Low-Power, Rail-to-Rail Output, 12-Bit Serial Input
DIGITAL-TO-ANALOG CONVERTER

FEATURES

- microPOWER OPERATION: 135μA at 5V
- POWER-DOWN: 200nA at 5V, 50nA at 3V
- POWER SUPPLY: +2.7V to +5.5V
- TESTED MONOTONIC BY DESIGN
- POWER-ON RESET TO 0V
- THREE POWER-DOWN FUNCTIONS
- LOW POWER SERIAL INTERFACE WITH SCHMITT-TRIGGERED INPUTS
- ON-CHIP OUTPUT BUFFER AMPLIFIER, RAIL-TO-RAIL OPERATION
- SYNC INTERRUPT FACILITY
- SOT23-6 AND MSOP-8 PACKAGES

APPLICATIONS

- PORTABLE BATTERY-POWERED INSTRUMENTS
- DIGITAL GAIN AND OFFSET ADJUSTMENT
- PROGRAMMABLE VOLTAGE AND CURRENT SOURCES

DESCRIPTION

The DAC7512 is a low-power, single, 12-bit buffered voltage output Digital-to-Analog Converter (DAC). Its on-chip precision output amplifier allows rail-to-rail output swing to be achieved. The DAC7512 uses a versatile three-wire serial interface that operates at clock rates up to 30MHz and is compatible with standard SPI™, QSPI™, Microwire™, and DSP interfaces. The reference for the DAC7512 is derived from the power supply, resulting in the widest dynamic output range possible. The DAC7512 incorporates a power-on reset circuit that ensures that the DAC output powers up at 0V and remains there until a valid write takes place in the device. The DAC7512 contains a power-down feature, accessed over the serial interface, that can reduce the current consumption of the device to 50nA at 5V.

The low power consumption of this part in normal operation makes it ideally suited to portable battery-operated equipment. The power consumption is 0.7mW at 5V reducing to 1µW in power-down mode.

The DAC7512 is available in a SOT23-6 package and an MSOP-8 package.

SPI and QSPI are registered trademarks of Motorola.
Microwire is a registered trademark of National Semiconductor.
ABSOLUTE MAXIMUM RATINGS(1)

V<sub>DD</sub> to GND .......................................................... -0.3V to +6V
Digital Input Voltage to GND .................................... -0.3V to +V<sub>DD</sub> + 0.3V
V<sub>OUT</sub> to GND .......................................................... -0.3V to +V<sub>DD</sub> + 0.3V
Operating Temperature Range .................................. -40°C to +105°C
Storage Temperature Range .................................... -65°C to +150°C
Junction Temperature Range (T<sub>J</sub> max) ....................... +150°C

SOT23 Package:
Power Dissipation .................................................. (T<sub>J</sub> max — T<sub>A</sub>) / JA
JA Thermal Impedance ................................................. 240°C/W
Lead Temperature, Soldering:
Vapor Phase (60s) ...................................................... +215°C
Infrared (15s) ......................................................... +220°C

MSOP Package:
Power Dissipation .................................................. (T<sub>J</sub> max — T<sub>A</sub>) / JA
JA Thermal Impedance ................................................. 206°C/W
JC Thermal Impedance .............................................. 44°C/W
Lead Temperature, Soldering:
Vapor Phase (60s) ...................................................... +215°C
Infrared (15s) ......................................................... +220°C

NOTE: (1) Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. Exposure to absolute maximum conditions for extended periods may affect device reliability.

PACKAGE/ORDERING INFORMATION

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>MINIMUM RELATIVE ACCURACY (LSB)</th>
<th>DIFFERENTIAL NONLINEARITY (LSB)</th>
<th>PACKAGE-LEAD</th>
<th>SPECIFIED TEMPERATURE RANGE</th>
<th>PACKAGE MARKING</th>
<th>ORDERING NUMBER(1)</th>
<th>TRANSPORT MEDIA, QUANTITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAC7512E</td>
<td>±8 *</td>
<td>±1</td>
<td>MSOP-8</td>
<td>−40°C to +105°C</td>
<td>D12E</td>
<td>DAC7512E/250</td>
<td>Tape and Reel, 250</td>
</tr>
<tr>
<td>DAC7512N</td>
<td>±8 *</td>
<td>±1</td>
<td>SOT23-6</td>
<td>−40°C to +105°C</td>
<td>D12N</td>
<td>DAC7512N/250</td>
<td>Tape and Reel, 2500</td>
</tr>
</tbody>
</table>

NOTES: (1) For the most current specifications and package information, refer to our web site at www.ti.com. (2) Models with a slash (/) are available only in Tape and Reel in the quantities indicated (e.g., /2K5 indicates 2500 devices per reel). Ordering 2500 pieces of “DAC7512E/2K5” will not get a single 2500-piece Tape and Reel.

