

### **General Description**

The MAX5360/MAX5361/MAX5362 are low-cost, 6-bit digital-to-analog converters (DACs) in miniature 5-pin SOT23 packages with a simple 2-wire serial interface that allows communication with multiple devices. The MAX5360 has an internal +2V reference and operates from a +2.7V to +3.6V supply. The MAX5361 has an internal +4V reference and operates from a +4.5V to +5.5V supply. The MAX5362 operates over the full +2.7V to +5.5V supply range and has an internal reference equal to  $0.9 \times V_{DD}$ .

The fast-mode I<sup>2</sup>C-compatible serial interface allows communication at data rates up to 400kbps, minimizing board space and reducing interconnect complexity in many applications. Each device is available with one of four factory-preset addresses (see Selector Guide).

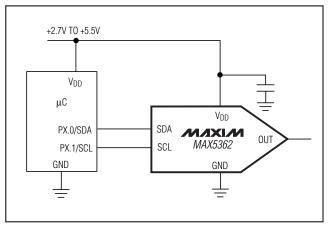
The MAX5360/MAX5361/MAX5362 also include an output buffer, a low-power shutdown mode, and a poweron reset that ensures the DAC outputs are at zero when power is initially applied. In shutdown mode, the supply current is reduced to less than 1µA and the output is pulled down with a  $10k\Omega$  resistor to GND.

The MAX5360/MAX5361/MAX5362 are available in miniature 5-pin SOT23 packages.

## **Applications**

Automatic Tuning (VCO) Power Amplifier Bias Control Programmable Threshold Levels Automatic Gain Control Automatic Offset Adjustment

## **Typical Operating Circuit**



#### **Features**

- ♦ 6-Bit Accuracy in a Tiny 5-Pin SOT23 Package
- ♦ Wide +2.7V to +5.5V Supply Range (MAX5362)
- ♦ 1µA Shutdown Mode
- **♦** Buffered Output Drives Resistive Loads
- ♦ Low Glitch Power-On-Reset to Zero DAC Output
- **♦** Fast I<sup>2</sup>C-Compatible Serial Interface
- ♦ ≤-5% Full-Scale Error (MAX5362)
- ♦ ≤1LSB (max) INL/DNL
- ♦ Low 230µA max Supply Current

### **Ordering Information**

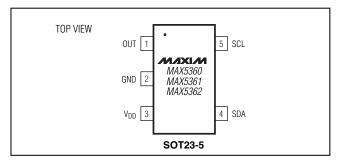
PART	TEMP RANGE	PIN-PACKAGE
<b>MAX5360</b> _EUK_ +T*	-40°C to +85°C	5 SOT23-5
<b>MAX5361</b> _EUK_ +T*	-40°C to +85°C	5 SOT23-5
MAX5362_EUK_ +T*	-40°C to +85°C	5 SOT23-5

<sup>\*</sup>See Selector Guide for address options.

#### **Selector Guide**

PART	ADDRESS	REFERENCE	TOP MARK
MAX5360LEUK	0x60	+2.0V	ADMM
MAX5360MEUK	0x62	+2.0V	ADMY
MAX5360NEUK	0x64	+2.0V	ADNE
MAX5360PEUK	0x66	+2.0V	ADMO
MAX5361LEUK	0x60	+4.0V	ADMU
MAX5361MEUK	0x62	+4.0V	ADNA
MAX5361NEUK	0x64	+4.0V	ADNG
MAX5361PEUK	0x66	+4.0V	ADMQ
MAX5362LEUK	0x60	$0.9 \times V_{DD}$	ADMW
MAX5362MEUK	0x62	0.9 x V <sub>DD</sub>	ADNC
MAX5362NEUK	0x64	0.9 x V <sub>DD</sub>	ADNI
MAX5362PEUK	0x66	0.9 x V <sub>DD</sub>	ADMS

## **Pin Configuration**



MIXIM

Maxim Integrated Products 1

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

#### **ABSOLUTE MAXIMUM RATINGS**

V <sub>DD</sub> to GND0.3V to +6V	Operating Temperature Range
OUT to GND0.3V to (V <sub>DD</sub> + 0.3V)	MAX536EUK-T40°C to +85°C
SCL, SDA to GND0.3V to +6V	Storage Temperature Range65°C to +150°C
Maximum Current into Any Pin50mA	Maximum Junction Temperature+150°C
Continuous Power Dissipation (T <sub>A</sub> = +70°C)	Lead Temperature (soldering, 10s)+300°C
5-Pin SOT23 (derate 7.1mW/°C above +70°C)571mW	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.

