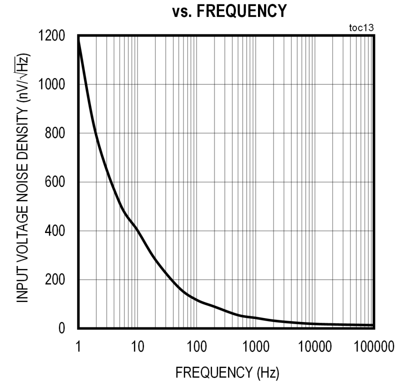
AC CMRR vs. FREQUENCY



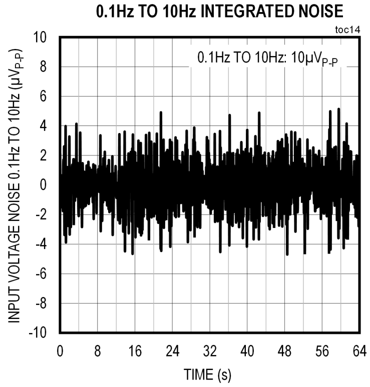
AC PSRR vs. FREQUENCY



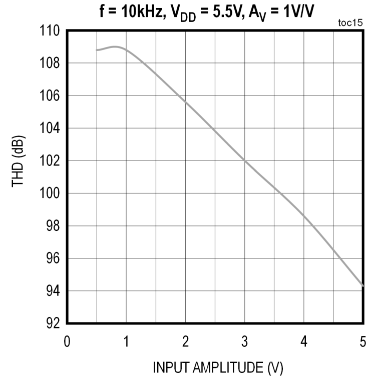
INPUT VOLTAGE NOISE DENSITY vs. FREQUENCY



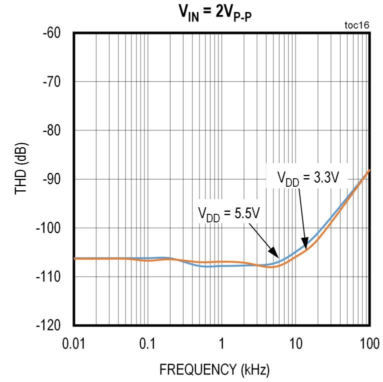
0.1Hz TO 10Hz INTEGRATED NOISE



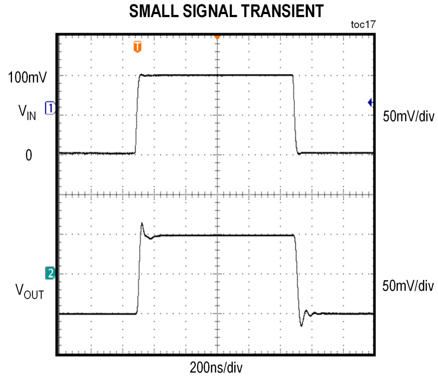
TOTAL HARMONIC DISTORTION vs. INPUT AMPLITUDE
f = 10kHz, V_{DD} = 5.5V, A_V = 1V/V



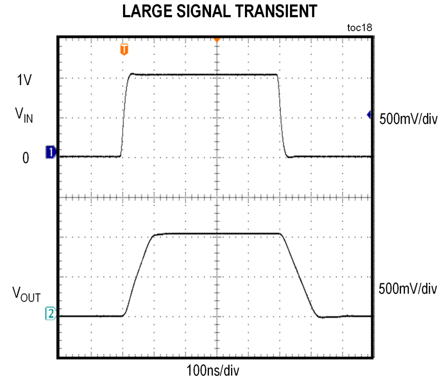
TOTAL HARMONIC DISTORTION vs. FREQUENCY
V_{IN} = $2V_{P-P}$



