



Low-Cost, Voltage-Output, 16-Bit DACs with Internal Reference in μ MAX

MAX5200–MAX5203

General Description

The MAX5200–MAX5203 serial input, voltage-output, 16-bit digital-to-analog converters (DACs) provide monotonic 16-bit output over temperature without any adjustments. The MAX5200/MAX5201 operate from a +5V single power supply featuring an internal reference of +2.5V and an internal gain of 2, while the MAX5202/MAX5203 operate from a +3V or +3.3V single power supply featuring an internal reference of +1.5V and an internal gain of 2. The MAX5200–MAX5203 DAC output range is typically from 0 to V_{DD} .

The MAX5200–MAX5203 feature a hardware reset input (CLR) that, when pulled low, clears the output to zero code 0000 hex (MAX5201/MAX5203) or resets the output to midscale code 8000 hex (MAX5200/MAX5202).

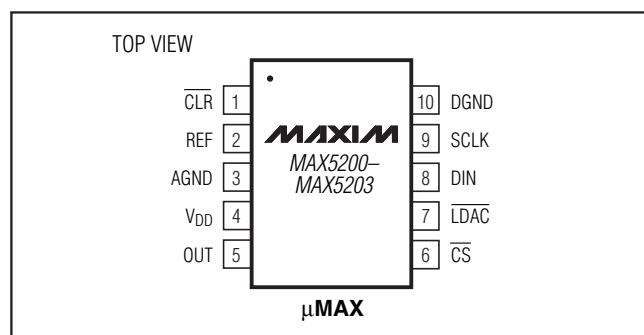
The 3-wire serial interface is compatible with SPI™/QSPI™/MICROWIRE™. All devices have a low-power shutdown mode that reduces the supply current consumption to 1 μ A.

The MAX5200–MAX5203 are available in a space-saving 10-pin μ MAX® package and are guaranteed over the extended temperature range (-40°C to +105°C). Refer to the MAX5204–MAX5207 data sheet for external reference versions.

Applications

Low-Cost VCO/VCXO Frequency Control
Industrial Process Control
High-Resolution Offset Adjustment

Pin Configuration



SPI/QSPI are trademarks of Motorola, Inc.

MICROWIRE is a trademark of National Semiconductor Corp.

μ MAX is a registered trademark of Maxim Integrated Products, Inc.

Features

- ◆ **Guaranteed 16-Bit Monotonic**
- ◆ **Internal Reference**
- ◆ **10-Pin 5mm × 3mm μ MAX Package**
- ◆ **Rail-to-Rail Output Amplifier**
- ◆ **Single-Supply Operation**
 - +5V (MAX5200/MAX5201)
 - +3V, +3.3V (MAX5202/MAX5203)
- ◆ **Low Power Consumption: 0.8mA**
- ◆ **Shutdown Mode Reduces Supply Current to 1 μ A**
- ◆ **SPI/QSPI/MICROWIRE-Compatible 3-Wire Serial Interface**
- ◆ **Power-On-Reset Sets Output to**
 - Midscale (MAX5200/MAX5202)
 - Zero Scale (MAX5201/MAX5203)

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX5200 AEUB	-40°C to +105°C	10 μ MAX
MAX5200BEUB	-40°C to +105°C	10 μ MAX
MAX5200ACUB	0°C to +70°C	10 μ MAX
MAX5201 AEUB	-40°C to +105°C	10 μ MAX
MAX5201BEUB	-40°C to +105°C	10 μ MAX
MAX5201ACUB	0°C to +70°C	10 μ MAX
MAX5202 AEUB	-40°C to +105°C	10 μ MAX
MAX5202BEUB	-40°C to +105°C	10 μ MAX
MAX5202ACUB	0°C to +70°C	10 μ MAX
MAX5203 AEUB	-40°C to +105°C	10 μ MAX
MAX5203BEUB	-40°C to +105°C	10 μ MAX
MAX5203ACUB	0°C to +70°C	10 μ MAX

Selector Guide appears at end of data sheet.



Maxim Integrated Products 1

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Low-Cost, Voltage-Output, 16-Bit DACs with Internal Reference in μ MAX

ABSOLUTE MAXIMUM RATINGS

V_{DD} to AGND, DGND-0.3V to +6V
 AGND to DGND-0.3V to +0.3V
 REF, OUT to AGND-0.3V to ($V_{DD} + 0.3V$)
 CLR, LDAC, SCLK, DIN, $\overline{CS}$ to DGND-0.3V to ($V_{DD} + 0.3V$)
 Maximum Current into Any Pin50mA
 Continuous Power Dissipation ($T_A = +70^\circ\text{C}$)
 10-Pin μ MAX (derate 5.6mW/ $^\circ\text{C}$ above $+70^\circ\text{C}$)444.4mW

Operating Temperature Ranges

MAX520_CUB 0°C to $+70^\circ\text{C}$
 MAX520_EUB -40°C to $+105^\circ\text{C}$
 Junction Temperature $+150^\circ\text{C}$
 Storage Temperature Range -60°C to $+150^\circ\text{C}$
 Lead Temperature (soldering, 10s) $+300^\circ\text{C}$