#### **ELECTRICAL CHARACTERISTICS**

 $(V_{DD}=2.7V\ to\ 3.6V\ (MAX5360);\ V_{DD}=4.5V\ to\ 5.5V\ (MAX5361);\ V_{DD}=2.7V\ to\ 5.5V\ (MAX5362);\ R_L=10k\Omega,\ C_L=50pF,\ T_A=T_{MIN}\ to\ T_{MAX},\ unless\ otherwise\ noted.$  Typical values are  $T_A=+25^{\circ}C.)$ 

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS	
STATIC ACCURACY				'			•	
Resolution				6			Bits	
Integral Linearity Error	INL	(Note 1)	(Note 1)			±1	LSB	
Differential Linearity Error	DNL	Guaranteed monot	tonic (Note 2)			±1	LSB	
Offset Error	Vos	Guaranteed monot	tonic (Note 2)		±1	±25	mV	
Offset Error Supply Rejection		MAX5362 (Notes 2	2, 3)	60			dB	
Offset Error Temperature		(Note 2)	MAX5360/MAX5361		3		100	
Coefficient			MAX5362		1		ppm/°C	
		0 1 00	MAX5360/MAX5361			10	% of Ideal	
Full-Scale Error		Code = 63	MAX5362			5	FS	
Full-Scale Error Supply Rejection		Code = 63, MAX53	B60/MAX5361 (Note 4)			60	dB	
Full-Scale Error Temperature		MAX5360/MAX	MAX5360/MAX5361		±40		ppm/°C	
Coefficient		Code = 63	MAX5362		±10			
DAC OUTPUT	I			1			1	
		MAX5360		1.8	2	2.2		
15 ( (1) 5)	555	MAX5361		3.6	4	4.4	1 ,,	
Internal Reference (Note 5)	REF -			0.85×	0.9×	0.95×	- V	
		MAX5362		V <sub>DD</sub>	$V_{DD}$	$V_{DD}$		
Output Load Degulation		Code = 63, 0 to 100µA			0.5		LSB	
Output Load Regulation		Code = 0, 0 to -10	•		0.5		LOD	
Output Resistance		V <sub>OUT</sub> = 0 to V <sub>DD</sub> , power-down mode			10		kΩ	
DYNAMIC PERFORMANCE								
Voltage Output Slew Rate		Positive and negative			0.4		V/µs	
Output Settling Time		To 1/2LSB, 50k $\Omega$ and 50pF load (Note 6)			20		μs	
Digital Feedthrough		Code = 0, all digita	Code = 0, all digital inputs from 0 to V <sub>DD</sub>		2		nVs	
Digital-Analog Glitch Impulse		Code 31 to 32			40		nVs	
Wake-Up Time		From software shu	tdown		50		μs	

### **ELECTRICAL CHARACTERISTICS (continued)**

 $(V_{DD}=2.7V\ to\ 3.6V\ (MAX5360);\ V_{DD}=4.5V\ to\ 5.5V\ (MAX5361);\ V_{DD}=2.7V\ to\ 5.5V\ (MAX5362);\ R_L=10k\Omega,\ C_L=50pF,\ T_A=T_{MIN}\ to\ T_{MAX},\ unless\ otherwise\ noted.$  Typical values are  $T_A=+25^{\circ}C.)$ 

PARAMETER	SYMBOL	CONE	DITIONS	MIN	TYP	MAX	UNITS
POWER REQUIREMENTS	'						
		MAX5360		2.7		3.6	
Supply Voltage	V <sub>DD</sub>	MAX5361		4.5		5.5	V
		MAX5362		2.7		5.5	
Supply Current	loo	No load, all digital inpu	its at 0 or V <sub>DD</sub> , code = 63		150	230	
Supply Current	IDD	Shutdown mode				1	μΑ
DIGITAL INPUTS (SCL, SDA)							
Input Low Voltage	VIL				0.	$.3 \times V_{DD}$	V
Input High Voltage	VIH			$0.7 \times V_{DD}$			V
Input Hysteresis	V <sub>hys</sub>			0.0	)5 × V <sub>D</sub>	D	V
Input Capacitance	CIN	(Note 7)			10		pF
Input Leakage Current	li					±10	μΑ
Pulse Width of Spike Suppressed	tsp			0		50	ns
DIGITAL OUTPUT (SDA) (open	drain)	I.		ı			
Output Low Voltage	Voi	I <sub>SINK</sub> = 3mA			0	0.4	V
Output Low Voltage	V <sub>OL</sub>	I <sub>SINK</sub> = 6mA			0	0.6	
Output Fall Time	tof	V <sub>IH</sub> min to V <sub>IL</sub> max, bus capacitance	I <sub>SINK</sub> = 3mA			250	ns
Output Faii Time	101	10pF to 400pF	ISINK = 6mA			250	