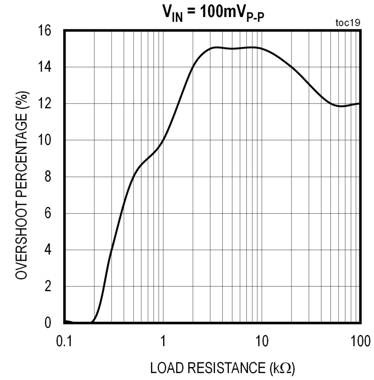
SMALL SIGNAL TRANSIENT



LARGE SIGNAL TRANSIENT

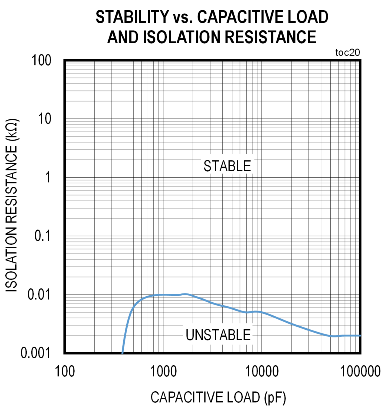


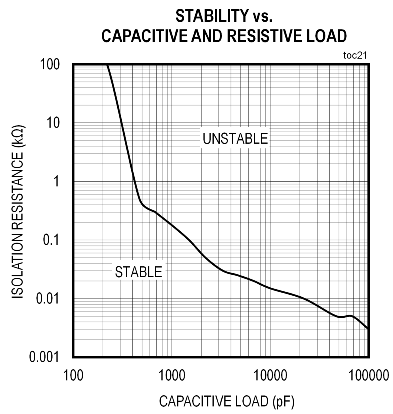
PERCENTAGE OVERSHOOT vs. LOAD RESISTANCE
V_{IN} = $100mV_{P-P}$

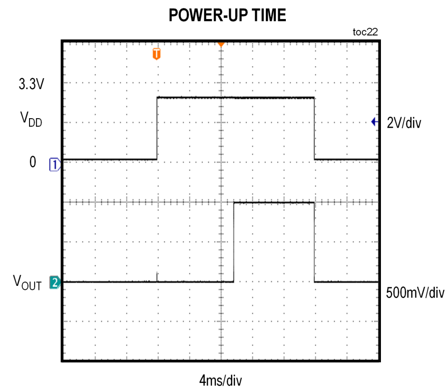


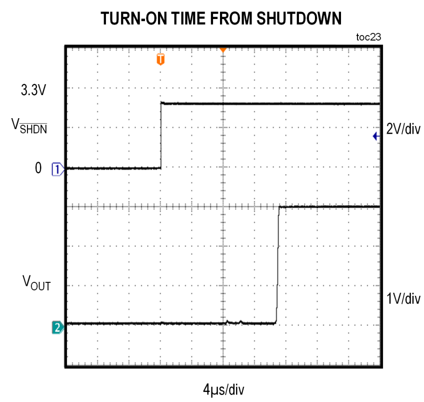
Typical Operating Characteristics (continued)

(T_A = +25°C, unless otherwise noted.)

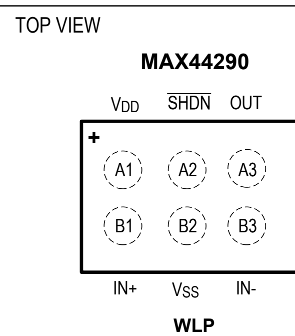








Pin Configuration



Pin Description

PIN	NAME	FUNCTION	TYPE
A1	V_{DD}	Positive Supply Voltage	Power

Pin Description (continued)

PIN	NAME	FUNCTION	TYPE
A2	$\overline{SHDN}$	Active-Low Shutdown Input. Connect to V_{DD} for normal operation.	Analog Input
A3	OUTA	Output	Analog Output
B1	IN+	Positive Input	Analog Input
B2	V_{SS}	Negative Supply Voltage. Connect to the ground return of the V_{DD} supply.	Power
B3	IN-	Negative Input	Analog Input

Detailed Description

The MAX44290 is a high-speed, low-power operational amplifier (op amp) ideal for signal-processing applications due to the device's high-precision and low-noise CMOS inputs. The device self-calibrates on power-up to eliminate the effects of temperature and power-supply variation.

The device also features a low-power shutdown mode that greatly reduces quiescent current while the device is not operational and recovers in less than 30µs. The device features autocalibration at a power-up event. The calibration routine takes less than 20ms.

Crossover Distortion

The device features a low-noise integrated charge pump that creates an internal voltage rail 1V above V_{DD}, which powers the input differential pair of PMOS transistors, as shown in Figure 1. Such a unique architecture eliminates crossover distortion common in traditional CMOS input architecture (Figure 2), especially when used in a noninverting configuration, such as for Sallen-Key filters.

The charge pump operating frequency lies well above the unity-gain frequency of the amplifier. Because of its high-frequency operation and ultra-quiet circuitry, the charge pump generates little noise, does not require external components, and is entirely transparent to the user.

