



# Low-Cost, Voltage-Output, 16-Bit DACs in $\mu$ MAX

## General Description

The MAX5204–MAX5207 serial input, voltage-output 16-bit digital-to-analog converters (DACs) provide monotonic 16-bit output over temperature without any adjustments. The MAX5204/MAX5205 operate from a +5V single power supply and use an external reference ranging from +4V to  $V_{DD}$ , while the MAX5206/MAX5207 operate from a +3V or +3.3V single power supply and use an external reference ranging from +2V to  $V_{DD}$ . The MAX5204–MAX5207 DAC output range is typically from 0 to  $V_{DD}$ .

The MAX5204–MAX5207 feature a hardware reset input ( $\overline{\text{CLR}}$ ) that when pulled low clears the output to zero code 0000 hex (MAX5205/MAX5207) or resets the output to midscale code 8000 hex (MAX5204/MAX5206).

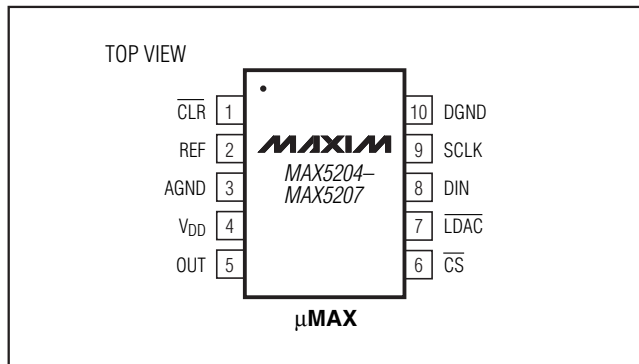
The 3-wire serial interface is compatible with SPI™/QSPI™/MICROWIRE™. All devices have a low-power shutdown mode that reduces the supply current consumption to 1 $\mu$ A.

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

## Applications

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

## Pin Configuration



## Features

- ◆ **Guaranteed 16-Bit Monotonic**
- ◆ **10-Pin 5mm × 3mm  $\mu$ MAX Package**
- ◆ **Rail-to-Rail Output Amplifier**
- ◆ **Single-Supply Operation**
  - +5V (MAX5204/MAX5205)
  - +3V, +3.3V (MAX5206/MAX5207)
- ◆ **Low Power Consumption: 0.5mA**
- ◆ **Shutdown Mode Reduces Supply Current to 1 $\mu$ A**
- ◆ **SPI/QSPI/MICROWIRE-Compatible 3-Wire Serial Interface**
- ◆ **Power-On-Reset Sets Output to**
  - Midscale (MAX5204/MAX5206)**
  - Zero-Scale (MAX5205/MAX5207)**

## Ordering Information

| PART                | TEMP RANGE      | PIN-PACKAGE  |
|---------------------|-----------------|--------------|
| <b>MAX5204</b> AEUB | -40°C to +105°C | 10 $\mu$ MAX |
| MAX5204BEUB         | -40°C to +105°C | 10 $\mu$ MAX |
| MAX5204ACUB         | 0°C to +70°C    | 10 $\mu$ MAX |
| <b>MAX5205</b> AEUB | -40°C to +105°C | 10 $\mu$ MAX |
| MAX5205BEUB         | -40°C to +105°C | 10 $\mu$ MAX |
| MAX5205ACUB         | 0°C to +70°C    | 10 $\mu$ MAX |
| <b>MAX5206</b> AEUB | -40°C to +105°C | 10 $\mu$ MAX |
| MAX5206BEUB         | -40°C to +105°C | 10 $\mu$ MAX |
| MAX5206ACUB         | 0°C to +70°C    | 10 $\mu$ MAX |
| <b>MAX5207</b> AEUB | -40°C to +105°C | 10 $\mu$ MAX |
| MAX5207BEUB         | -40°C to +105°C | 10 $\mu$ MAX |
| MAX5207ACUB         | 0°C to +70°C    | 10 $\mu$ MAX |

**Selector Guide appears at end of data sheet.**

SPI/QSPI are trademarks of Motorola, Inc.

MICROWIRE is a trademark of National Semiconductor Corp.

$\mu$ MAX is a registered trademark of Maxim Integrated Products, Inc.

MAX5204–MAX5207

# Low-Cost, Voltage-Output, 16-Bit DACs in $\mu$ 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 Pin .....                                                 | 50mA                         |
| Continuous Power Dissipation ( $T_A = +70^\circ\text{C}$ )                         |                              |
| 10-Pin $\mu$ MAX (derate 5.6mW/ $^\circ\text{C}$ above $+70^\circ\text{C}$ ) ..... | 444.4mW                      |

### Operating Temperature Ranges

|                                         |                                             |
|-----------------------------------------|---------------------------------------------|
| MAX520_CUB .....                        | $0^\circ\text{C}$ to $+70^\circ\text{C}$    |
| MAX520_EUB .....                        | $-40^\circ\text{C}$ to $+105^\circ\text{C}$ |
| Junction Temperature .....              | $+150^\circ\text{C}$                        |
| Storage Temperature Range .....         | $-60^\circ\text{C}$ 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—MAX5204/MAX5205

( $V_{DD} = +4.75V$  to  $+5.25V$ ,  $f_{SCLK} = 10\text{MHz}$  (50% duty cycle),  $V_{REF} = 4.096V$ , output load =  $10k\Omega$  in parallel with  $250\text{pF}$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ\text{C}$ .)