### **TIMING CHARACTERISTICS**

 $(V_{DD}=2.7V \text{ to } 3.6V \text{ (MAX5360)}; V_{DD}=4.5V \text{ to } 5.5V \text{ (MAX5361)}; V_{DD}=2.7V \text{ to } 5.5V \text{ (MAX5362)}; R_L=10k\Omega, C_L=50pF, T_A=T_{MAX} \text{ to } T_{MIN}$ , Figure 3, unless otherwise noted. Typical values are  $T_A=+25^{\circ}C$ .)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
SCL Clock Frequency	fscL		0		400	kHz
Bus-Free Time Between a STOP and a START Condition	t <sub>BUF</sub>		1.3			μs
Hold Time (Repeated) START Condition	tHD, STA		0.6			μs
Low Period of the SCL Clock	tLOW		1.3			μs
High Period of the SCL Clock	tHIGH		0.6			μs

### **TIMING CHARACTERISTICS (continued)**

 $(V_{DD}=2.7V \text{ to } 3.6V \text{ (MAX5360)}; V_{DD}=4.5V \text{ to } 5.5V \text{ (MAX5361)}; V_{DD}=2.7V \text{ to } 5.5V \text{ (MAX5362)}; R_L=10k\Omega, C_L=50pF, T_A=T_{MAX} \text{ to } T_{MIN}, Figure 3, unless otherwise noted. Typical values are T_A=+25°C.)$ 

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Setup Time for a Repeated START Condition	t <sub>SU, STA</sub>		0.6			μs
Data Hold Time	thd, dat		0		0.9	μs
Data Setup Time	tsu, dat		100			ns
Rise Time of Both SDA and SCL Signals	t <sub>r</sub>				300	ns
Fall Time of Both SDA and SCL Signals	t <sub>f</sub>				300	ns
Setup Time for STOP Condition	tsu, sto		0.6			μs
Capacitive Load for Each Bus Line	Cb				400	pF

Note 1: Guaranteed from code 1 to code 63.

Note 2: The offset value extrapolated from the range over which the INL is guaranteed.

**Note 3:** MAX5362, tested at  $V_{DD} = 5V \pm 10\%$ .

**Note 4:** MAX5360, tested at  $V_{DD} = 3V \pm 10\%$ ; MAX5361, tested at  $V_{DD} = 5V \pm 10\%$ .

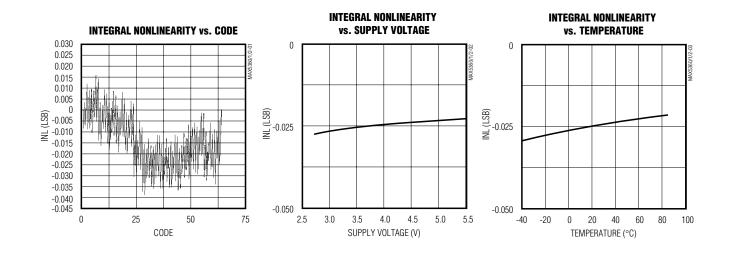
Note 5: Actual output voltage at full scale is 63/64 × V<sub>REF</sub>.

Note 6: Output settling time is measured by taking the code from code 1 to code 63, and from code 63 to code 1.

Note 7: Guaranteed by design.