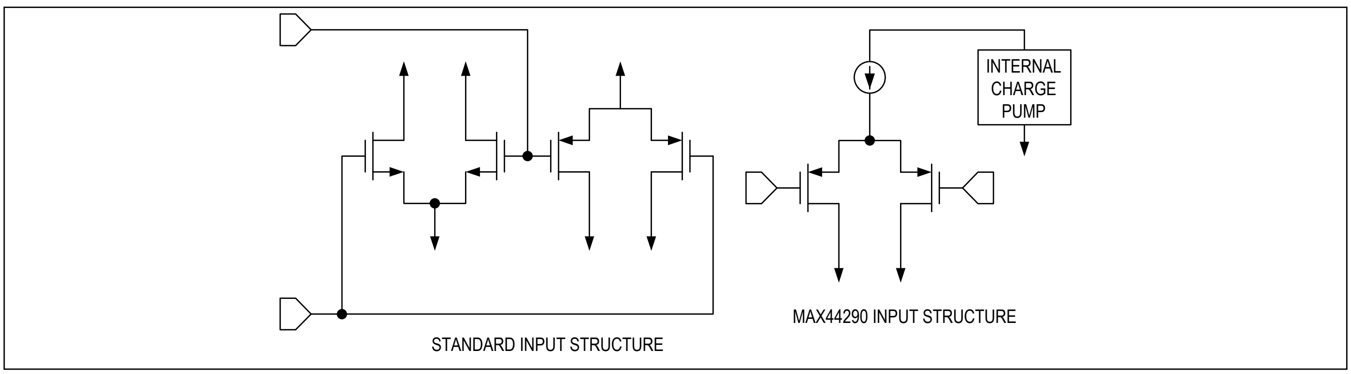


Figure 1. Comparing the Input Structure of the MAX44290 to Standard Op Amps

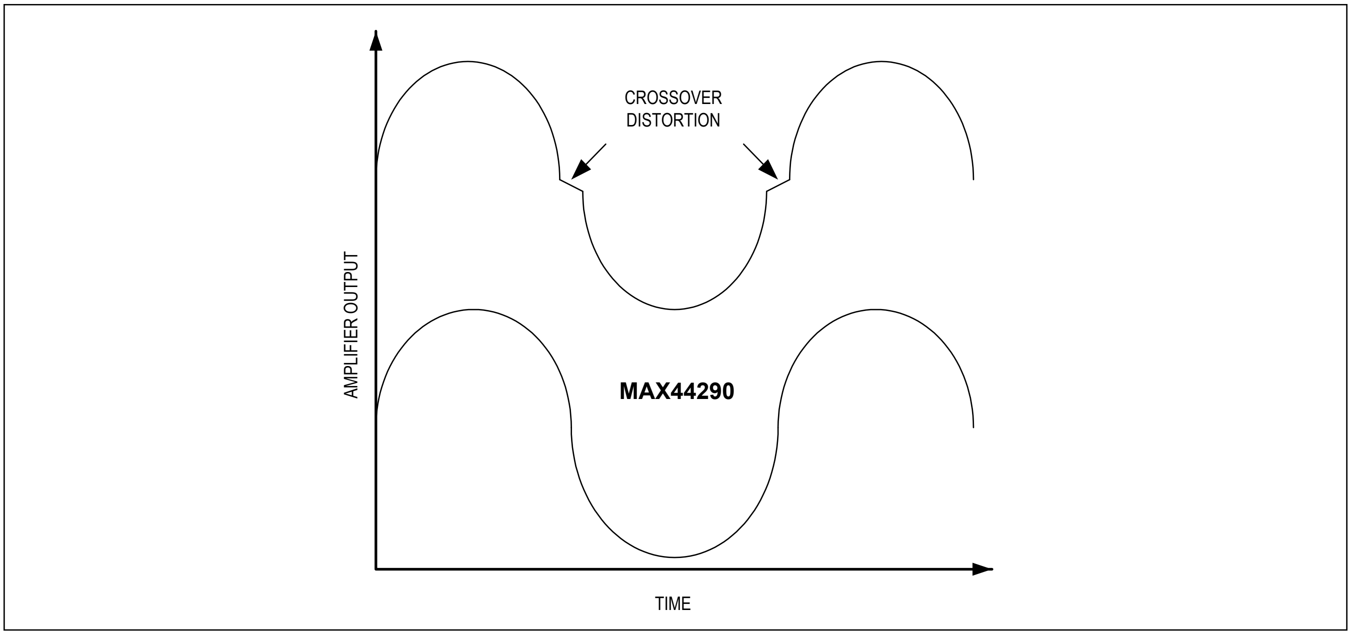


Figure 2. Crossover Distortion of Typical Amplifiers

Applications Information

Power-Up Autotrim

The device features an automatic trim that self-calibrates the input offset voltage (V_{OS}) to less than 50μV of input offset voltage on power-up. This self-calibration feature allows the device to eliminate input offset voltage effects due to power supply and operating temperature variation simply by cycling its power. The autotrim sequence takes less than 20ms to complete and is triggered by an internal power-on-reset (POR) circuitry. During this time, the inputs and outputs are at high impedance and left unconnected.