| PARAMETER                          | SYMBOL | CONDITIONS                                                                                    | MIN | TYP           | MAX       | UNITS                        |
|------------------------------------|--------|-----------------------------------------------------------------------------------------------|-----|---------------|-----------|------------------------------|
| <b>STATIC PERFORMANCE</b> (Note 1) |        |                                                                                               |     |               |           |                              |
| Resolution                         | N      |                                                                                               | 16  |               |           | Bits                         |
| Integral Nonlinearity (Note 2)     | INL    | MAX520_AEUB                                                                                   |     | $\pm 10$      | $\pm 20$  | LSB                          |
|                                    |        | MAX520_ACUB                                                                                   |     | $\pm 10$      | $\pm 20$  |                              |
|                                    |        | MAX520_BEUB                                                                                   |     | $\pm 20$      | $\pm 40$  |                              |
| Differential Nonlinearity (Note 2) | DNL    | MAX520_A_UB (Note 3)                                                                          |     |               | $\pm 1$   | LSB                          |
|                                    |        | MAX520_BEUB ( $0^\circ\text{C}$ to $+105^\circ\text{C}$ ) (Note 3)                            |     |               | $\pm 1$   |                              |
|                                    |        | MAX520_BEUB ( $-40^\circ\text{C}$ to $0^\circ\text{C}$ )                                      |     |               | $\pm 2$   |                              |
| Offset Error                       |        | Inferred from measurement at 1C00 hex and FFFF hex                                            |     | $\pm 3$       | $\pm 25$  | mV                           |
| Gain Error                         | GE     | Within DAC output range (Note 4)                                                              |     | $\pm 0.01$    | $\pm 1$   | %FSR                         |
| Offset Temperature Coefficient     |        |                                                                                               |     | 1.5           |           | $\mu\text{V}/^\circ\text{C}$ |
| Gain Temperature Coefficient       |        |                                                                                               |     | 3             |           | ppm of FSR/ $^\circ\text{C}$ |
| Power-Supply Rejection             | PSR    | $V_{DD} = 5V \pm 5\%$ , midscale input                                                        |     | $\pm 0.06$    | $\pm 0.5$ | mV/V                         |
| <b>DYNAMIC PERFORMANCE</b>         |        |                                                                                               |     |               |           |                              |
| DAC Output Range                   |        | (Note 2)                                                                                      |     | 0 to $V_{DD}$ |           | V                            |
| Output-Voltage Slew Rate           | SR     |                                                                                               |     | 0.6           |           | V/ $\mu\text{s}$             |
| Output Settling Time               |        | To $\pm 1\text{LSB}$ of FS, $V_{STEP} = 0.25 \times V_{REF}$ to $0.75 \times V_{REF}$         |     | 25            |           | $\mu\text{s}$                |
| Output Noise                       |        | DAC code = 8400 hex, 10kHz                                                                    |     | 120           |           | $\text{nV}/\sqrt{\text{Hz}}$ |
| 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                                       |     | 50            |           | $\mu\text{s}$                |
| Power-Up Time                      |        | From power applied to 90% of output code = FFFF hex                                           |     | 10            |           | ms                           |

# Low-Cost, Voltage-Output, 16-Bit DACs in $\mu$ MAX

MAX5204-MAX5207

## ELECTRICAL CHARACTERISTICS—MAX5204/MAX5205 (continued)

( $V_{DD} = +4.75V$  to  $+5.25V$ ,  $f_{SCLK} = 10MHz$  (50% duty cycle),  $V_{REF} = 4.096V$ , output load =  $10k\Omega$  in parallel with  $250pF$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .)

| PARAMETER                                                                                                                                                                | SYMBOL      | CONDITIONS                                   | MIN  | TYP | MAX      | UNITS     |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|----------------------------------------------|------|-----|----------|-----------|
| <b>REFERENCE INPUT</b>                                                                                                                                                   |             |                                              |      |     |          |           |
| $V_{REF}$ Input Range                                                                                                                                                    |             |                                              | 4.0  |     | $V_{DD}$ | V         |
| $V_{REF}$ Input Current                                                                                                                                                  |             |                                              |      | 40  |          | $\mu A$   |
| $V_{REF}$ Input Resistance                                                                                                                                               |             |                                              |      | 100 |          | $k\Omega$ |
| Input Capacitance                                                                                                                                                        |             |                                              |      | 18  |          | pF        |
| <b>DIGITAL INPUTS (<math>\overline{DIN}</math>, <math>\overline{SCLK}</math>, <math>\overline{CS}</math>, <math>\overline{CLR}</math>, <math>\overline{LDAC}</math>)</b> |             |                                              |      |     |          |           |
| 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 $V_{DD}$               |      |     | $\pm 1$  | $\mu A$   |
| Input Capacitance                                                                                                                                                        | $C_{IN}$    |                                              |      | 15  |          | pF        |
| <b>POWER REQUIREMENTS</b>                                                                                                                                                |             |                                              |      |     |          |           |
| 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       | $\mu A$   |
| <b>TIMING CHARACTERISTICS</b>                                                                                                                                            |             |                                              |      |     |          |           |
| $\overline{SCLK}$ Frequency                                                                                                                                              | $f_{SCLK}$  |                                              |      |     | 10       | MHz       |
| $\overline{SCLK}$ Clock Period                                                                                                                                           | $t_{CP}$    |                                              | 100  |     |          | ns        |
| $\overline{SCLK}$ Pulse Width High                                                                                                                                       | $t_{CH}$    |                                              | 40   |     |          | ns        |
| $\overline{SCLK}$ Pulse Width Low                                                                                                                                        | $t_{CL}$    |                                              | 40   |     |          | ns        |
| $\overline{DIN}$ Setup Time                                                                                                                                              | $t_{DS}$    |                                              | 40   |     |          | ns        |
| $\overline{DIN}$ Hold Time                                                                                                                                               | $t_{DH}$    |                                              | 0    |     |          | ns        |
| $\overline{CS}$ Fall to $\overline{SCLK}$ Rise Setup Time                                                                                                                | $t_{CSS}$   |                                              | 40   |     |          | ns        |
| $\overline{SCLK}$ Rise to $\overline{CS}$ Rise Hold Time                                                                                                                 | $t_{CSH}$   |                                              | 0    |     |          | ns        |
| $\overline{SCLK}$ Rise to $\overline{CS}$ Fall Ignore                                                                                                                    | $t_{CS0}$   |                                              | 10   |     |          | ns        |
| $\overline{CS}$ Rise to $\overline{SCLK}$ Rise Ignore                                                                                                                    | $t_{CS1}$   |                                              | 40   |     |          | ns        |
| $\overline{LDAC}$ Pulse Width                                                                                                                                            | $t_{LDAC}$  |                                              | 40   |     |          | ns        |
| $\overline{CS}$ Rise to $\overline{LDAC}$ Low Setup                                                                                                                      | $t_{LDACS}$ |                                              | 40   |     |          | ns        |
| $\overline{SCLK}$ 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 in $\mu$ MAX

MAX5204-MAX5207

## ELECTRICAL CHARACTERISTICS—MAX5206/MAX5207

( $V_{DD} = +2.7V$  to  $+3.6V$ ,  $f_{SCLK} = 10MHz$  (50% duty cycle),  $V_{REF} = 2.048V$ , output load =  $10k\Omega$  in parallel with  $250pF$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .)