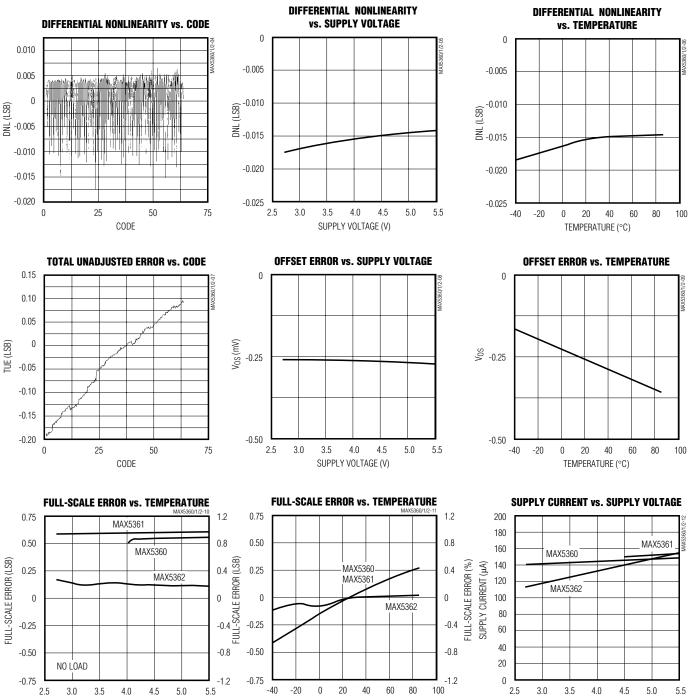
## Typical Operating Characteristics

(V<sub>DD</sub> = 3V (MAX5360), V<sub>DD</sub> = 5V (MAX5361/MAX5362), T<sub>A</sub> = +25°C, unless otherwise noted.)



## Typical Operating Characteristics (continued)

(V<sub>DD</sub> = 3V (MAX5360), V<sub>DD</sub> = 5V (MAX5361/MAX5362), T<sub>A</sub> = +25°C, unless otherwise noted.)



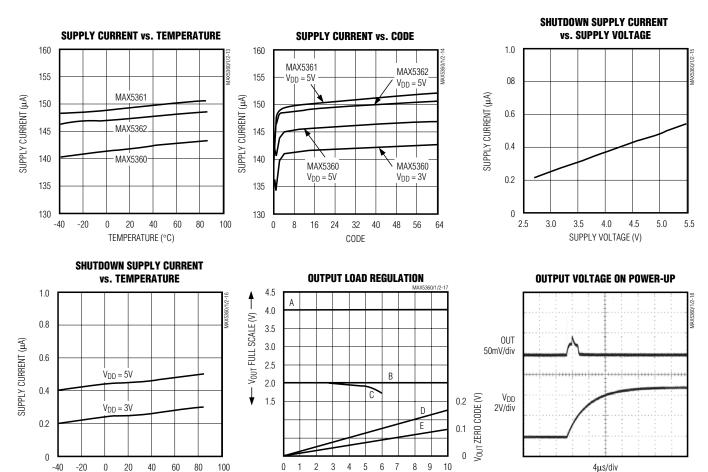
TEMPERATURE (°C)

SUPPLY VOLTAGE (V)

SUPPLY VOLTAGE (V)

### Typical Operating Characteristics (continued)

(V<sub>DD</sub> = 3V (MAX5360), V<sub>DD</sub> = 5V (MAX5361/MAX5362), T<sub>A</sub> = +25°C, unless otherwise noted.)



- A: MAX5361/MAX5362,  $V_{DD}$  = 4.5V, FULL-SCALE OR SOURCIN B: MAX5360, FULL-SCALE,  $V_{DD} = 2.7 \text{V}$  SINKING,  $V_{DD} = 5 \text{V}$  SO
- C: MAX5360, FULL-SCALE, V<sub>DD</sub> = 2.7V, SOURCING D: ZERO CODE, V<sub>DD</sub> = 2.7V, SINKING

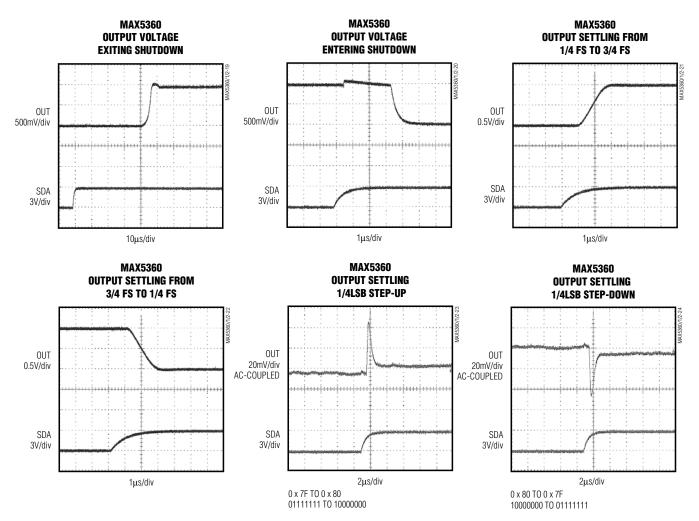
LOAD CURRENT (mA)