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS—MAX5200/MAX5201

($V_{DD} = +4.75V$ to $+5.25V$, $f_{SCLK} = 10\text{MHz}$ (50% duty cycle), output load = $10k\Omega$ in parallel with $250pF$, $T_A = T_{MIN}$ to T_{MAX} , unless otherwise noted. Typical values are at $T_A = +25^\circ\text{C}$.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
STATIC PERFORMANCE (Note 1)						
Resolution	N		16			Bits
Integral Nonlinearity (Note 2)	INL	MAX520_AEUB		± 10	± 20	LSB
		MAX520_ACUB		± 10	± 20	
		MAX520_BEUB		± 20	± 40	
Differential Nonlinearity (Note 2)	DNL	MAX520_A_UB (Note 3)		± 1		LSB
		MAX520_BEUB (0°C to $+105^\circ\text{C}$) (Note 3)		± 1		
		MAX520_BEUB (-40°C to 0°C)		± 2		
Offset Error		Inferred from measurement at 1C00 hex and FFFF hex		± 3	± 25	mV
Gain Error	GE	Within DAC output range (Note 4)		± 0.01	± 1	%FSR
Power-Supply Rejection	PSR	$V_{DD} = 5V \pm 5\%$, midscale input		± 0.06	± 0.5	mV/V
DYNAMIC PERFORMANCE						
DAC Output Range		(Note 2)		0 to V_{DD}		V
Output-Voltage Slew Rate	SR			0.6		V/ μs
Output Settling Time		To $\pm 1\text{LSB}$ of FS, $V_{STEP} = 0.25 \times V_{REF}$ to $0.75 \times V_{REF}$		25		μs
Output Noise		DAC code = 8400 hex, 10kHz		175		nV/ $\sqrt{\text{Hz}}$
DAC Glitch Impulse		Major carry transition (code 7FFF hex to code 8000 hex)		10		nV·s
Digital Feedthrough		Code = 0000 hex; $\overline{CS} = V_{DD}$; $\overline{LDAC} = 0$; SCLK, DIN = 0 or V_{DD}		10		nV·s
Wake-Up Time		From software shutdown to 90% of output code = FFFF hex, $C_{REF} = 0.1\mu\text{F}$		50		μs
Power-Up Time		From power applied to 90% of output code = FFFF hex		10		ms

Low-Cost, Voltage-Output, 16-Bit DACs with Internal Reference in μ MAX

MAX5200-MAX5203

ELECTRICAL CHARACTERISTICS—MAX5200/MAX5201 (continued)

(V_{DD} = +4.75V to +5.25V, f_{SCLK} = 10MHz (50% duty cycle), output load = 10k Ω in parallel with 250pF, T_A = T_{MIN} to T_{MAX} , unless otherwise noted. Typical values are at T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
INTERNAL REFERENCE						
VREF Output Voltage		T _A = +25°C	2.48	2.5	2.52	V
VREF Tempco		T _A = 0°C to +70°C	±15			ppm/°C
		T _A = -40°C to +105°C	±20			
DIGITAL INPUTS (DIN, SCLK, $\overline{CS}$, CLR, LDAC)						
Input High Voltage	V _{IH}		2.4			V
Input Low Voltage	V _{IL}		0.8			V
Input Hysteresis	V _{HYST}		200			mV
Input Leakage	I _{IN}	Digital inputs = 0 or V _{DD}	±1			µA
Input Capacitance	C _{IN}		15			pF
POWER REQUIREMENTS						
Positive Power Supply	V _{DD}		4.75		5.25	V
Positive Supply Current	I _{DD}	All digital inputs at 0 or V _{DD} (Note 5)		0.8	1.5	mA
Shutdown Supply Current	I _{SHDN}	All digital inputs at 0 or V _{DD}		1	10	µA
TIMING CHARACTERISTICS						
SCLK Frequency	f _{SCLK}		10			MHz
SCLK Clock Period	t _{CP}		100			ns
SCLK Pulse Width High	t _{CH}		40			ns
SCLK Pulse Width Low	t _{CL}		40			ns
DIN Setup Time	t _{DS}		40			ns
DIN Hold Time	t _{DH}		0			ns
$\overline{CS}$ Fall to SCLK Rise Setup Time	t _{CSS}		40			ns
SCLK Rise to $\overline{CS}$ Rise Hold Time	t _{CSH}		0			ns
SCLK Rise to $\overline{CS}$ Fall Ignore	t _{CS0}		10			ns
$\overline{CS}$ Rise to SCLK Rise Ignore	t _{CS1}		40			ns
LDAC Pulse Width	t _{LDAC}		40			ns
$\overline{CS}$ Rise to $\overline{LDAC}$ Low Setup	t _{LDACS}		40			ns
SCLK Fall to $\overline{CS}$ Fall Ignore	t _{CSOL}		10			ns
$\overline{CS}$ Pulse Width Low for Shutdown	t _{CSWL}		40			ns
$\overline{CS}$ Pulse Width High	t _{CSWH}		100			ns

Low-Cost, Voltage-Output, 16-Bit DACs with Internal Reference in μ MAX

ELECTRICAL CHARACTERISTICS—MAX5202/MAX5203

(V_{DD} = +2.7V to +3.6V, f_{SCLK} = 10MHz (50% duty cycle), output load = 10k Ω in parallel with 250pF, T_A = T_{MIN} to T_{MAX} , unless otherwise noted. Typical values are at T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
STATIC PERFORMANCE (Note 1)						
Resolution	N		16			Bits
Integral Nonlinearity (Note 2)	INL	MAX520_AEUB		± 10	± 20	LSB
		MAX520_ACUB		± 10	± 20	
		MAX520_BEUB		± 20	± 40	
Differential Nonlinearity (Note 2)	DNL	MAX520_A_UB (Note 3)		± 1		LSB
		MAX520_BEUB (0°C to +105°C) (Note 3)		± 1		
		MAX520_BEUB (-40°C to 0°C)		± 2		
Offset Error		Inferred from measurement at 3800 hex and FFFF hex		± 3	± 25	mV
Gain Error	GE	Within DAC output range (Note 4)		± 0.01	± 1.0	%FSR
Power-Supply Rejection	PSR	V_{DD} = 3V $\pm 10\%$, midscale input		± 0.06	± 0.5	mV/V
DYNAMIC PERFORMANCE						
DAC Output Range		(Note 2)		0 to V_{DD}		V
Voltage-Output Slew Rate	SR			0.6		V/ μ s
Output Settling Time		To ± 1 LSB of FS, V_{STEP} = 0.25 $\times$ V_{REF} to 0.75 $\times$ V_{REF}		25		μ s
Output Noise		Code = 8400 hex, 10kHz		175		nV/ $\sqrt{Hz}$
Reference Feedthrough		Code = 0000 hex at 100kHz, V_{REF} = 1V _{P-P}		1		mV _{P-P}
DAC Glitch Impulse		Major carry transition (code 7FFF hex to code 8000 hex)		10		nV $\cdot$ s
Digital Feedthrough		Code = 0000 hex; $\overline{CS}$ = V_{DD} ; $\overline{LDAC}$ = 0; SCLK, DIN = 0 or V_{DD} levels		10		nV $\cdot$ s
Wake-Up Time		From software shutdown to 90% of output code = FFFF hex		50		μ s
Power-Up Time		From power applied to 90% of output code = FFFF hex		10		ms