| PARAMETER                          | SYMBOL | CONDITIONS                                                                         | MIN | TYP           | MAX       | UNITS                  |
|------------------------------------|--------|------------------------------------------------------------------------------------|-----|---------------|-----------|------------------------|
| <b>STATIC PERFORMANCE</b> (Note 1) |        |                                                                                    |     |               |           |                        |
| Resolution                         | N      |                                                                                    | 16  |               |           | Bits                   |
| Integral Nonlinearity (Note 2)     | INL    | MAX520_AEUB                                                                        |     | $\pm 10$      | $\pm 20$  | LSB                    |
|                                    |        | MAX520_ACUB                                                                        |     | $\pm 10$      | $\pm 20$  |                        |
|                                    |        | MAX520_BEUB                                                                        |     | $\pm 20$      | $\pm 40$  |                        |
| Differential Nonlinearity (Note 2) | DNL    | MAX520_A_UB (Note 3)                                                               |     |               | $\pm 1$   | LSB                    |
|                                    |        | MAX520_BEUB ( $0^\circ C$ to $+105^\circ C$ ) (Note 3)                             |     |               | $\pm 1$   |                        |
|                                    |        | MAX520_BEUB ( $-40^\circ C$ to $0^\circ C$ )                                       |     |               | $\pm 2$   |                        |
| Offset Error                       |        | Inferred from measurement at 3800 hex and FFFF hex                                 |     | $\pm 3$       | $\pm 25$  | mV                     |
| Gain Error                         | GE     | Within DAC output range (Note 4)                                                   |     | $\pm 0.01$    | $\pm 1.0$ | %FSR                   |
| Offset Temperature Coefficient     |        |                                                                                    |     | 1.5           |           | $\mu V/^\circ C$       |
| Gain Temperature Coefficient       |        |                                                                                    |     | 3             |           | ppm of FSR/ $^\circ C$ |
| Power-Supply Rejection             | PSR    | $V_{DD} = 3V \pm 10\%$ , midscale input                                            |     | $\pm 0.06$    | $\pm 0.5$ | mV/V                   |
| <b>DYNAMIC PERFORMANCE</b>         |        |                                                                                    |     |               |           |                        |
| DAC Output Range                   |        | (Note 2)                                                                           |     | 0 to $V_{DD}$ |           | V                      |
| Voltage-Output Slew Rate           | SR     |                                                                                    |     | 0.6           |           | V/ $\mu s$             |
| Output Settling Time               |        | To $\pm 1LSB$ of FS,<br>$V_{STEP} = 0.25 \times V_{REF}$ to $0.75 \times V_{REF}$  |     | 25            |           | $\mu s$                |
| Output Noise                       |        | Code = 8400 hex, 10kHz                                                             |     | 120           |           | nV/ $\sqrt{Hz}$        |
| DAC Glitch Impulse                 |        | Major carry transition (code 7FFF hex to code 8000 hex)                            |     | 10            |           | nV·s                   |
| Digital Feedthrough                |        | Code = 0000 hex; $\overline{CS} = V_{DD}$ ;<br>LDAC = 0; SCLK, DIN = 0 or $V_{DD}$ |     | 10            |           | nV·s                   |
| Wake-Up Time                       |        | From software shutdown to 90% of output code = FFFF hex                            |     | 50            |           | $\mu s$                |
| Power-Up Time                      |        | From power boosting to 90% of output code = FFFF hex                               |     | 10            |           | ms                     |
| <b>REFERENCE INPUT</b>             |        |                                                                                    |     |               |           |                        |
| $V_{REF}$ Input Range              |        |                                                                                    | 2.0 |               | $V_{DD}$  | V                      |
| $V_{REF}$ Input Current            |        |                                                                                    |     | 20            |           | $\mu A$                |
| $V_{REF}$ Input Resistance         |        |                                                                                    |     | 100           |           | k $\Omega$             |
| Input Capacitance                  |        |                                                                                    |     | 18            |           | pF                     |

# Low-Cost, Voltage-Output, 16-Bit DACs in $\mu$ MAX

MAX5204-MAX5207

## ELECTRICAL CHARACTERISTICS—MAX5206/MAX5207 (continued)

( $V_{DD} = +2.7V$  to  $+3.6V$ ,  $f_{SCLK} = 10MHz$  (50% duty cycle),  $V_{REF} = 2.048V$ , output load =  $10k\Omega$  in parallel with  $250pF$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .)

| PARAMETER                                                                                                                | SYMBOL      | CONDITIONS                                   | MIN | TYP | MAX     | UNITS   |
|--------------------------------------------------------------------------------------------------------------------------|-------------|----------------------------------------------|-----|-----|---------|---------|
| <b>DIGITAL INPUTS (DIN, SCLK, <math>\overline{CS}</math>, <math>\overline{CLR}</math>, <math>\overline{LDAC}</math>)</b> |             |                                              |     |     |         |         |
| 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 $V_{DD}$               |     |     | $\pm 1$ | $\mu A$ |
| Input Capacitance                                                                                                        | $C_{IN}$    |                                              |     | 15  |         | pF      |
| <b>POWER REQUIREMENTS</b>                                                                                                |             |                                              |     |     |         |         |
| 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) |     | 0.5 | 1.5     | mA      |
| Shutdown Supply Current                                                                                                  | $I_{SHDN}$  | All digital inputs at 0 or $V_{DD}$          |     | 1   | 10      | $\mu A$ |
| <b>TIMING CHARACTERISTICS</b>                                                                                            |             |                                              |     |     |         |         |
| 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      |
| $\overline{LDAC}$ 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      |

**Note 1:** Static performance tested at  $V_{DD} = +5.0V$  (MAX5204/MAX5205) and at  $V_{DD} = +3.0V$  (MAX5206/MAX5207).

