

# MAXIM

## 8-Bit Parallel DAC in QSOP-16 Package

MAX5480

### General Description

The MAX5480 is a CMOS, 8-bit digital-to-analog converter (DAC) that interfaces directly with most microprocessors. On-chip input latches make the DAC load cycle interface similar to a RAM write cycle, where  $\overline{CS}$  and  $\overline{WR}$  are the only control inputs required.

Linearity of  $\pm 1/2$ LSB is guaranteed, and power consumption is less than 500 $\mu$ W. Monotonicity is guaranteed over the full operating temperature range.

The MAX5480 can be operated in either voltage-output or current-output mode. It is available in a small 16-pin QSOP package.

### Applications

Digitally Adjusted Power Supplies

Programmable Gain

Automatic Test Equipment

Portable, Battery-Powered Instruments

VCO Frequency Control

RF Transmit Control in Portable Radios

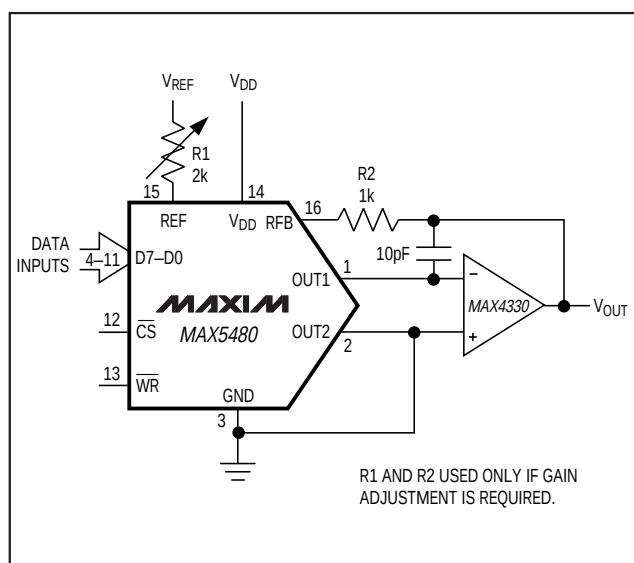
### Features

- ♦ QSOP-16 Package (same footprint as SO-8)
- ♦ Single +5V Supply Operation
- ♦  $V_{OUT}$  or  $I_{OUT}$  Operation
- ♦ 8-Bit Parallel Interface
- ♦ Guaranteed Monotonic Over Temperature
- ♦ Low Power Consumption—100 $\mu$ A max
- ♦  $\pm 1/2$ LSB Linearity Over Temperature

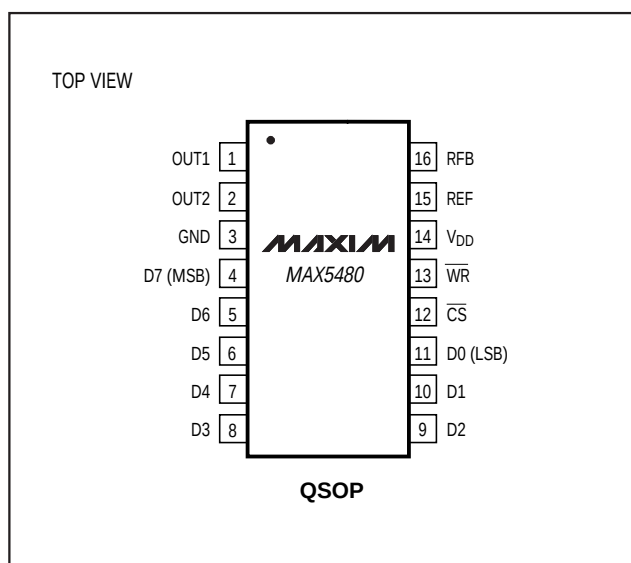
### Ordering Information

| PART        | TEMP. RANGE    | PIN-PACKAGE | ERROR (LSB) |
|-------------|----------------|-------------|-------------|
| MAX5480ACEE | 0°C to +70°C   | 16 QSOP     | $\pm 1/2$   |
| MAX5480BCEE | 0°C to +70°C   | 16 QSOP     | $\pm 1/2$   |
| MAX5480AEEE | -40°C to +85°C | 16 QSOP     | $\pm 1/2$   |
| MAX5480BEEE | -40°C to +85°C | 16 QSOP     | $\pm 1/2$   |