Low-Cost, Voltage-Output, 16-Bit DACs with Internal Reference in μ MAX

MAX5200–MAX5203

ELECTRICAL CHARACTERISTICS—MAX5202/MAX5203 (continued)

(V_{DD} = +2.7V to +3.6V, f_{SCLK} = 10MHz (50% duty cycle), output load = 10k Ω in parallel with 250pF, T_A = T_{MIN} to T_{MAX} , unless otherwise noted. Typical values are at T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	
INTERNAL REFERENCE							
VREF Output Voltage		T _A = +25°C	1.46	1.5	1.54	V	
VREF Tempco		T _A = 0°C to +70°C	±15			ppm/°C	
		T _A = -40°C to +105°C	±20				
DIGITAL INPUTS (DIN, SCLK, CS, CLR, LDAC)							
Input High Voltage	V _{IH}		2.1			V	
Input Low Voltage	V _{IL}		0.6			V	
Input Hysteresis	V _{HYST}		200			mV	
Input Leakage	I _{IN}	Digital inputs = 0 or V _{DD}	±1			μA	
Input Capacitance	C _{IN}		15			pF	
POWER REQUIREMENTS							
Positive Power Supply	V _{DD}		2.7			3.6	V
Positive Supply Current	I _{DD}	All digital inputs at 0 or V _{DD} (Note 5)	0.8			1.5	mA
Shutdown Supply Current	I _{SHDN}	All digital inputs at 0 or V _{DD}	1			10	μA
TIMING CHARACTERISTICS							
SCLK Frequency	f _{SCLK}		10			MHz	
SCLK Clock Period	t _{CP}		100			ns	
SCLK Pulse Width High	t _{CH}		40			ns	
SCLK Pulse Width Low	t _{CL}		40			ns	
DIN Setup Time	t _{DS}		40			ns	
DIN Hold Time	t _{DH}		0			ns	
CS Fall to SCLK Rise Setup Time	t _{CSS}		40			ns	
SCLK Rise to CS Rise Hold Time	t _{CSH}		0			ns	
SCLK Rise to CS Fall Ignore	t _{CS0}		10			ns	
CS Rise to SCLK Rise Ignore	t _{CS1}		40			ns	
LDAC Pulse Width	t _{LDAC}		40			ns	
CS Rise to LDAC Low Setup	t _{LDACS}		40			ns	
SCLK Fall to CS Fall Ignore	t _{CSOL}		10			ns	
CS Pulse Width Low for Shutdown	t _{CSWL}		40			ns	
CS Pulse Width High	t _{CSWH}		100			ns	

Note 1: Static performance tested at V_{DD} = +5.0V (MAX5200/MAX5201) and at V_{DD} = +3.0V (MAX5202/MAX5203).

Note 2: INL and DNL are guaranteed for outputs between 0.5V to (V_{DD} - 0.5V).

Note 3: Guaranteed monotonic.