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

**Note 3:** Guaranteed monotonic.

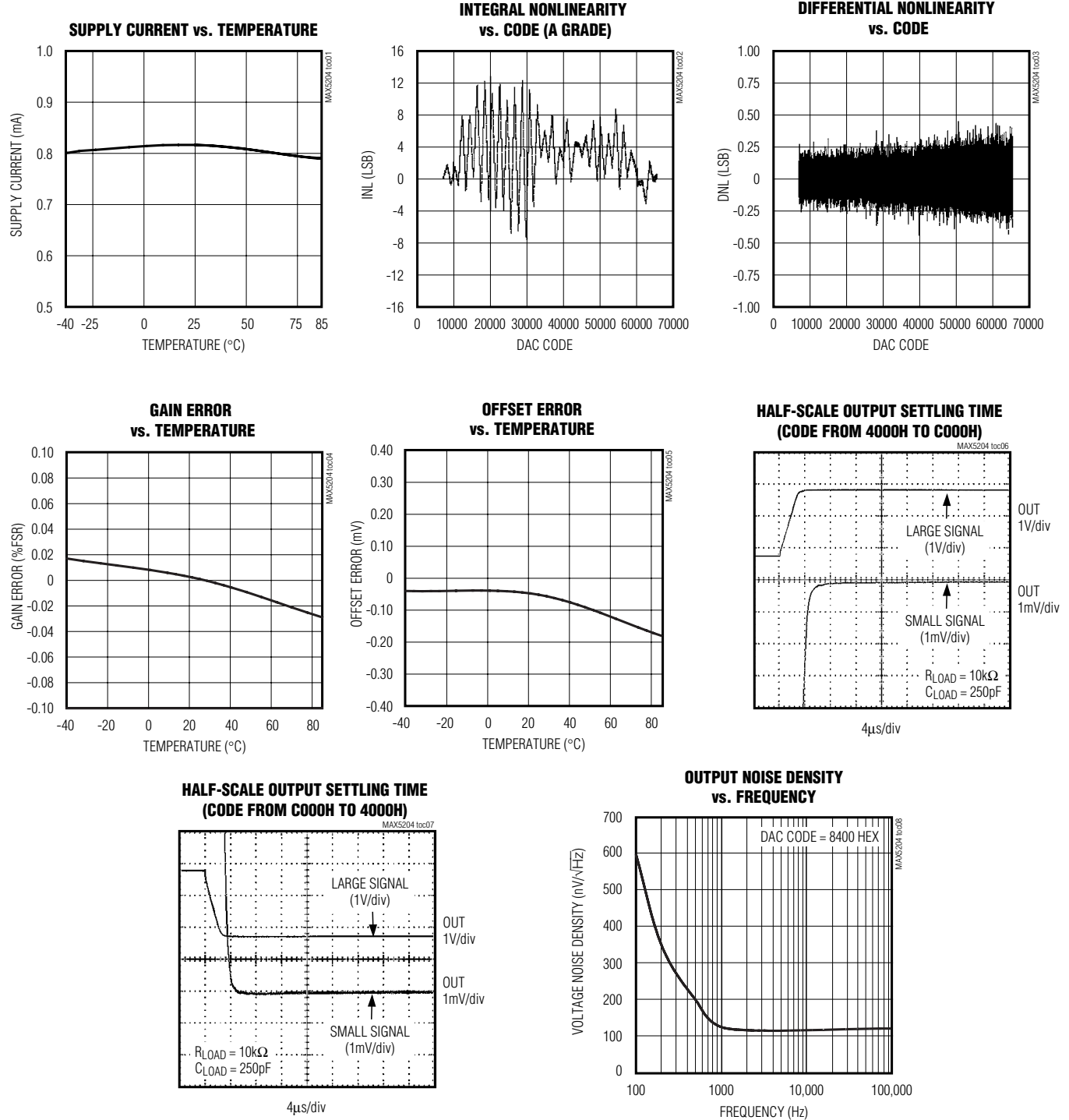
**Note 4:**  $V_{REF} = 4.096V$  (MAX5204/MAX5205) and  $V_{REF} = 2.048V$  (MAX5206/MAX5207).

**Note 5:**  $R_L = \infty$ , digital inputs are at  $V_{DD}$  or DGND.

# Low-Cost, Voltage-Output, 16-Bit DACs in $\mu$ MAX

## Typical Operating Characteristics

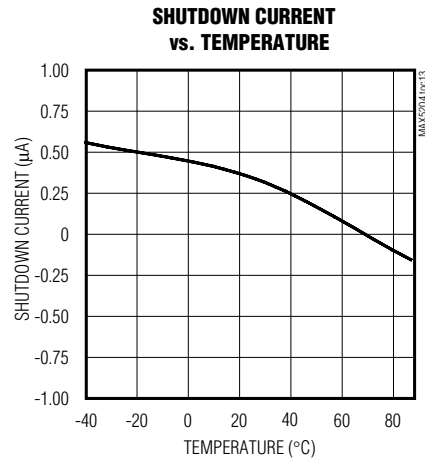
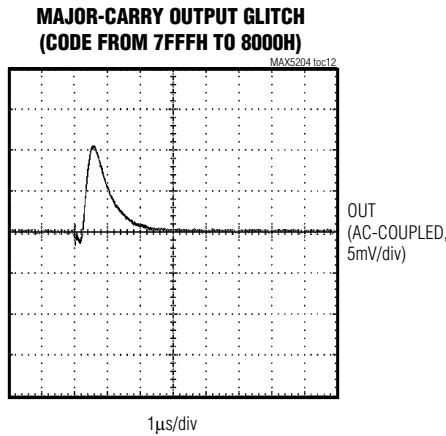
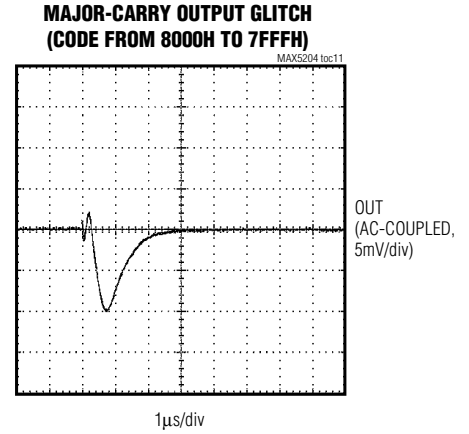
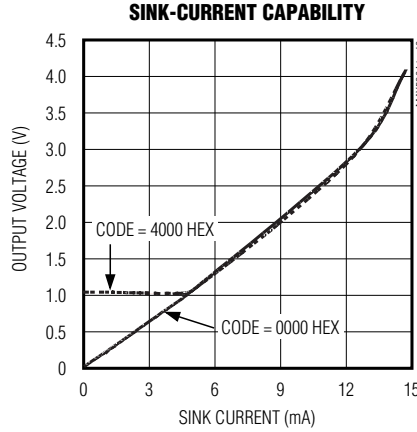
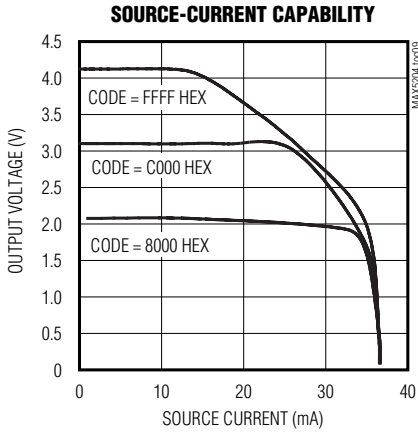
( $V_{DD} = +5V$ ,  $V_{REF} = 4.096V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