- E: ZERO CODE, V<sub>DD</sub> = 5.5V SINKING

TEMPERATURE (°C)

### Typical Operating Characteristics (continued)

(V<sub>DD</sub> = 3V (MAX5360), V<sub>DD</sub> = 5V (MAX5361/MAX5362), T<sub>A</sub> = +25°C, unless otherwise noted.)



## **Pin Description**

PIN	NAME	FUNCTION
1	OUT	DAC Voltage Output
2	GND	Ground
3	V <sub>DD</sub>	Power-Supply Input
4	SDA	Serial Data Input
5	SCL	Serial Clock Input

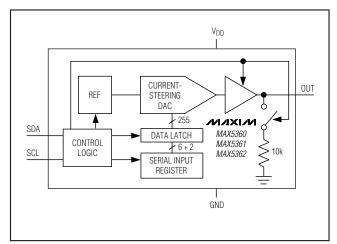


Figure 1. Functional Diagram

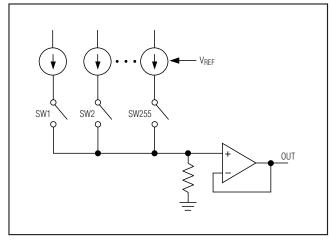


Figure 2. Current-Steering Topology

### Table 1. Unipolar Code Current

DAC CODE	OUTPUT VOLTAGE				
6 BITS + 2 SUBBITS	MAX5360	MAX5361	MAX5362		
111111 (00)	2V × (63/64)	4V × (63/64)	0.9 × V <sub>DD</sub> × (63/64)		
100000 (00)	1V	2V	0.9 × V <sub>DD</sub> / 2		
000001 (00)	31mV	62mV	0.9 × V <sub>DD</sub> / 64		
000000 (00)	0	0	0		

## **Detailed Description**

The MAX5360/MAX5361/MAX5362 voltage-output, 6-bit DACs offer full 6-bit performance with less than 1LSB integral nonlinearity (INL) error and less than 1LSB differential nonlinearity (DNL) error ensuring monotonic performance. The devices use a simple two-wire, fast-mode I<sup>2</sup>C-compatible serial interface that operates up to 400kHz. The MAX5360/MAX5361/MAX5362 include an internal reference, an output buffer, and low-current shutdown mode, making them ideal for low-power, highly integrated applications. Figure 1 shows the devices' functional diagram.

#### **Analog Section**

The MAX5360/MAX5361/MAX5362 employ a current-steering DAC topology as shown in Figure 2. At the core of the DAC is a reference voltage-to-current converter (V/I) that generates a reference current. This current is mirrored to 255 equally weighted current sources. DAC switches control the outputs of these current mirrors, so only the desired fraction of the total current-mirror currents is steered to the DAC output. The

current is then converted to a voltage across a resistor, and this voltage is buffered by the output buffer amplifier.

#### **Output Voltage**

Table 1 shows the relationship between the DAC code and the analog output voltage. The 6-bit DAC code is binary unipolar with 1LSB = ( $V_{REF}$  / 64). The MAX5360/MAX5361 have a full-scale output voltage of (+2V - 1LSB) and (+4V - 1LSB), respectively, set by the internal references. The MAX5362 has a full-scale output voltage of (0.9 ×  $V_{DD}$  - 1LSB). Each device accepts 8-bit DAC codes, but the accuracy is guaranteed only for 6 bits.

#### **Output Buffer**

The DAC voltage output is an internally buffered unity-gain follower that typically slews at  $\pm 0.4 \text{V/}\mu\text{s}$ . The output can swing from 0 to full scale. With a 1/4 FS to 3/4 FS output transition, the amplifier outputs typically settle to 1/2LSB in less than 5µs when loaded with 10k $\Omega$  in parallel with 50pF. The buffer amplifiers are stable with any combination of resistive loads >10k $\Omega$  and capacitive loads <50pF.