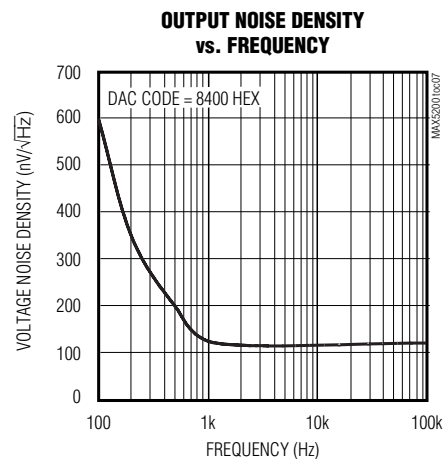
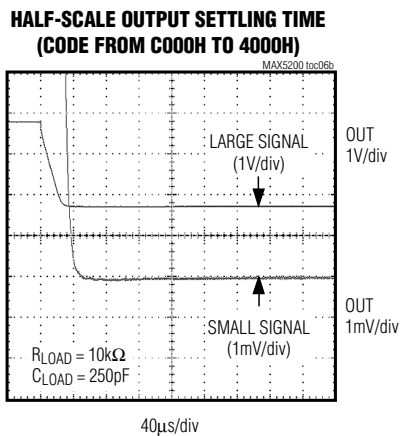
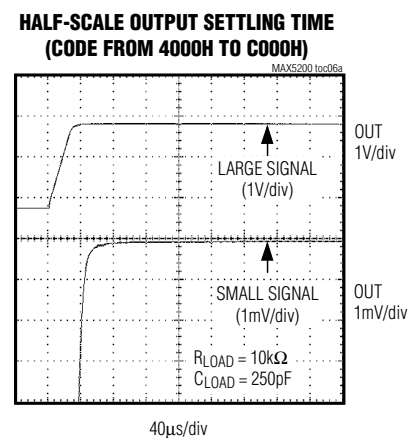
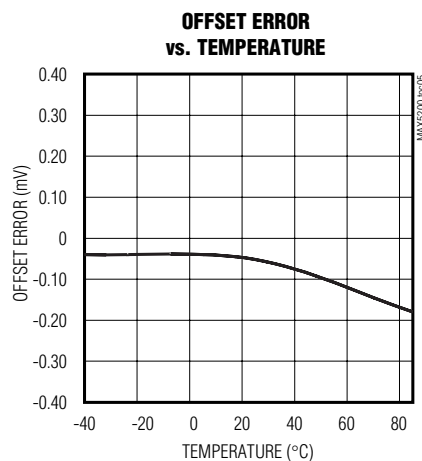
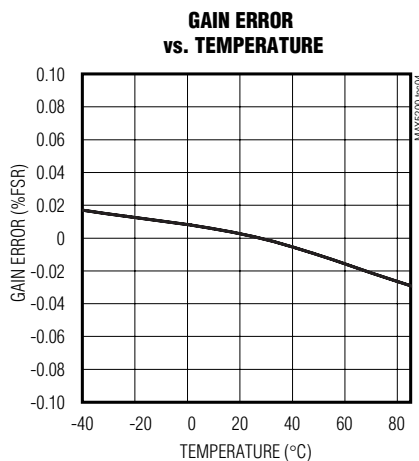
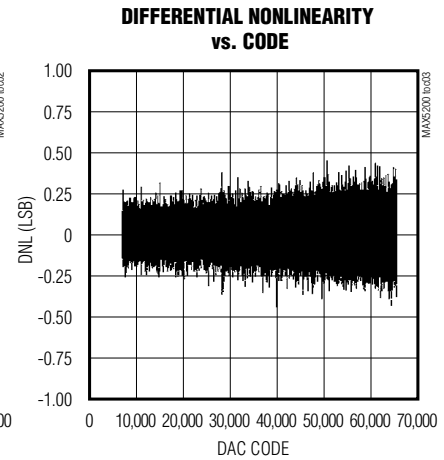
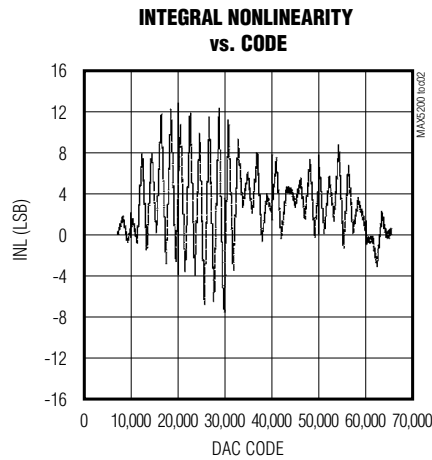
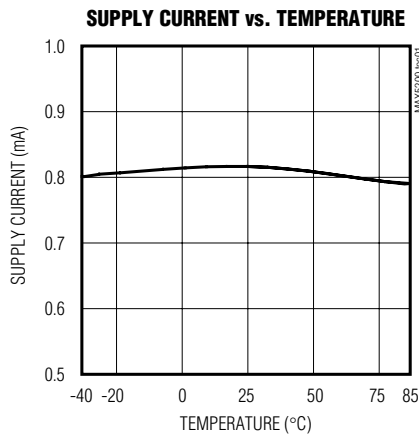
Note 4: V_{REF} = 2.5V (MAX5200/MAX5201) and V_{REF} = 1.5V (MAX5202/MAX5203).

Note 5: R_L = ∞ , digital inputs are at V_{DD} or DGND.

Low-Cost, Voltage-Output, 16-Bit DACs with Internal Reference in μ MAX

Typical Operating Characteristics

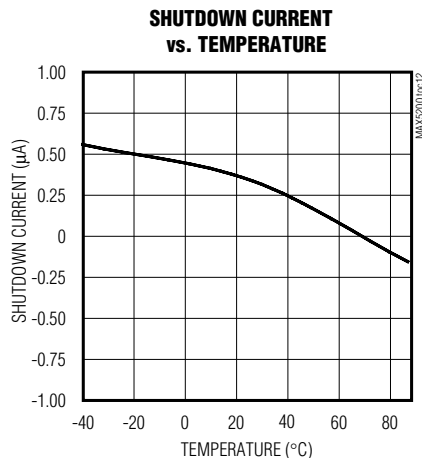
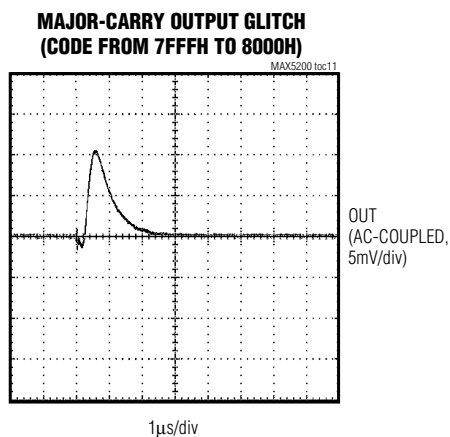
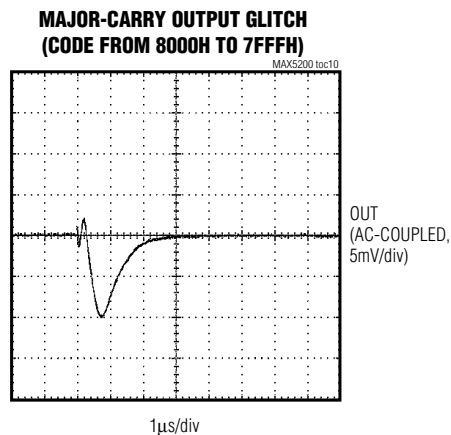
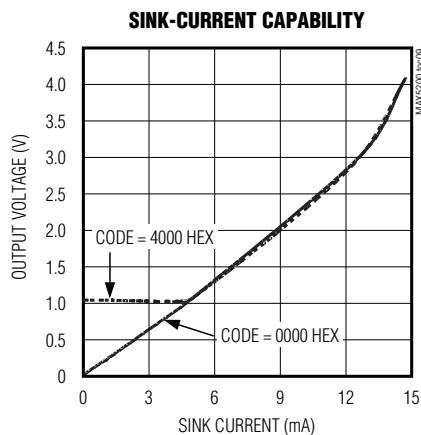
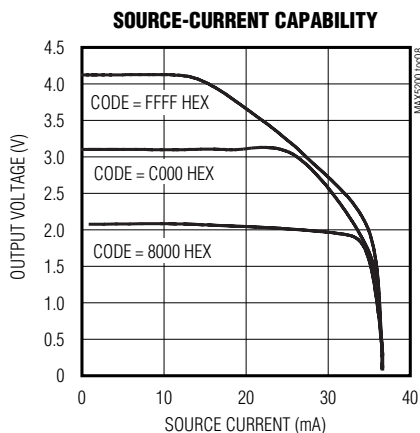
($V_{DD} = +5V$, $T_A = +25^\circ C$, unless otherwise noted.)