# Low-Cost, Voltage-Output, 16-Bit DACs in $\mu$ MAX

## Typical Operating Characteristics (continued)

( $V_{DD} = +5V$ ,  $V_{REF} = 4.096V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



MAX5204-MAX5207

# Low-Cost, Voltage-Output, 16-Bit DACs in $\mu$ MAX

## Pin Description

| 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 MAX5204/MAX5206 and to zero-scale output (0000 hex) for MAX5205/MAX5207. For normal operation, connect $\overline{\text{CLR}}$ to $V_{\text{DD}}$ . |
| 2   | REF                      | External Reference Voltage Input                                                                                                                                                                                                                                           |
| 3   | AGND                     | Analog Ground                                                                                                                                                                                                                                                              |
| 4   | $V_{\text{DD}}$          | Positive Supply Voltage. Bypass $V_{\text{DD}}$ to AGND with a 10 $\mu$ F capacitor in parallel with a 0.1 $\mu$ 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                                                                                                                                                                                                                                                             |

## Detailed Description

The MAX5204–MAX5207 serial 16-bit, voltage-output DACs are easily configured with a 3-wire serial interface. These devices offer full 16-bit performance with less than  $\pm 20$ LSB integral linearity error and less than  $\pm 1$ LSB differential linearity error, thus ensuring monotonic performance. Serial data transfer minimizes the number of package pins required. The MAX5204–MAX5207 include control-logic circuitry, a 16-bit data-in shift register, and a DAC register. The MAX5204–MAX5207 output is buffered and the full-scale output voltage is  $V_{\text{REF}}$  (typ).

The MAX5204–MAX5207 feature a hardware reset input ( $\overline{\text{CLR}}$ ) that when pulled low clears the DAC output to zero code 0000 hex (MAX5205/MAX5207) or resets the DAC output to midscale code 8000 hex (MAX5204/MAX5206). For normal operation, connect  $\overline{\text{CLR}}$  to  $V_{\text{DD}}$ .

### Reference Input

The MAX5204/MAX5205 (+5V supply) use an external reference between 4V to  $V_{\text{DD}}$ , while the MAX5206/MAX5207 (+3V supply) use an external reference from 2V to  $V_{\text{DD}}$ . The DAC output range is from 0 to  $V_{\text{REF}}$ .

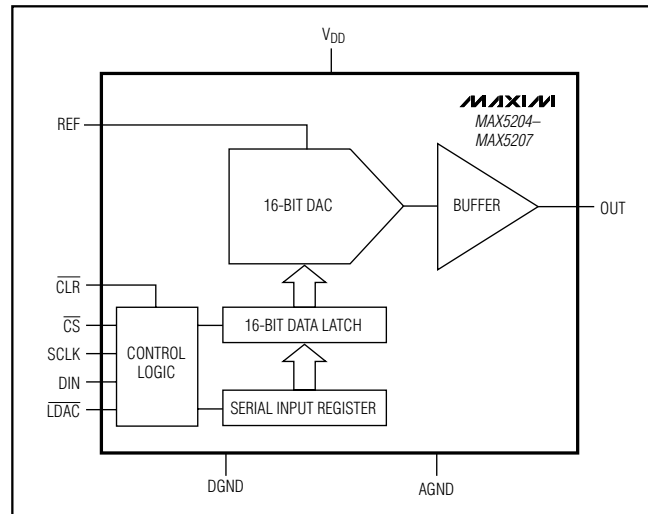


Figure 1. MAX5204–MAX5207 Simplified Functional Diagram

### Digital Interface

The MAX5204–MAX5207 digital interface is a standard 3-wire connection compatible with SPI/QSPI/MICROWIRE and most DSP interfaces. All of the digital input pins ( $\overline{\text{CS}}$ , SCLK, DIN,  $\overline{\text{CLR}}$ , and  $\overline{\text{LDAC}}$ ) are TTL compatible. SCLK can accept clock frequencies as high as 10MHz for a +5V supply and 10MHz for a +3V or +3.3V supply.

One of two methods can be used when interfacing and updating the MAX5204–MAX5207. The first requires