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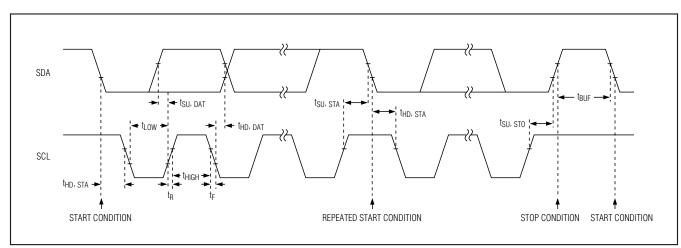


Figure 3. Two-Wire Serial Interface Timing Diagram

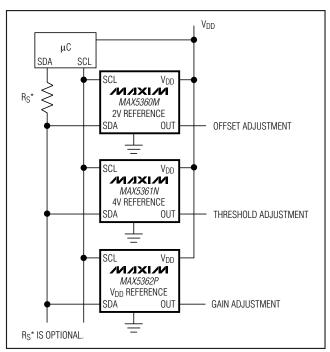


Figure 4. Typical Application Circuit

#### Power-On Reset

The MAX5360/MAX5361/MAX5362 have a power-on reset circuit to set the DAC's output to 0 when  $V_{DD}$  is first applied or when  $V_{DD}$  dips below 1.7V. This ensures that unwanted DAC output voltages will not occur immediately following a system startup, such as after a loss of power. The output glitch on startup is typically <50mV.

#### Shutdown Mode

The MAX5360/MAX5361/MAX5362 include a software-controlled shutdown mode that reduces the supply current to <1 $\mu$ A. All internal circuitry is disabled and an internal 10k $\Omega$  resistor is placed from OUT to GND to ensure 0V at OUT while in shutdown. The device enters shutdown in less than 5 $\mu$ s and exits shutdown in less than 50 $\mu$ s.

#### **Digital Section**

#### Serial interface

The MAX5360/MAX5361/MAX5362 use a simple two-wire serial interface requiring only two I/O lines (two-wire bus) of a standard microprocessor ( $\mu$ P) port. Figure 3 shows the timing diagram for signals on the 2-wire bus.

The two bus lines (SDA and SCL) must be high when the bus is not in use. The MAX5360/MAX5361/ MAX5362 are receive-only devices (slaves) and must be controlled by a bus master device. Figure 4 shows a typical application where multiple devices can be connected to the bus provided they have different address settings. External pullup resistors are not necessary on these lines (when driven by push-pull drivers), though the MAX5360/MAX5361/MAX5362 can be used in applications where pullup resistors are required (such as in I<sup>2</sup>C systems) to maintain compatibility with existing circuitry. The serial interface operates at SCL rates up to 400kHz. The SDA state is allowed to change only while SCL is low, with the exception of START and STOP conditions as shown in Figure 5. Each transmission consists of a START condition sent by the bus master device, followed by the MAX5360/MAX5361/ MAX5362's preset slave address, a power-mode bit, the DAC data (6 bits + 2 subbits), and finally, a STOP

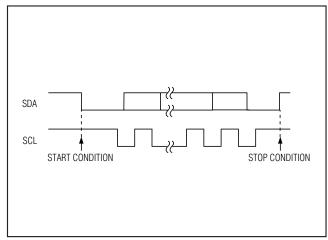


Figure 5. Start and Stop Conditions

condition (Figure 6). The bus is then free for another transmission.

SDA's state is sampled, and therefore must remain stable while SCL is high. Data is transmitted in 8-bit bytes. Nine clock cycles are required to transfer each byte to the MAX5360/MAX5361/MAX5362. Release SDA during the 9th clock cycle as the selected device acknowledges the receipt of the byte, by pulling SDA low during this time. A series resistor on the SDA line may be needed if the master's output is forced high while the selected device acknowledges (Figure 4).

#### Slave Address

The MAX5360/MAX5361/MAX5362 are available with one of four preset slave addresses. Each address

option is identified by the suffix L, M, N, or P added to the part number. The address is defined as the 7 most significant bits (MSBs) sent by the master after a START condition. The address options are 0x60, 0x62, 0x64, and 0x66 (left justified with LSB set to 0). The 8th bit, typically used to define a write or read protocol, sets the device's power mode (SHDN); the device is powered down when SHDN is set to 1. During a device search routine, the MAX5360/MAX5361/MAX5362 acknowledge both options (SHDN = 0 or SHDN = 1) but does not change its power state if a stop condition (or restart) is issued immediately. The second byte (DAC data) must be sent/received for the device to update both power mode and DAC output.