Low-Cost, Voltage-Output, 16-Bit DACs with Internal Reference in μ MAX

Typical Operating Characteristics (continued)

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



MAX5200-MAX5203

PIN	NAME	FUNCTION
1	$\overline{\text{CLR}}$	Reset DAC Active-Low Input. Pull $\overline{\text{CLR}}$ low to reset the DAC output to midscale output (8000 hex) for MAX5200/MAX5202 and to zero-scale output (0000 hex) for MAX5201/MAX5203. For normal operation, connect $\overline{\text{CLR}}$ to V_{DD} .
2	REF	Reference Voltage Output. Provides a +2.5V (MAX5200/MAX5201) or +1.5V (MAX5202/MAX5203) nominal output. For improved noise performance, bypass with a minimum 0.1 μ F capacitor to AGND.
3	AGND	Analog Ground
4	V_{DD}	Positive Supply Voltage. Bypass V_{DD} to AGND with a 10 μ F capacitor in parallel with a 0.1 μ F capacitor.
5	OUT	DAC Output Voltage
6	$\overline{\text{CS}}$	Active-Low Chip-Select Input
7	$\overline{\text{LDAC}}$	Load DAC Input
8	DIN	Serial Data Input
9	SCLK	Serial Clock Input. Duty cycle must be 40% to 60%.
10	DGND	Digital Ground

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Low-Cost, Voltage-Output, 16-Bit DACs with Internal Reference in μ MAX

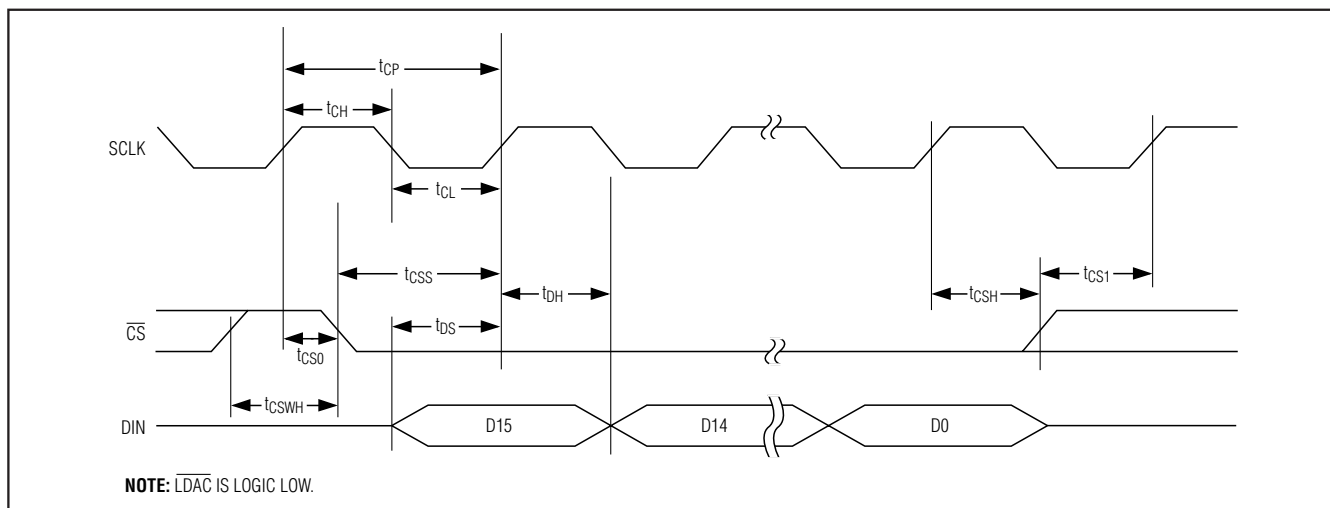


Figure 2. 3-Wire Interface Timing Diagram

data loading at the data input (DIN). Pull $\overline{\text{CS}}$ low and clock in each bit of the 16-bit digital word on the rising edge of the serial clock (SCLK). Two 8-bit bytes can be used, and do not require any additional time between them. Pulling $\overline{\text{CS}}$ high after loading the 16-bit word transfers that code into the DAC register and then updates the output. If $\overline{\text{CS}}$ is not kept low during the entire loading of the 16-bit word, data is corrupted. In this case, a new 16-bit word must be loaded. $\overline{\text{LDAC}}$ must be kept low at all times for the above instructions.