### Typical Operating Circuit



### Pin Configuration



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# 8-Bit Parallel DAC in QSOP-16 Package

## ABSOLUTE MAXIMUM RATINGS

V<sub>DD</sub> to GND .....-0.3V to +17V  
 REF to GND .....±25V  
 RFB to GND .....±25V  
 Digital Inputs to GND .....-0.3V to (V<sub>DD</sub> + 0.3V)  
 OUT1, OUT2 to GND.....-0.3V to V<sub>DD</sub>

### Operating Temperature Ranges

MAX5480\_CEE.....0°C to +70°C  
 MAX5480\_EEE.....-40°C to +85°C  
 Storage Temperature Range .....-65°C to +160°C  
 Continuous Power Dissipation (T<sub>A</sub> = +70°C)  
 MAX5480\_EE (derate 8.3mW/°C above +70°C) .....667mW  
 Lead Temperature (soldering 10sec).....+300°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<sub>DD</sub> = +5V, V<sub>REF</sub> = +10V, V<sub>OUT1</sub> = V<sub>OUT2</sub> = 0V, Circuit of Figure 1, T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>, unless otherwise noted.)

| PARAMETER                                   | SYMBOL            | CONDITIONS                                                                                                               |                                                       | MIN                                                   | TYP                    | MAX | UNITS  |
|---------------------------------------------|-------------------|--------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|-------------------------------------------------------|------------------------|-----|--------|
| DC ACCURACY                                 |                   |                                                                                                                          |                                                       |                                                       |                        |     |        |
| Resolution                                  |                   |                                                                                                                          |                                                       | 8                                                     |                        |     | Bits   |
| Relative Accuracy                           | INL               |                                                                                                                          |                                                       | ±1/2                                                  |                        |     | LSB    |
| Differential Nonlinearity                   | DNL               | All grades guaranteed monotonic over temperature                                                                         |                                                       | ±1                                                    |                        |     | LSB    |
| Gain Error (Note 1)                         |                   | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub>                                                                    |                                                       | ±1                                                    |                        |     | LSB    |
| Gain Temperature Coefficient (Note 2)       |                   |                                                                                                                          |                                                       | ±2                                                    |                        |     | ppm/°C |
| Supply Rejection                            | PSR               | MAX5480A (Note 3)                                                                                                        | T <sub>A</sub> = +25°C                                | 0.002                                                 | 0.08                   |     | %FSR/% |
|                                             |                   |                                                                                                                          | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub> | 0.01                                                  | 0.16                   |     |        |
|                                             |                   | MAX5480B                                                                                                                 | T <sub>A</sub> = +25°C                                | 0.002                                                 |                        |     |        |
|                                             |                   |                                                                                                                          | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub> | 0.01                                                  |                        |     |        |
| Output Leakage Current (I <sub>OUT1</sub> ) |                   | V <sub>REF</sub> = ±10V<br>DAC code = full scale                                                                         | T <sub>A</sub> = +25°C                                | ±50                                                   |                        | nA  |        |
|                                             |                   |                                                                                                                          | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub> | ±400                                                  |                        |     |        |
| Output Leakage Current (I <sub>OUT2</sub> ) |                   | V <sub>REF</sub> = ±10V<br>DAC code = zero scale                                                                         | T <sub>A</sub> = +25°C                                | ±50                                                   |                        | nA  |        |
|                                             |                   |                                                                                                                          | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub> | ±400                                                  |                        |     |        |
| REFERENCE INPUT                             |                   |                                                                                                                          |                                                       |                                                       |                        |     |        |
| Input Resistance                            | R <sub>REF</sub>  | pin 15 to GND                                                                                                            |                                                       | 5                                                     | 10                     | 20  | kΩ     |
| DYNAMIC PERFORMANCE                         |                   |                                                                                                                          |                                                       |                                                       |                        |     |        |
| Output Current Settling Time to 1/2LSB      |                   | D0–D7 = 0V to V <sub>DD</sub> or V <sub>DD</sub> to 0V, $\overline{WR}$ = $\overline{CS}$ = 0V, OUT1 load = 100Ω    13pF | MAX5480A (Note 3)                                     | T <sub>A</sub> = +25°C                                | 400                    |     | ns     |
|                                             |                   |                                                                                                                          |                                                       | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub> | 500                    |     |        |
|                                             |                   |                                                                                                                          |                                                       | MAX5480B                                              | T <sub>A</sub> = +25°C | 250 |        |
| AC Feedthrough (OUT1 or OUT2)               |                   | V <sub>REF</sub> = ±10V, 100kHz sine wave, $\overline{WR}$ = $\overline{CS}$ = 0V                                        | MAX5480A (Note 3)                                     | T <sub>A</sub> = +25°C                                | 0.25                   |     | ns     |
|                                             |                   |                                                                                                                          |                                                       | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub> | 0.5                    |     |        |
|                                             |                   |                                                                                                                          |                                                       | MAX5480B                                              | T <sub>A</sub> = +25°C | 0.1 |        |
| ANALOG OUTPUTS                              |                   |                                                                                                                          |                                                       |                                                       |                        |     |        |
| OUT1 Capacitance (Note 3)                   | C <sub>OUT1</sub> | D0–D7 = V <sub>DD</sub> , $\overline{WR}$ = $\overline{CS}$ = 0V                                                         |                                                       | 120                                                   |                        | pF  |        |
|                                             |                   | D0–D7 = 0V, $\overline{WR}$ = $\overline{CS}$ = 0V                                                                       |                                                       | 30                                                    |                        |     |        |
| OUT2 Capacitance (Note 3)                   | C <sub>OUT2</sub> | D0–D7 = V <sub>DD</sub> , $\overline{WR}$ = $\overline{CS}$ = 0V                                                         |                                                       | 30                                                    |                        | pF  |        |
|                                             |                   | D0–D7 = 0V, $\overline{WR}$ = $\overline{CS}$ = 0V                                                                       |                                                       | 120                                                   |                        |     |        |