#### DAC Data

The 6-bit DAC data is decoded as straight binary MSB first with  $1LSB = (V_{REF} / 64)$  and converted into the corresponding analog voltage as shown in Table 1. Two subbits complete the data byte; these 2 bits should be set to zero since they are not tested to guaranteed-monotonic performance.

After receiving the data byte, the MAX5360/MAX5361/MAX5362 acknowledge its receipt and expect a STOP condition, at which point the DAC output is updated. The devices update the output and the power mode only if the second byte is clocked in (SHDN = 0) or out (SHDN = 1) of the device. When SHDN = 1, the master will read all ones when clocking out a data byte. The MAX5360/MAX5361/MAX5362 do not drive SDA except for the acknowledge bit.

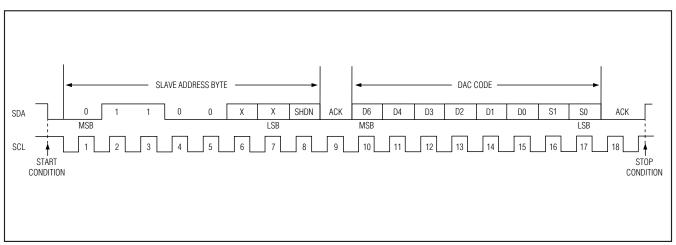


Figure 6. Complete Serial Transmission

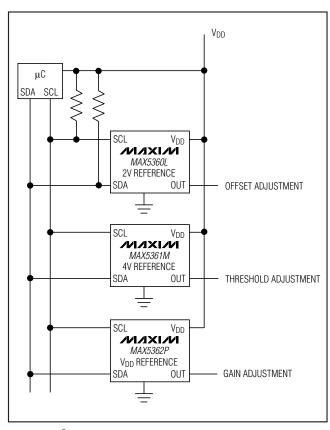


Figure 7. I<sup>2</sup>C Typical Application

#### I<sup>2</sup>C Compatibility

The MAX5360/MAX5361/MAX5362 are compatible with existing I<sup>2</sup>C systems. SCL and SDA are high-impedance inputs; SDA has an open drain that pulls the data line low during the 9th clock pulse. Figure 7 shows a

typical I<sup>2</sup>C application. The communication protocol supports the standard I<sup>2</sup>C 8-bit communications. The general call address is ignored, and CBUS formats are not supported. The MAX5360/MAX5361/MAX5362 address is compatible with the 7-bit I<sup>2</sup>C addressing protocol only. No 10-bit formats are supported. RESTART protocol is supported, but an immediate STOP condition is necessary to update the DAC.

## Applications Information

### **Digital Inputs and Interface Logic**

The serial 2-wire interface has logic levels defined as  $V_{OL} = 0.3 \times V_{DD}$  and  $V_{OH} = 0.7 \times V_{DD}$ . All of the inputs include Schmitt-trigger buffers to accept slow-transition interfaces. This means that optocouplers can interface directly to the MAX5360/MAX5361/MAX5362 without additional external logic. The digital inputs are compatible with CMOS logic levels and must not be driven with voltages higher than  $V_{DD}$ .

#### **Power-Supply Bypassing and Layout**

Careful PC board layout is important for best system performance. To reduce crosstalk and noise injection, keep analog and digital signals separate. Ensure that the ground return from GND to the supply ground is short and low impedance; a ground plane is recommended. Bypass  $V_{DD}$  with a  $0.1\mu F$  to ground as close as possible to the device. If the supply is excessively noisy, connect a  $10\Omega$  resistor in series with the supply and  $V_{DD}$ , and add additional capacitance

Chip Information

PROCESS: BICMOS

### **Package Information**

For the latest package outline information and land patterns (footprints), go to <a href="www.maxim-ic.com/packages">www.maxim-ic.com/packages</a>. 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.
5 SOT23	U5+1	21-0057	<u>90-0174</u>

**Revision History** 

REVISION	REVISION	DESCRIPTION	PAGES
NUMBER	DATE		CHANGED
2	3/11	Corrected offset error specification in Electrical Characteristics table	2

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## Maxim Integrated:

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MAX5362PEUK+T