An alternate method of interfacing and updating the MAX5200–MAX5203 can be done with a fourth digital input, the active-low load DAC ($\overline{\text{LDAC}}$). $\overline{\text{LDAC}}$ allows the output to update asynchronously after $\overline{\text{CS}}$ goes high. It is useful when updating multiple MAX5200–MAX5203s synchronously when sharing a single $\overline{\text{LDAC}}$ and $\overline{\text{CS}}$ line. $\overline{\text{LDAC}}$ must be kept high at all times during the data-loading sequence and must only be asserted when $\overline{\text{CS}}$ is high. Asserting $\overline{\text{LDAC}}$ when $\overline{\text{CS}}$ is low can cause corrupted data. To operate the MAX5200–MAX5203 using $\overline{\text{LDAC}}$, pull $\overline{\text{LDAC}}$ high, pull $\overline{\text{CS}}$ low, load the 16-bit word as described in the previous paragraph, and pull $\overline{\text{CS}}$ high again. Following these commands, the DAC output only updates when $\overline{\text{LDAC}}$ is asserted low (Figure 3).

Shutdown Mode

The low-power shutdown mode reduces supply current to typically 1 μ A and a maximum of 10 μ A. Shutdown mode is not activated through command words, as is common among D/A converters. These devices require careful manipulation of $\overline{\text{CS}}$ and SCLK (Figure 4).

Shutting Down

To shut down the MAX5200–MAX5203, change the state of SCLK (either a high to low or low to high transition can be used) and pulse two falling $\overline{\text{CS}}$ edges. In order to keep the device in shutdown mode, SCLK **must** not change state. SCLK must remain in the state it is in after the two $\overline{\text{CS}}$ pulses.

Waking Up

There are two methods to wake up the MAX5200–MAX5203. Pulse one falling $\overline{\text{CS}}$ edge or transition SCLK. It takes 50 μ s typically from the $\overline{\text{CS}}$ falling edge or SCLK transition for the DAC to return to normal operation.

Power-On Reset

The MAX5200–MAX5203 have a power-on reset circuit to set the DAC's output to a known state when V_{DD} is first applied. The MAX5200/MAX5202 reset to midscale (code 8000 hex) upon power-up. The MAX5201/MAX5203 reset to zero scale (code 0000 hex) upon power-up. This ensures that unwanted output voltages do not occur immediately following a system power-up, such as a loss of power. It is required to apply V_{DD} first before any other inputs (DIN, SCLK, CLR, $\overline{\text{LDAC}}$, and $\overline{\text{CS}}$).

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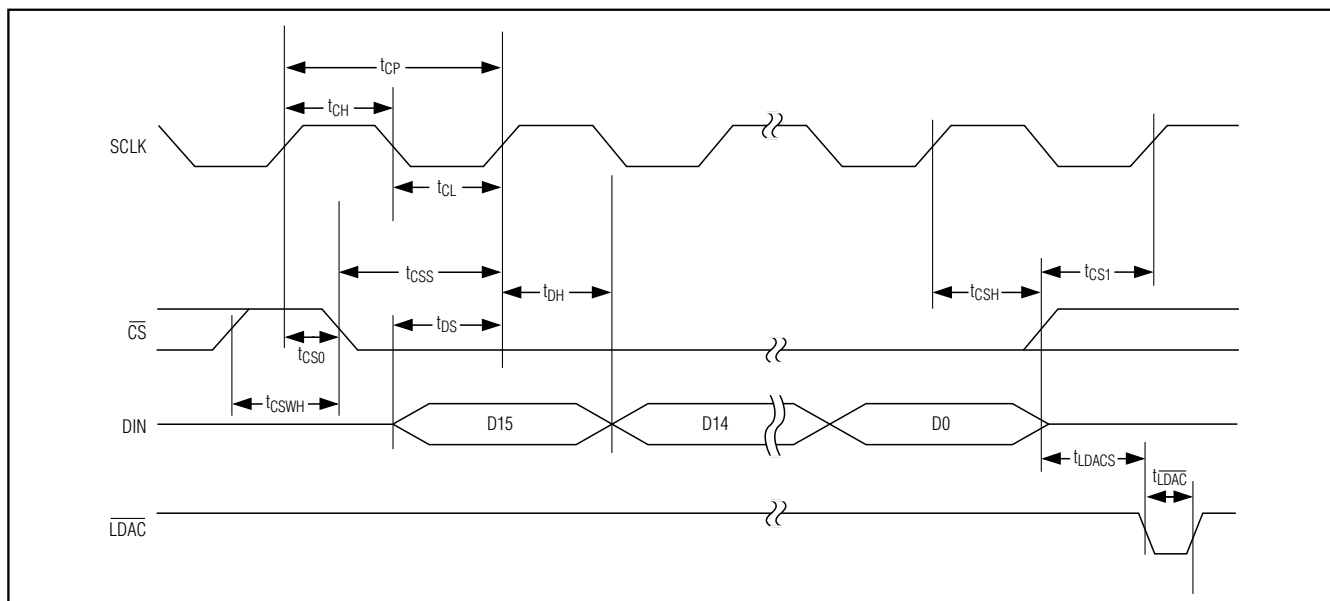