# Low-Cost, Voltage-Output, 16-Bit DACs in $\mu$ MAX

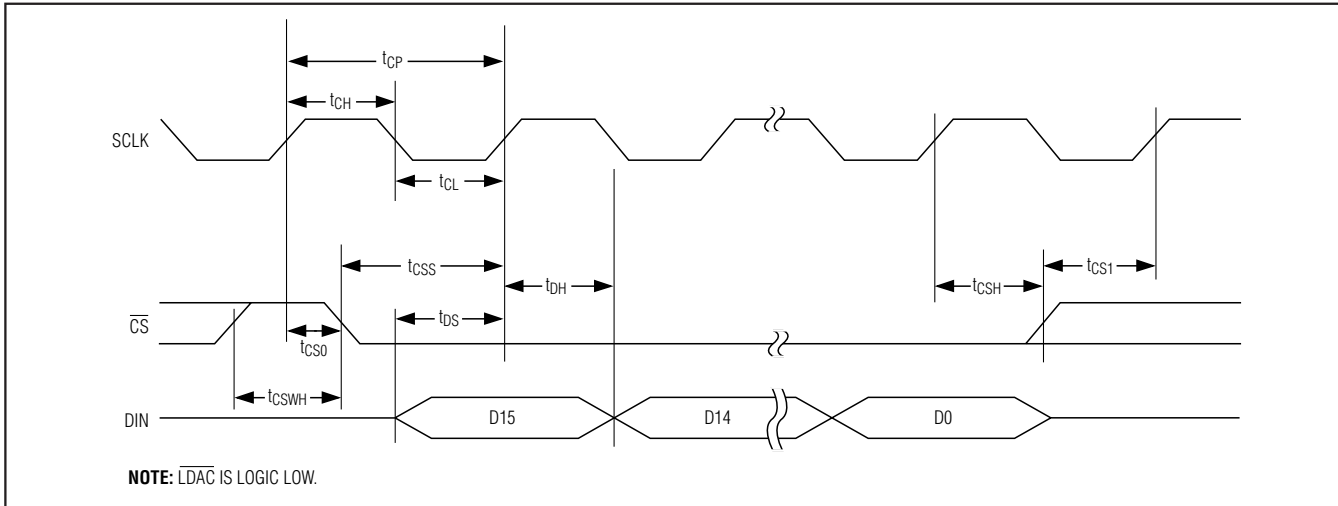


Figure 2. 3-Wire Interface Timing Diagram

three digital inputs:  $\overline{CS}$ , DIN, and SCLK (Figure 2). The active-low chip-select input ( $\overline{CS}$ ) enables the serial data loading at the data input (DIN). Pull  $\overline{CS}$  low and clock in each bit of the 16-bit digital word on the rising edge of the serial clock (SCLK). Two eight-bit bytes can be used, and do not require any additional time between them. Pulling  $\overline{CS}$  high after loading the 16-bit word transfers that code into the DAC register and then updates the output. If  $\overline{CS}$  is not kept low during the entire loading of the 16-bit word, data will be corrupted. In this case, a new 16-bit word must be loaded.  $\overline{LDAC}$  must be kept low at all times for the above instructions.

An alternate method of interfacing and updating the MAX5204–MAX5207 can be done with a fourth digital input, the active-low load DAC ( $\overline{LDAC}$ ).  $\overline{LDAC}$  allows the output to update asynchronously after  $\overline{CS}$  goes high. It is useful when updating multiple MAX5204–MAX5207s synchronously when sharing a single  $\overline{LDAC}$  and  $\overline{CS}$  line.  $\overline{LDAC}$  must be kept high at all times during the data loading sequence and must only be asserted when  $\overline{CS}$  is high. Asserting  $\overline{LDAC}$  when  $\overline{CS}$  is low can cause corrupted data. To operate the MAX5204–MAX5207 using  $\overline{LDAC}$ , pull  $\overline{LDAC}$  high, pull  $\overline{CS}$  low, load the 16-bit word as described in the previous paragraph, and pull  $\overline{CS}$  high again. Following these commands, the DAC output only updates when  $\overline{LDAC}$  is asserted low (Figure 3).

### Shutdown Mode

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

### Shutting Down

To shut down the MAX5204–MAX5207, change the state of SCLK (either a high to low or low to high transition can be used) and pulse two falling  $\overline{CS}$  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  $\overline{CS}$  pulses.

### Waking Up

There are two methods to wake up the MAX5204–MAX5207. Pulse one falling  $\overline{CS}$  edge or transition SCLK. It takes 50 $\mu$ s typically from the  $\overline{CS}$  falling edge or SCLK transition for the DAC to return to normal operation.

### Power-On Reset

The MAX5204–MAX5207 have a power-on reset circuit to set the DAC's output to a known state when  $V_{DD}$  is first applied. The MAX5204/MAX5206 reset to midscale (code 8000 hex) upon power-up. The MAX5205/MAX5207 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 input (DIN, SCLK,  $\overline{CLR}$ ,  $\overline{LDAC}$ ,  $\overline{CS}$ , and REF).