Shutdown Operation

The MAX44290 features an active-low shutdown mode that puts both inputs and outputs into high impedance and substantially lowers the quiescent current to less than 1μA. Putting the output into high impedance allows multiple outputs to be multiplexed onto a single output line without the additional external buffers. The device does not self-calibrate when exiting shutdown mode and retains its power-up trim settings. Figure 3 shows how the device recovers from shutdown in less than 30μs.

The shutdown logic levels of the device are independent of supply, allowing the shutdown feature of the device to operate off a 1.8V or 3.3V microcontroller, regardless of supply voltage.

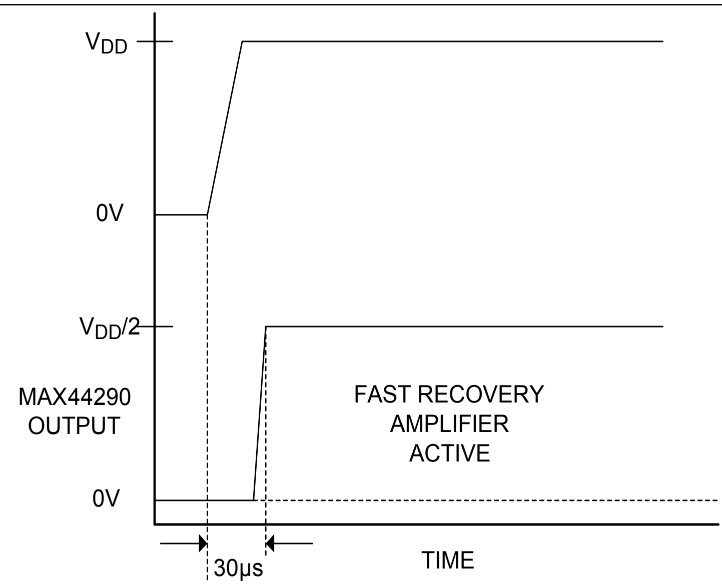


Figure 3. Shutdown Input Operation

Rail-to-Rail Input/Output

The input voltage range of the device extends 100mV above V_{DD} and below V_{SS}. The wide input common mode voltage range allows the op amp to be used as a buffer and as a differential amplifier in a variety of signal processing applications. Output voltage high/low is only 50mV above V_{SS} and below V_{DD}, allowing maximum dynamic range in single-supply applications. The high output current and capacitance drive capability of the device make it ideal as an ADC driver and a line driver.

Input Bias Current

The MAX44290 features a high-impedance CMOS input stage and a specialized ESD structure that allows low input bias current operation at low-input, common-mode voltages. Low-input bias current is useful when interfacing with high-impedance sensors. It is also beneficial for designing transimpedance amplifiers for photodiode sensors. This makes the device ideal for ground referenced medical and industrial sensor applications.

Driver for Interfacing with the MAX11645 ADC

The device's tiny size and low noise makes it a good fit for driving 12- to 16-bit resolution ADCs in space-constrained applications. The *Typical Application Circuits* show the MAX44290 amplifier output connected to a lowpass filter driving the MAX11645 ADC. The MAX11645 is part of a family of 3V and 5V, 12-bit and 10-bit, 2-channel ADCs.

The MAX11645 offers sample rates up to 94ksps and measures two single-ended inputs or one differential input. These ADCs dissipate 670μA at the maximum sampling rate, but just 6μA at 1ksps and 0.5μA in shutdown. Offered in ultra-tiny, 1.9mm x 2.2mm WLP and 8-pin μMAX packages, the MAX11645 ADCs are an ideal fit to pair with the MAX44290 in portable applications where higher resolution is required. Refer to the MAX1069 (14-bit) and MAX1169 (16-bit) ADC families.

$$I_{LOAD} = \frac{V_{IN}}{(R3 + R4)} \times \left(1 + \left(\frac{2 \times R4}{R5}\right)\right)$$