Figure 3. 4-Wire Interface Timing Diagram

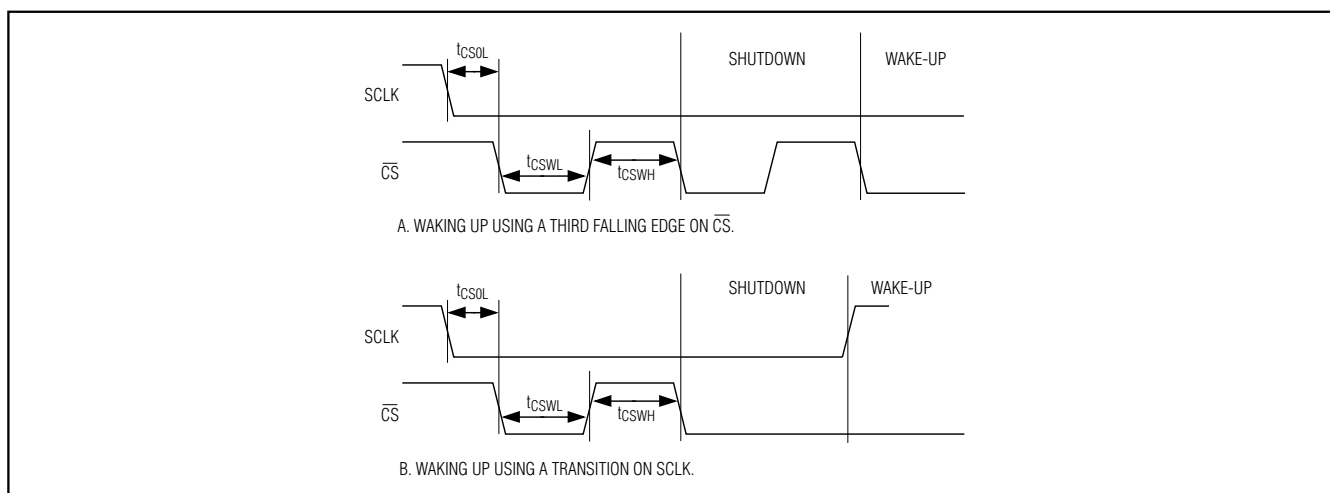


Figure 4. Shutdown Timing

Applications Information

Power-Supply and Bypassing Considerations

Bypass the power supply with a 10 μ F capacitor in parallel with a 0.1 μ F capacitor to AGND. Minimize lead lengths to reduce lead inductance. If noise becomes an issue, use shielding and/or ferrite beads to increase isolation.

Output Buffer

The MAX5200–MAX5203 include low-offset, low-noise buffers enabling the output to source 15mA or sink 5mA. The output buffer operates at a slew rate of 0.6V/ μ s. With a 1/4 FS to 3/4 FS output transition, the buffer output typically settles to 1 LSB in less than 25 μ s. The MAX5200–MAX5203 output buffers provide a low 0.2 Ω typical output impedance. The MAX5200–MAX5203 buffer amplifiers typically produce 175nV/ $\sqrt{\text{Hz}}$ noise at 10kHz.

Low-Cost, Voltage-Output, 16-Bit DACs with Internal Reference in μ MAX

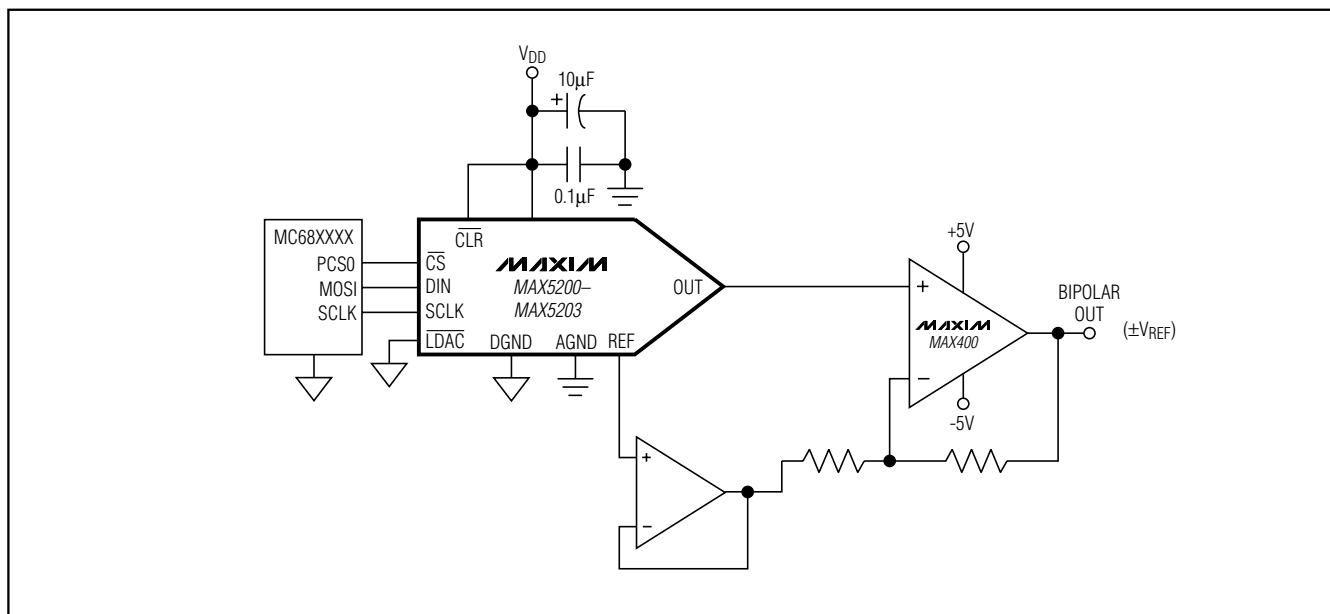


Figure 5. MAX5200–MAX5203 Typical Operating Circuit—Bipolar Output

Table 1. Bipolar Code Table

DAC LATCH CONTENTS		ANALOG OUTPUT, V_{OUT}
MSB	LSB	
1111 1111 1111 1111		$+V_{REF} \times (32,767 / 32,768)$
1000 0000 0000 0001		$+V_{REF} \times (1 / 32,768)$
1000 0000 0000 0000		0V
0111 1111 1111 1111		$-V_{REF} \times (1 / 32,768)$
0000 0000 0000 0000		$-V_{REF} \times (32,768 / 32,768)$

Bipolar Configuration

The MAX5200–MAX5203 are designed for unipolar operation, but can be used in bipolar applications with an external amplifier and resistors. Figure 5 shows the MAX5200–MAX5203 configured for bipolar operation. The op amp is set for unity gain. Table 1 lists the offset binary code for this circuit. The output voltage range is $\pm V_{REF}$.