# 8-Bit Parallel DAC in QSOP-16 Package

MAX5480

## ELECTRICAL CHARACTERISTICS (continued)

( $V_{DD} = +5V$ ,  $V_{REF} = +10V$ ,  $V_{OUT1} = V_{OUT2} = 0V$ , Circuit of Figure 1,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted.)

| PARAMETER                            | SYMBOL          | CONDITIONS                                                      |                                                       | MIN | TYP | MAX | UNITS |
|--------------------------------------|-----------------|-----------------------------------------------------------------|-------------------------------------------------------|-----|-----|-----|-------|
| DIGITAL INPUTS                       |                 |                                                                 |                                                       |     |     |     |       |
| Input High Voltage                   | V <sub>IH</sub> |                                                                 |                                                       | 2.4 |     |     | V     |
| Input Low Voltage                    | V <sub>IL</sub> |                                                                 |                                                       |     |     | 0.8 | V     |
| Input Current                        | I <sub>IN</sub> | T <sub>A</sub> = +25°C; V <sub>IN</sub> = 0V to V <sub>DD</sub> |                                                       |     |     | ±1  | μA    |
|                                      |                 | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub>           |                                                       |     |     | ±10 |       |
| Input Capacitance (Note 3)           | C <sub>IN</sub> | D0–D7                                                           |                                                       |     |     | 8   | pF    |
|                                      |                 | WR, CS                                                          |                                                       |     |     | 20  |       |
| POWER REQUIREMENTS                   |                 |                                                                 |                                                       |     |     |     |       |
| Supply Current                       | I <sub>DD</sub> | Digital inputs at 0V or V <sub>DD</sub>                         | T <sub>A</sub> = +25°C                                |     |     | 100 | μA    |
|                                      |                 |                                                                 | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub> |     |     | 500 |       |
| SWITCHING CHARACTERISTICS (Figure 4) |                 |                                                                 |                                                       |     |     |     |       |
| Chip-Select to Write-Setup Time      | t <sub>CS</sub> | MAX5480A                                                        |                                                       |     | 220 |     | ns    |
|                                      |                 | MAX5480B                                                        |                                                       |     | 35  |     |       |
| Chip-Select to Write-Hold Time       | t <sub>CH</sub> | MAX5480A                                                        |                                                       |     | 0   |     | ns    |
|                                      |                 | MAX5480B                                                        |                                                       |     | 0   |     |       |
| Write Pulse Width                    | t <sub>WR</sub> | MAX5480A                                                        |                                                       |     | 220 |     | ns    |
|                                      |                 | MAX5480B                                                        |                                                       |     | 35  |     |       |
| Data-Setup Time                      | t <sub>DS</sub> | MAX5480A                                                        |                                                       |     | 170 |     | ns    |
|                                      |                 | MAX5480B                                                        |                                                       |     | 55  |     |       |
| Data-Hold Time                       | t <sub>DH</sub> | MAX5480A                                                        |                                                       |     | 10  |     | ns    |
|                                      |                 | MAX5480B                                                        |                                                       |     | -7  |     |       |