AND

$$\frac{R2}{R1} = \frac{R4 + R5}{R3}$$

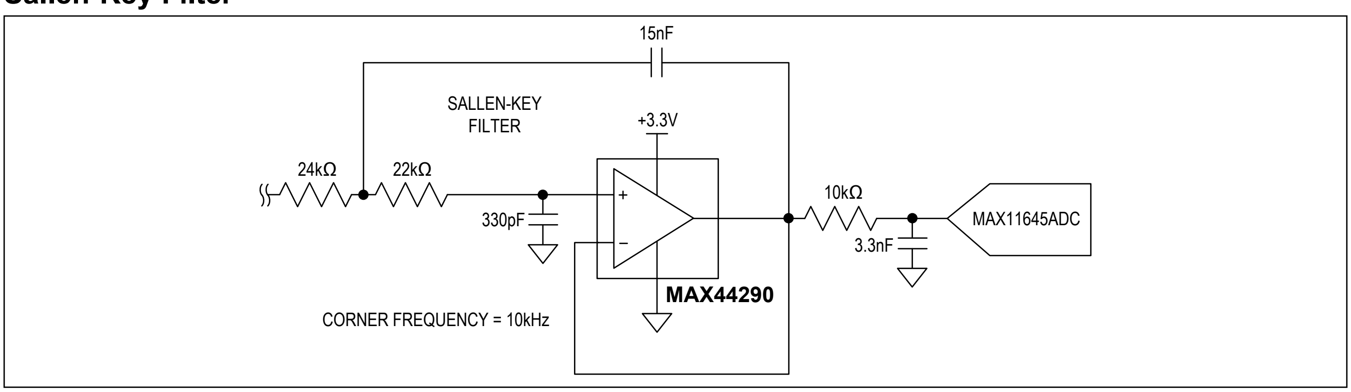
High-Impedance Source/Sensor Preamp Application

High-impedance sources, such as pH sensors and photodiodes, in applications require negligible input leakage currents to the input transimpedance/buffer structure. The MAX44290 benefits with clean and precise signal conditioning due to its input structure.

The device interfaces to both current-output sensors (photodiodes), and high-impedance voltage sources (piezoelectric sensors). For current output sensors, a transimpedance amplifier is the most noise-efficient method for converting the input signal to a voltage. High-value feedback resistors are commonly chosen to create large gains, while feedback capacitors help stabilize the amplifier by cancelling any poles introduced in the feedback loop by the highly capacitive sensor or cabling. A combination of low-current noise and low-voltage noise is important for these applications. Care must be taken to calibrate out photodiode dark current if DC accuracy is important. The high bandwidth and slew rate also allow AC signal processing in certain medical photodiode sensor applications such as pulse-oximetry. For voltage-output sensors, a noninverting amplifier is typically used to buffer and/or apply a small gain to the input voltage signal. Due to the extremely high impedance of the sensor output, a low input bias current with minimal temperature variation is very important for these applications.

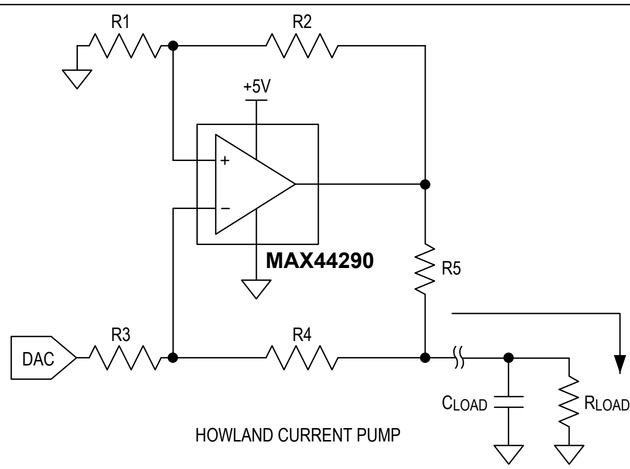
Typical Application Circuits

Sallen-Key Filter



Typical Application Circuits (continued)

Howland Current Pump



Ordering Information

PART NUMBER	TEMP RANGE	PIN-PACKAGE	PACKAGE COMMENTS
MAX44290ANT+	-40°C to +125°C	6 WLP	0.4mm pitch, 0.5mm (max) height

+Denotes a lead(Pb)-free/RoHS-compliant package.

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	12/15	Initial release	—
1	3/20	Added package outline drawing	13
2	5/20	Updated *Electrical Characteristics* table	2
3	6/20	Updated Absolute Max Ratings section, and typos in *Electrical Characteristics* table	2-4
4	2/21	Updates *Electrical Characteristics* table, resized TOCs, updated *Detailed Description*, and *Applications Information*	6-8, 13-15