Layout Considerations

Digital and AC transient signals coupling to AGND can create noise at the output. Connect AGND to the highest quality ground available. Use proper grounding techniques, such as a multilayer board with a low-inductance ground plane. Wire-wrapped boards and sockets are not recommended. For optimum system performance, use printed circuit (PC) boards with separate analog and digital ground planes. Connect the two ground planes together at the low-impedance power-supply source. Connect DGND and AGND pins together at the IC. The best ground connection is achieved by connecting the DAC's DGND and AGND together, and then connecting that point to the system analog ground plane. If the DAC's DGND is connected to the system digital ground, digital noise can get through the DAC's analog portion.

Chip Information

TRANSISTOR COUNT: 8764

PROCESS: BiCMOS

Low-Cost, Voltage-Output, 16-Bit DACs with Internal Reference in μ MAX

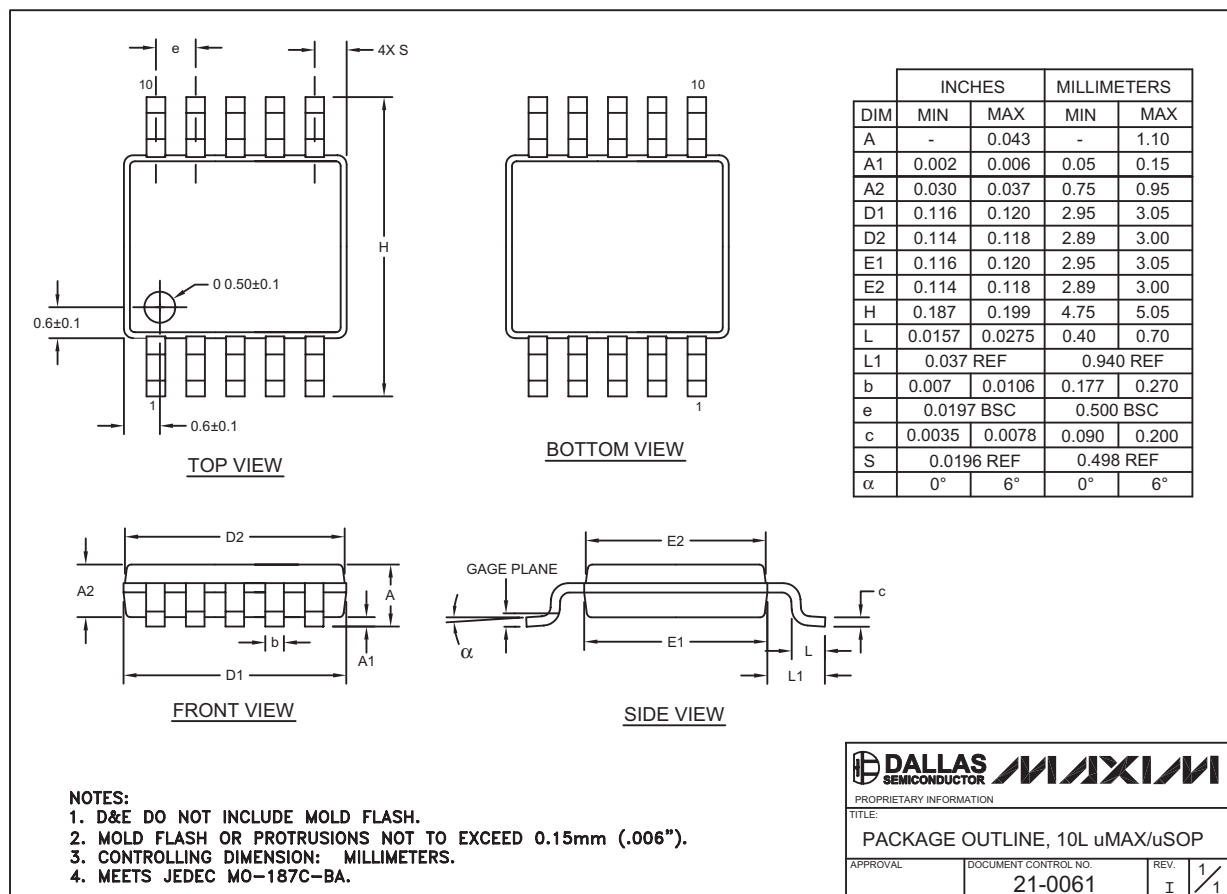
Selector Guide

PART	INTEGRAL NONLINEARITY (LSB, MAX)	SUPPLY VOLTAGE RANGE (V)	REFERENCE INPUT RANGE (V)	POWER-ON-RESET VALUE
MAX5200AEUB	20	4.75 to 5.25	2.5	Midscale
MAX5200ACUB	20	4.75 to 5.25	2.5	Midscale
MAX5200BEUB	40	4.75 to 5.25	2.5	Midscale
MAX5201AEUB	20	4.75 to 5.25	2.5	Zero
MAX5201ACUB	20	4.75 to 5.25	2.5	Zero
MAX5201BEUB	40	4.75 to 5.25	2.5	Zero
MAX5202AEUB	20	2.7 to 3.6	1.5	Midscale
MAX5202ACUB	20	2.7 to 3.6	1.5	Midscale
MAX5202BEUB	40	2.7 to 3.6	1.5	Midscale
MAX5203AEUB	20	2.7 to 3.6	1.5	Zero
MAX5203ACUB	20	2.7 to 3.6	1.5	Zero
MAX5203BEUB	40	2.7 to 3.6	1.5	Zero

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Package Information

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to www.maxim-ic.com/packages.)



10L uMAX.EPS

MAX5200-MAX5203

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Maxim Integrated Products, 120 San Gabriel Drive, Sunnyvale, CA 94086 408-737-7600 13