PIN CONFIGURATIONS

**Top View**

- **SOT23-6**
  - V<sub>OUT</sub> (1)
  - GND (2)
  - V<sub>DD</sub> (3)
  - SYNC
  - SCLK
  - DIN
  - DAC7512

**MSOP-8**

- V<sub>DD</sub> (1)
- NC (2)
- NC (3)
- V<sub>OUT</sub> (4)
- GND
- DIN
- SCLK
- SYNC
- DAC7512

NC = No Internal Connection

**PIN DESCRIPTION (SOT23-6)**

<table>
<thead>
<tr>
<th>PIN</th>
<th>NAME</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>V&lt;sub&gt;OUT&lt;/sub&gt;</td>
<td>Analog output voltage from DAC. The output amplifier has rail-to-rail operation.</td>
</tr>
<tr>
<td>2</td>
<td>GND</td>
<td>Ground reference point for all circuitry on the part.</td>
</tr>
<tr>
<td>3</td>
<td>V&lt;sub&gt;DD&lt;/sub&gt;</td>
<td>Power Supply Input, +2.7V to 5.5V.</td>
</tr>
<tr>
<td>4</td>
<td>DIN</td>
<td>Serial Data Input. Data is clocked into the 16-bit input shift register on the falling edge of the serial clock input.</td>
</tr>
<tr>
<td>5</td>
<td>SCLK</td>
<td>Serial Clock Input. Data can be transferred at rates up to 30MHz.</td>
</tr>
<tr>
<td>6</td>
<td>SYNC</td>
<td>Level triggered control input (active LOW). This is the frame synchronization signal for the input data. When SYNC goes LOW, it enables the input shift register and data is transferred in on the falling edges of the following clocks. The DAC is updated following the 16th clock cycle unless SYNC is taken HIGH before this edge, in which case the rising edge of SYNC acts as an interrupt and the write sequence is ignored by the DAC7512.</td>
</tr>
</tbody>
</table>

**DAC7512N LOT TRACE LOCATION**

Top View

- **D12N**
  - Pin 1

Bottom View

- **YMLL**
  - Lot Trace Code

NOTE: (1) Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. Exposure to absolute maximum conditions for extended periods may affect device reliability.

ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.
## ELECTRICAL CHARACTERISTICS