**Note 1:** Gain error is measured using internal feedback resistor. Full-scale range (FSR) =  $V_{REF}$ .

**Note 2:** Gain TempCo measured from  $+25^{\circ}C$  to  $T_{MAX}$  and from  $+25^{\circ}C$  to  $T_{MIN}$ .

**Note 3:** Guaranteed by design.

## Pin Description

| PIN  | NAME            | FUNCTION                                     |
|------|-----------------|----------------------------------------------|
| 1    | OUT1            | R-2R Ladder Output                           |
| 2    | OUT2            | R-2R Ladder Output, complement of OUT1       |
| 3    | GND             | Ground                                       |
| 4–11 | D7–D0           | Data Inputs, D7 is the most significant bit. |
| 12   | $\overline{CS}$ | Chip Select Input. Active Low.               |
| 13   | $\overline{WR}$ | Write Control Input. Active Low.             |
| 14   | $V_{DD}$        | Power Supply Input, +5V                      |
| 15   | REF             | Reference Voltage Input                      |
| 16   | RFB             | Feedback Resistor Connection                 |

# 8-Bit Parallel DAC in QSOP-16 Package

## Detailed Description

The MAX5480 is an 8-bit multiplying digital-to-analog converter (DAC) that consists of a thin-film R-2R resistor array with CMOS current steering switches. Figure 3 shows a simplified schematic of the DAC. The inverted R-2R ladder divides the voltage or current reference in a binary manner among the eight steering switches. The magnitude of the current appearing at either OUT terminal depends on the number of switches selected; therefore, the output is an analog representation of the digital input. The two OUT terminals must be held at the same potential so a constant current is maintained in each ladder leg. This makes the REF input current independent of switch state and also ensures that the MAX5480 maintains its excellent linearity performance.

## Interface-Logic Information

### Mode Selection

The inputs  $\overline{CS}$  and  $\overline{WR}$  control the MAX5480's operating mode (see Table 1).

### Write Mode

When  $\overline{CS}$  and  $\overline{WR}$  are both low, the MAX5480 is in write mode, and its analog output responds to data activity at the D0–D7 data-bus inputs. In this mode, the data latches are transparent (see Tables 2 and 3).

### Hold Mode

In hold mode, the MAX5480 retains the data that was present on D0–D7 just prior to  $\overline{CS}$  or  $\overline{WR}$  assuming a high state. The analog output remains at the value corresponding to the digital code locked in the data latch.

## Applications Information

### Using the MAX5480 in Voltage-Output Mode (Single Supply)

The MAX5480 can be used either as a current-output DAC (Figures 1 and 6) or as a voltage-output DAC (Figures 2 and 5).

To use the MAX5480 in voltage mode, connect OUT1 to the reference input and connect OUT2 to ground. REF, now the DAC output, is a voltage source with a constant output resistance of 10k $\Omega$  (nominally). This output is often buffered with an op amp (Figure 5).

An advantage of voltage-mode operation is single-supply operation for the complete circuit; i.e., a negative reference is not required for a positive output. It is important to note that the range of the reference is restricted in voltage mode. The reference input (voltage at OUT1) must always be positive and is limited to no more than  $V_{DD} - 3V$ . If the reference voltage exceeds this value, linearity is degraded.