# Low-Cost, Voltage-Output, 16-Bit DACs in $\mu$ MAX

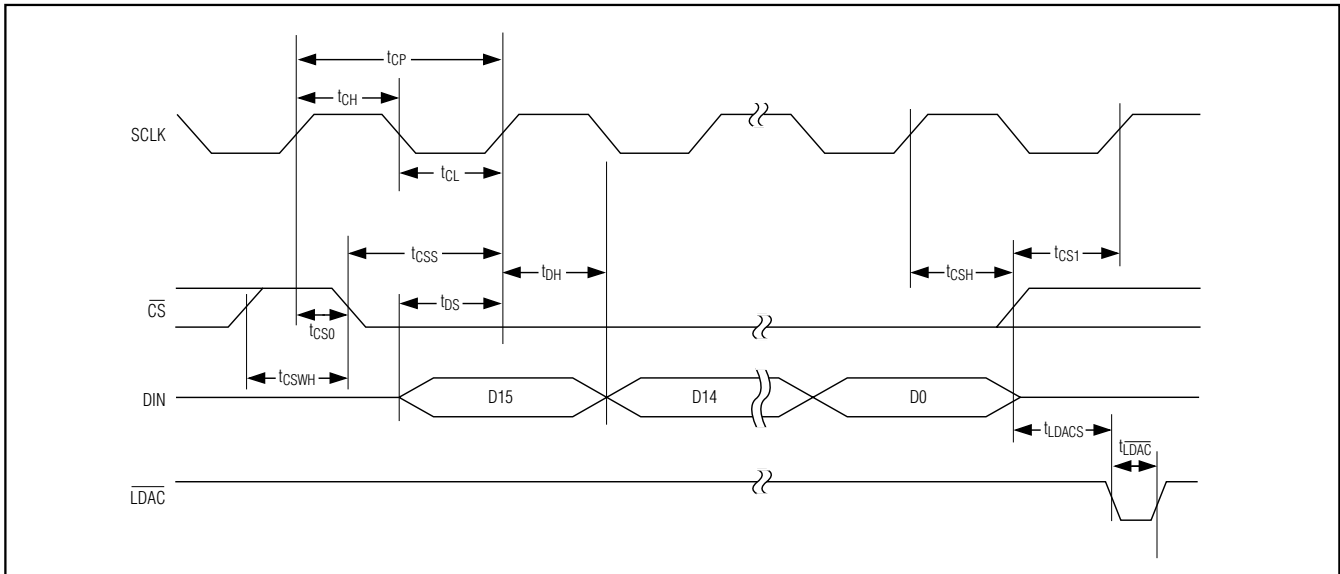


Figure 3. 4-Wire Interface Timing Diagram

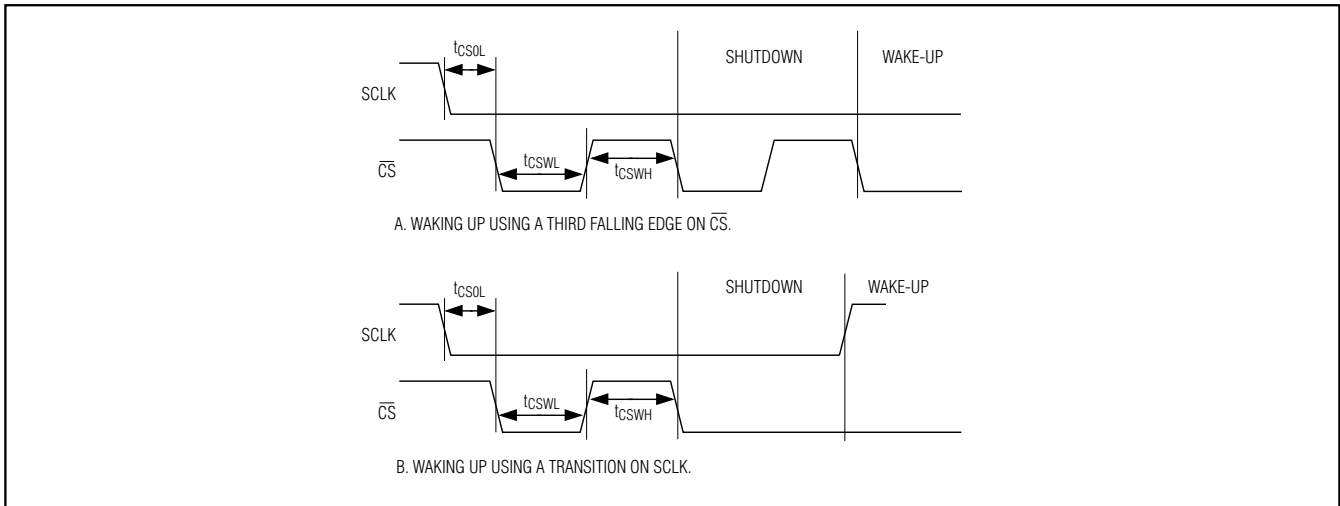


Figure 4. Shutdown Timing

## Applications Information

### Power Supply and Bypassing Considerations

Bypass the power supply with a 10 $\mu$ F capacitor in parallel with a 0.1 $\mu$ 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 MAX5204-MAX5207 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/ $\mu$ s. With a 1/4 FS to 3/4 FS output transition, the buffer output typically settles to 1LSB in about 25 $\mu$ s. The MAX5204-MAX5207 output buffers provide a low 0.2 $\Omega$  typical output impedance. The MAX5204-MAX5207 buffer amplifiers typically produce 120nV/ $\sqrt{\text{Hz}}$  noise at 10kHz.

# Low-Cost, Voltage-Output, 16-Bit DACs in $\mu$ MAX

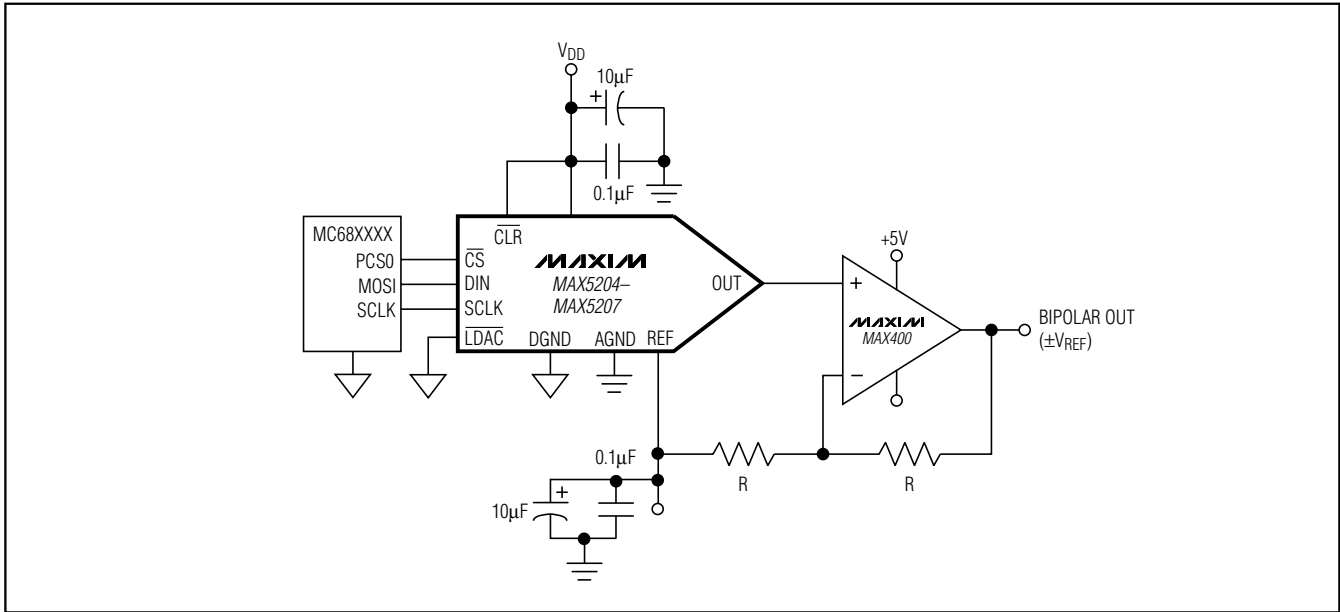


Figure 5. MAX5204–MAX5207 Typical Operating Circuit—Bipolar Output

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 MAX5204–MAX5207 are designed for unipolar operation, but can be used in bipolar applications with an external amplifier and resistors. Figure 5 shows the MAX5204–MAX5207 configured for bipolar operation. The op amp is set for unity gain. Table 1 lists the offset binary code for this circuit. 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 in $\mu$ MAX