\( \text{V}_{\text{DD}} = +2.7 \text{V to } +5.5 \text{V; } R_L = 2k\Omega \text{ to GND; } C_L = 200\text{pF to GND.} \)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>STATIC PERFORMANCE (1)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resolution</td>
<td></td>
<td>12</td>
<td></td>
<td></td>
<td>Bits</td>
</tr>
<tr>
<td>Relative Accuracy</td>
<td>Tested Monotonic by Design</td>
<td></td>
<td>±8</td>
<td></td>
<td>LSB</td>
</tr>
<tr>
<td>Differential Nonlinearity</td>
<td></td>
<td></td>
<td>±1</td>
<td></td>
<td>LSB</td>
</tr>
<tr>
<td>Zero Code Error</td>
<td>All Zeros Loaded to DAC Register</td>
<td></td>
<td>+5</td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td>Full-Scale Error</td>
<td>All Ones Loaded to DAC Register</td>
<td></td>
<td>+2.0</td>
<td></td>
<td>% of FSR</td>
</tr>
<tr>
<td>Gain Error</td>
<td></td>
<td></td>
<td>±1.25</td>
<td></td>
<td>% of FSR</td>
</tr>
<tr>
<td>Zero Code Error Drift</td>
<td></td>
<td></td>
<td>–20</td>
<td></td>
<td>μV/°C</td>
</tr>
<tr>
<td>Gain Temperature Coefficient</td>
<td></td>
<td></td>
<td>–5</td>
<td></td>
<td>ppm of FSR/°C</td>
</tr>
<tr>
<td><strong>OUTPUT CHARACTERISTICS (2)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Voltage Range</td>
<td>1/4 Scale to 3/4 Scale Change</td>
<td>0</td>
<td>( \text{V}_{\text{DD}} )</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Output Voltage Settling Time</td>
<td>( R_L = 2k\Omega; 0\text{pF} &lt; C_L &lt; 200\text{pF} )</td>
<td>8</td>
<td>10</td>
<td></td>
<td>μs</td>
</tr>
<tr>
<td>Slew Rate</td>
<td>( R_L = 2k\Omega; C_L = 500\text{pF} )</td>
<td>1</td>
<td>12</td>
<td>μs</td>
<td>μs</td>
</tr>
<tr>
<td>Capacitive Load Stability</td>
<td></td>
<td></td>
<td>470</td>
<td></td>
<td>pF</td>
</tr>
<tr>
<td>Code Change Glitch Impulse</td>
<td>1LSB Change Around Major Carry</td>
<td></td>
<td>20</td>
<td></td>
<td>nV-s</td>
</tr>
<tr>
<td>Digital Feedthrough</td>
<td></td>
<td></td>
<td>0.5</td>
<td></td>
<td>nV-s</td>
</tr>
<tr>
<td>DC Output Impedance</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td>Ω</td>
</tr>
<tr>
<td>Short-Circuit Current</td>
<td>( V_{\text{DD}} = +5\text{V} )</td>
<td>50</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td>( V_{\text{DD}} = +3\text{V} )</td>
<td>20</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>Power-Up Time</td>
<td>Coming Out of Power-Down Mode</td>
<td>( V_{\text{DD}} = +5\text{V} )</td>
<td>2.5</td>
<td></td>
<td>μs</td>
</tr>
<tr>
<td></td>
<td>Coming Out of Power-Down Mode</td>
<td>( V_{\text{DD}} = +3\text{V} )</td>
<td>5</td>
<td></td>
<td>μs</td>
</tr>
<tr>
<td><strong>LOGIC INPUTS (2)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Current</td>
<td>( V_{\text{DD}} = +5\text{V} )</td>
<td>±1</td>
<td></td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td></td>
<td>( V_{\text{DD}} = +3\text{V} )</td>
<td>0.8</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>( V_{\text{INL}} ), Input Low Voltage</td>
<td>( V_{\text{DD}} = +5\text{V} )</td>
<td>0.6</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>( V_{\text{INH}} ), Input High Voltage</td>
<td>( V_{\text{DD}} = +5\text{V} )</td>
<td>2.4</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Pin Capacitance</td>
<td>( V_{\text{DD}} = +5\text{V} )</td>
<td>2.1</td>
<td></td>
<td></td>
<td>pF</td>
</tr>
<tr>
<td><strong>POWER REQUIREMENTS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( V_{\text{DD}} ) (normal mode)</td>
<td></td>
<td>2.7</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>( i_{\text{DD}} ) (normal mode)</td>
<td>DAC Active and Excluding Load Current</td>
<td>135</td>
<td>200</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>( V_{\text{DD}} = +3.6 \text{V to } +5.5 \text{V} )</td>
<td>( V_{\text{IH}} = V_{\text{DD}} \text{ and } V_{\text{IL}} = \text{GND} )</td>
<td>115</td>
<td>160</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>( V_{\text{DD}} = +2.7 \text{V to } +3.6 \text{V} )</td>
<td>( V_{\text{IH}} = V_{\text{DD}} \text{ and } V_{\text{IL}} = \text{GND} )</td>
<td>0.2</td>
<td>1</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>( V_{\text{DD}} = +3.6 \text{V to } +5.5 \text{V} )</td>
<td>( V_{\text{IH}} = V_{\text{DD}} ) and ( V_{\text{IL}} = \text{GND} )</td>
<td>0.05</td>
<td>1</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>( i_{\text{OUT}}/i_{\text{DD}} )</td>
<td>( I_{\text{LOAD}} = 2\text{mA}, V_{\text{DD}} = +5\text{V} )</td>
<td>93</td>
<td></td>
<td></td>
<td>%</td>
</tr>
<tr>
<td><strong>POWER EFFICIENCY</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TEMPERATURE RANGE</strong></td>
<td>Specified Performance</td>
<td>–40</td>
<td></td>
<td></td>
<td>°C</td>
</tr>
</tbody>
</table>
| NOTES: (1) Linearity calculated using a reduced code range of 48 to 4047; output unloaded. (2) Guaranteed by design and characterization, not production tested.
## TIMING CHARACTERISTICS\(^{(1, 2)}\)