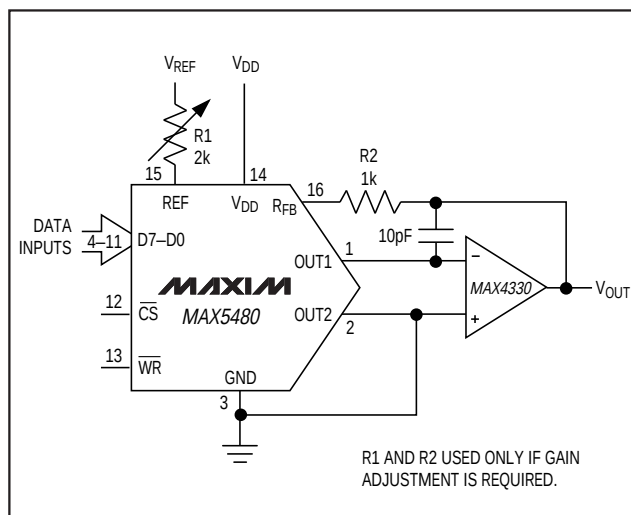


Figure 1. Unipolar Binary Operation (Two-Quadrant Multiplication)

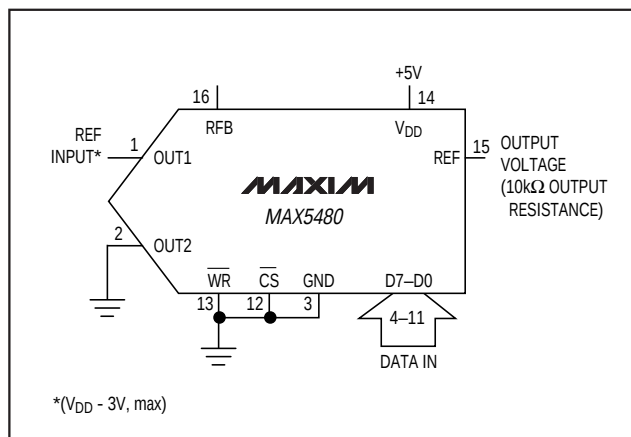


Figure 2. Typical Operating Circuit (Voltage Mode—Unbuffered)

Table 1. Mode-Selection Table

| $\overline{CS}$ | $\overline{WR}$ | MODE         | DAC Response                                                                                                            |
|-----------------|-----------------|--------------|-------------------------------------------------------------------------------------------------------------------------|
| L               | L               | Write        | DAC responds to data bus (D0–D7) inputs.                                                                                |
| H<br>X          | X<br>H          | Hold<br>Hold | Data bus (D0–D7) is locked out; DAC holds last data present when $\overline{CS}$ or $\overline{WR}$ assumed high state. |

L = Low State, H = High State, X = Don't Care

## 8-Bit Parallel DAC in QSOP-16 Package

Table 2. Unipolar Binary Code Table

| DIGITAL INPUT<br>MSB                      LSB | ANALOG OUTPUT                                                  |
|-----------------------------------------------|----------------------------------------------------------------|
| 1 1 1 1 1 1 1 1                               | $-V_{REF} \left( \frac{255}{256} \right)$                      |
| 1 0 0 0 0 0 0 1                               | $-V_{REF} \left( \frac{129}{256} \right)$                      |
| 1 0 0 0 0 0 0 0                               | $-V_{REF} \left( \frac{128}{256} \right) = -\frac{V_{REF}}{2}$ |
| 0 1 1 1 1 1 1 1                               | $-V_{REF} \left( \frac{127}{256} \right)$                      |
| 0 0 0 0 0 0 0 1                               | $-V_{REF} \left( \frac{1}{256} \right)$                        |
| 0 0 0 0 0 0 0 0                               | $-V_{REF} \left( \frac{0}{256} \right) = 0$                    |