## Selector Guide

| PART        | INTEGRAL NONLINEARITY (LSB MAX) | SUPPLY VOLTAGE RANGE (V) | REFERENCE INPUT RANGE (V) | POWER-ON-RESET VALUE |
|-------------|---------------------------------|--------------------------|---------------------------|----------------------|
| MAX5204AEUB | 20                              | 4.75 to 5.25             | 4 to $V_{DD}$             | Midscale             |
| MAX5204ACUB | 20                              | 4.75 to 5.25             | 4 to $V_{DD}$             | Midscale             |
| MAX5204BEUB | 40                              | 4.75 to 5.25             | 4 to $V_{DD}$             | Midscale             |
| MAX5205AEUB | 20                              | 4.75 to 5.25             | 4 to $V_{DD}$             | Zero                 |
| MAX5205ACUB | 20                              | 4.75 to 5.25             | 4 to $V_{DD}$             | Zero                 |
| MAX5205BEUB | 40                              | 4.75 to 5.25             | 4 to $V_{DD}$             | Zero                 |
| MAX5206AEUB | 20                              | 2.7 to 3.6               | 2 to $V_{DD}$             | Midscale             |
| MAX5206ACUB | 20                              | 2.7 to 3.6               | 2 to $V_{DD}$             | Midscale             |
| MAX5206BEUB | 40                              | 2.7 to 3.6               | 2 to $V_{DD}$             | Midscale             |
| MAX5207AEUB | 20                              | 2.7 to 3.6               | 2 to $V_{DD}$             | Zero                 |
| MAX5207ACUB | 20                              | 2.7 to 3.6               | 2 to $V_{DD}$             | Zero                 |
| MAX5207BEUB | 40                              | 2.7 to 3.6               | 2 to $V_{DD}$             | Zero                 |

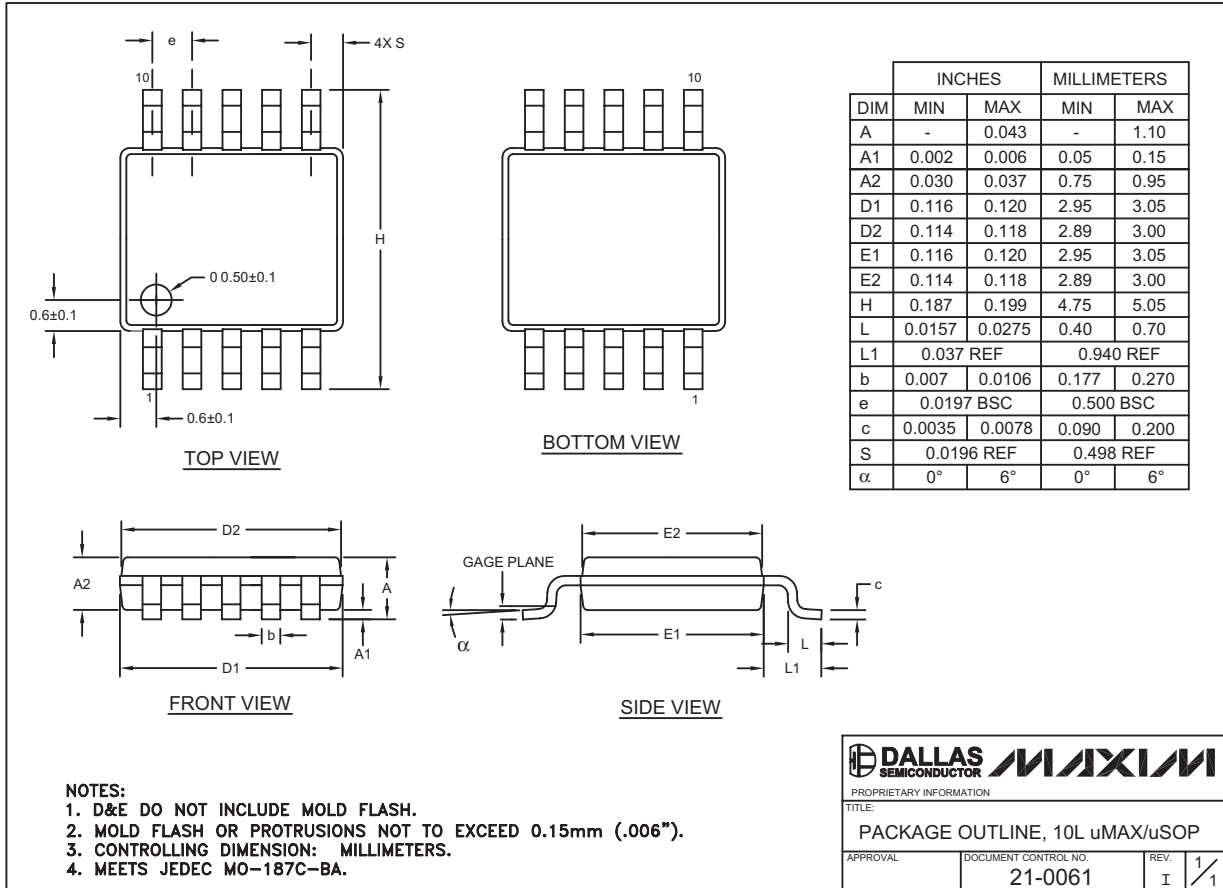
MAX5204-MAX5207

# Low-Cost, Voltage-Output, 16-Bit DACs in $\mu$ MAX

## 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](http://www.maxim-ic.com/packages).)

MAX5204-MAX5207



10L uMAX EPS

Maxim cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a Maxim product. No circuit patent licenses are implied. Maxim reserves the right to change the circuitry and specifications without notice at any time.

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

## Данный компонент на территории Российской Федерации

### Вы можете приобрести в компании MosChip.

Для оперативного оформления запроса Вам необходимо перейти по данной ссылке:

<http://moschip.ru/get-element>

Вы можете разместить у нас заказ для любого Вашего проекта, будь то серийное производство или разработка единичного прибора.

В нашем ассортименте представлены ведущие мировые производители активных и пассивных электронных компонентов.

Нашей специализацией является поставка электронной компонентной базы двойного назначения, продукции таких производителей как XILINX, Intel (ex.ALTERA), Vicor, Microchip, Texas Instruments, Analog Devices, Mini-Circuits, Amphenol, Glenair.

Сотрудничество с глобальными дистрибьюторами электронных компонентов, предоставляет возможность заказывать и получать с международных складов практически любой перечень компонентов в оптимальные для Вас сроки.

На всех этапах разработки и производства наши партнеры могут получить квалифицированную поддержку опытных инженеров.

Система менеджмента качества компании отвечает требованиям в соответствии с ГОСТ Р ИСО 9001, ГОСТ РВ 0015-002 и ЭС РД 009

### Офис по работе с юридическими лицами:

105318, г.Москва, ул.Щербаковская д.3, офис 1107, 1118, ДЦ «Щербаковский»

Телефон: +7 495 668-12-70 (многоканальный)

Факс: +7 495 668-12-70 (доб.304)

E-mail: [info@moschip.ru](mailto:info@moschip.ru)

Skype отдела продаж:

moschip.ru

moschip.ru\_4

moschip.ru\_6

moschip.ru\_9