\(V_{DD} = +2.7\, \text{V to} +5.5\, \text{V};\) all specifications \(-40^\circ\text{C to} +105^\circ\text{C},\) unless otherwise noted.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>DESCRIPTION</th>
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<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>(t_1(3))</td>
<td>SCLK Cycle Time</td>
<td>(V_{DD} = 2.7, \text{V to} 3.6, \text{V})</td>
<td>50</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(V_{DD} = 3.6, \text{V to} 5.5, \text{V})</td>
<td>33</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>(t_2)</td>
<td>SCLK HIGH Time</td>
<td>(V_{DD} = 2.7, \text{V to} 3.6, \text{V})</td>
<td>13</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(V_{DD} = 3.6, \text{V to} 5.5, \text{V})</td>
<td>13</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>(t_3)</td>
<td>SCLK LOW Time</td>
<td>(V_{DD} = 2.7, \text{V to} 3.6, \text{V})</td>
<td>22.5</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(V_{DD} = 3.6, \text{V to} 5.5, \text{V})</td>
<td>13</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>(t_4)</td>
<td>(SYNC) to SCLK Rising Edge Setup Time</td>
<td>(V_{DD} = 2.7, \text{V to} 3.6, \text{V})</td>
<td>0</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(V_{DD} = 3.6, \text{V to} 5.5, \text{V})</td>
<td>0</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>(t_5)</td>
<td>Data Setup Time</td>
<td>(V_{DD} = 2.7, \text{V to} 3.6, \text{V})</td>
<td>5</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(V_{DD} = 3.6, \text{V to} 5.5, \text{V})</td>
<td>5</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>(t_6)</td>
<td>Data Hold Time</td>
<td>(V_{DD} = 2.7, \text{V to} 3.6, \text{V})</td>
<td>4.5</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(V_{DD} = 3.6, \text{V to} 5.5, \text{V})</td>
<td>4.5</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>(t_7)</td>
<td>SCLK Falling Edge to (SYNC) Rising Edge</td>
<td>(V_{DD} = 2.7, \text{V to} 3.6, \text{V})</td>
<td>0</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(V_{DD} = 3.6, \text{V to} 5.5, \text{V})</td>
<td>0</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>(t_8)</td>
<td>Minimum (SYNC) HIGH Time</td>
<td>(V_{DD} = 2.7, \text{V to} 3.6, \text{V})</td>
<td>50</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(V_{DD} = 3.6, \text{V to} 5.5, \text{V})</td>
<td>33</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
</tbody>
</table>

NOTES: (1) All input signals are specified with \(t_R = t_F = 5\, \text{ns}\) (10% to 90% of \(V_{DD}\)) and timed from a voltage level of \((V_{IL} + V_{IH})/2\). (2) See Serial Write Operation timing diagram, below. (3) Maximum SCLK frequency is 30MHz at \(V_{DD} = +3.6\, \text{V to} +5.5\, \text{V}\) and 20MHz at \(V_{DD} = +2.7\, \text{V to} +3.6\, \text{V}.

### SERIAL WRITE OPERATION

![Serial Write Operation Diagram](image-url)
TYPICAL CHARACTERISTICS: $V_{DD} = +5V$

At $T_A = +25^\circ C$, $+V_{DD} = +5V$, unless otherwise noted.
TYPICAL CHARACTERISTICS: $V_{DD} = +5\text{V}$ (Cont.)

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

**SOURCE AND SINK CURRENT CAPABILITY**

- DAC Loaded with $\text{FFF}_H$
- DAC Loaded with $\text{000}_H$

**SUPPLY CURRENT vs CODE**

**SUPPLY CURRENT vs TEMPERATURE**

**SUPPLY CURRENT vs SUPPLY VOLTAGE**

**POWER-DOWN CURRENT vs SUPPLY VOLTAGE**
TYPICAL CHARACTERISTICS: \( V_{DD} = +5V \) (Cont.)

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

**SUPPLY CURRENT vs LOGIC INPUT VOLTAGE**

**FULL-SCALE SETTLING TIME**

- Full-Scale Code Change: \( \text{FFFF} \to \text{0000} \)
- Output Loaded with 2k\( \Omega \) and 200pF to GND