NOTE: 1 LSB =  $(2^{-8})(V_{REF}) = \frac{1}{256}(V_{REF})$

Table 3. Bipolar (Offset Binary) Code Table

| DIGITAL INPUT<br>MSB                      LSB | ANALOG OUTPUT                             |
|-----------------------------------------------|-------------------------------------------|
| 1 1 1 1 1 1 1 1                               | $+V_{REF} \left( \frac{127}{128} \right)$ |
| 1 0 0 0 0 0 0 1                               | $+V_{REF} \left( \frac{1}{128} \right)$   |
| 1 0 0 0 0 0 0 0                               | 0                                         |
| 0 1 1 1 1 1 1 1                               | $-V_{REF} \left( \frac{1}{128} \right)$   |
| 0 0 0 0 0 0 0 1                               | $-V_{REF} \left( \frac{127}{128} \right)$ |
| 0 0 0 0 0 0 0 0                               | $-V_{REF} \left( \frac{128}{128} \right)$ |

NOTE: 1 LSB =  $(2^{-7})(V_{REF}) = \frac{1}{128}(V_{REF})$

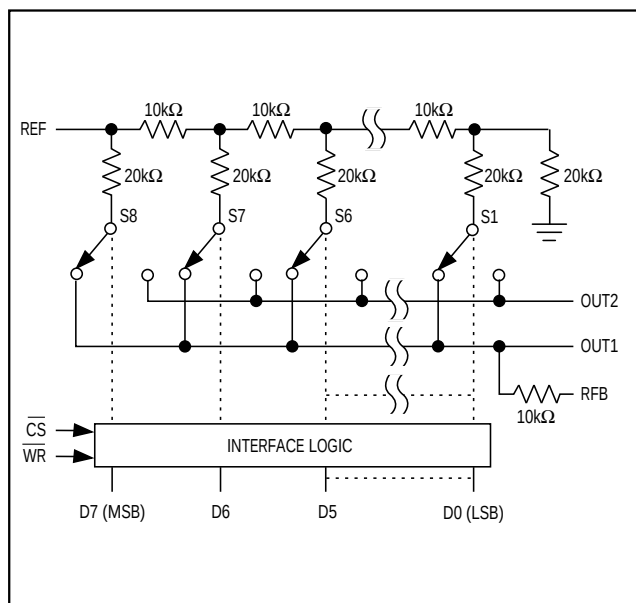


Figure 3. MAX5480 Functional Diagram

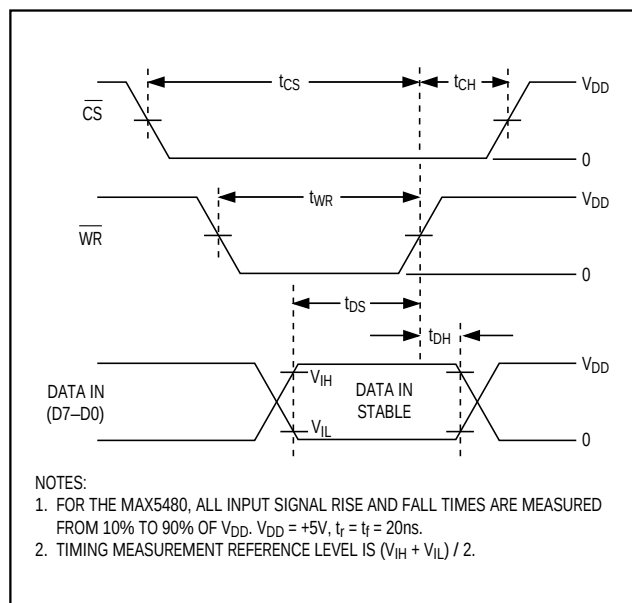


Figure 4. Write-Cycle Timing Diagram

# 8-Bit Parallel DAC in QSOP-16 Package

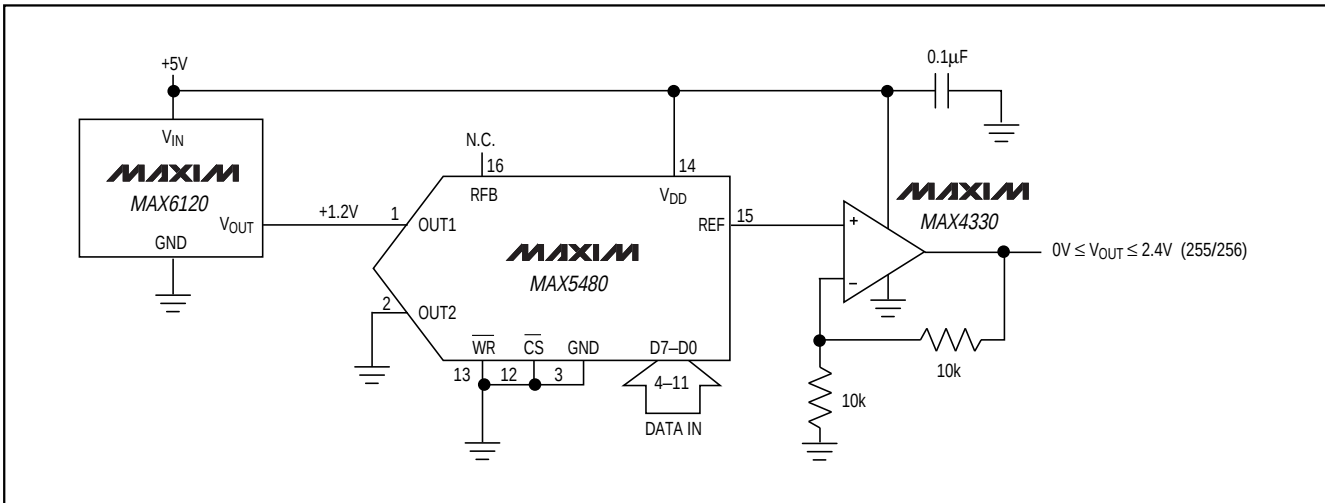


Figure 5. Single-Supply Voltage-Output Mode (Buffered)

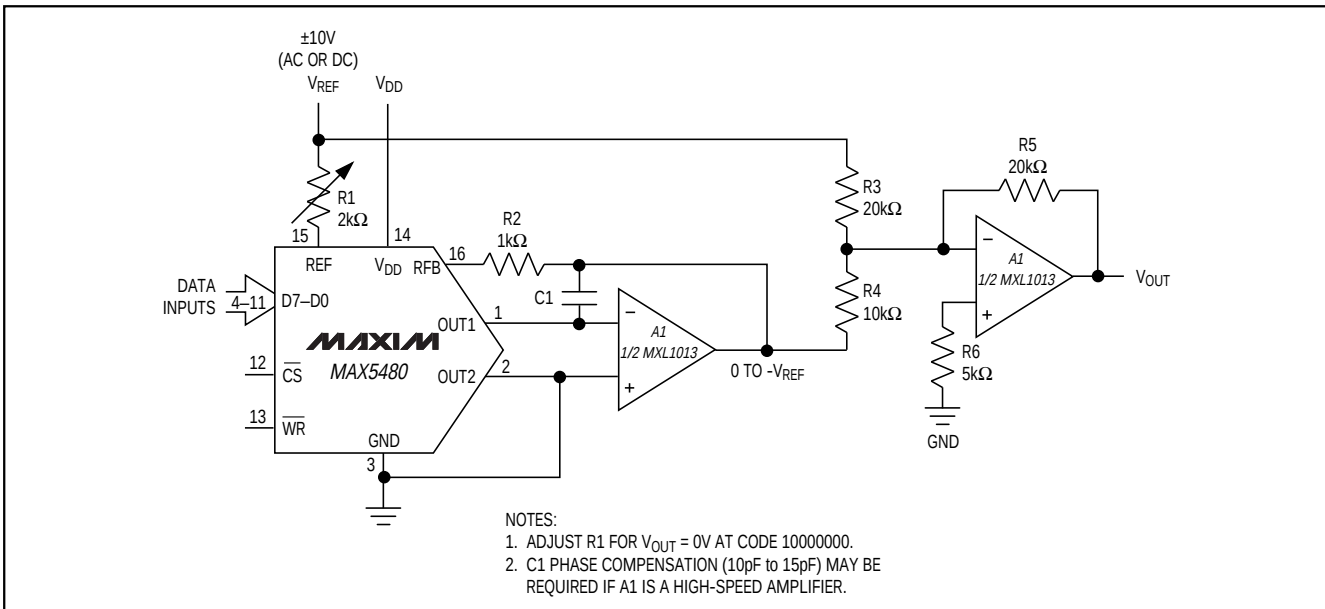


Figure 6. Bipolar (Four-Quadrant) Operation

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