**HALF-SCALE SETTLING TIME**

- Half-Scale Code Change: \( \text{C000} \to \text{4000} \)
- Output Loaded with 2k\( \Omega \) and 200pF to GND

**POWER-ON RESET TO 0V**

- Loaded with 2k\( \Omega \) to \( V_{DD} \)

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**SUPPLY CURRENT vs LOGIC INPUT VOLTAGE**

**FULL-SCALE SETTLING TIME**

- Full-Scale Code Change: \( \text{FFFF} \to \text{0000} \)
- Output Loaded with 2k\( \Omega \) and 200pF to GND

**HALF-SCALE SETTLING TIME**

- Half-Scale Code Change: \( \text{C000} \to \text{4000} \)
- Output Loaded with 2k\( \Omega \) and 200pF to GND

**POWER-ON RESET TO 0V**

- Loaded with 2k\( \Omega \) to \( V_{DD} \)
TYPICAL CHARACTERISTICS: $V_{DD} = +5V$ (Cont.)

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

TYPICAL CHARACTERISTICS: $V_{DD} = +2.7V$

At $T_A = +25^\circ C$, $+V_{DD} = +2.7V$, unless otherwise noted.
TYPICAL CHARACTERISTICS: $V_{DD} = +2.7V$ (Cont.)

At $T_A = +25^\circ C$, $+V_{DD} = +2.7V$, unless otherwise noted.

![Graphs and tables showing typical characteristics of DAC7512](image-url)
TYPICAL CHARACTERISTICS: $V_{DD} = +2.7V$ (Cont.)

At $T_A = +25^\circ C$, $+V_{DD} = +2.7V$, unless otherwise noted.

SUPPLY CURRENT vs LOGIC INPUT VOLTAGE

FULL-SCALE SETTLING TIME

HALF-SCALE SETTLING TIME

POWER-ON RESET to 0V

SUPPLY CURRENT vs LOGIC INPUT VOLTAGE

FULL-SCALE SETTLING TIME

HALF-SCALE SETTLING TIME

POWER-ON RESET to 0V
TYPICAL CHARACTERISTICS: \(V_{DD} = +2.7V\) (Cont.)

At \(T_A = +25^\circ C, +V_{DD} = +2.7V\), unless otherwise noted.

**THEORY OF OPERATION**

**DAC SECTION**

The DAC7512 is fabricated using a CMOS process. The architecture consists of a string DAC followed by an output buffer amplifier. Since there is no reference input pin, the power supply \(V_{DD}\) acts as the reference. Figure 1 shows a block diagram of the DAC architecture.

\[
V_{OUT} = V_{DD} \cdot \frac{D}{4096}
\]

where \(D = \) decimal equivalent of the binary code that is loaded to the DAC register; it can range from 0 to 4095.

**RESISTOR STRING**

The resistor string section is shown in Figure 2. It is simply a string of resistors, each of value \(R\). The code loaded into the DAC register determines at which node on the string the voltage is tapped off to be fed into the output amplifier by closing one of the switches connecting the string to the amplifier. It is tested monotonic because it is a string of resistors.

**OUTPUT AMPLIFIER**

The output buffer amplifier is capable of generating rail-to-rail voltages on its output which gives an output range of 0V to \(V_{DD}\). It is capable of driving a load of 2k\(\Omega\) in parallel with 1000pF to GND. The source and sink capabilities of the output amplifier can be seen in the typical characteristics. The slew rate is 1V/\(\mu s\) with a half-scale settling time of 8\(\mu s\) with the output unloaded.
SERIAL INTERFACE

The DAC7512 has a three-wire serial interface (SYNC, SCLK, and DIN), which is compatible with SPI, QSPI, and Microwire interface standards as well as most Digital Signal Processors (DSPs). See the Serial Write Operation timing diagram for an example of a typical write sequence. The write sequence begins by bringing the SYNC line LOW. Data from the DIN line is clocked into the 16-bit shift register on the falling edge of SCLK. The serial clock frequency can be as high as 30MHz, making the DAC7512 compatible with high-speed DSPs. On the 16th falling edge of the serial clock, the last data bit is clocked in and the programmed function is executed (i.e., a change in DAC register contents and/or a change in operation).

At this point, the SYNC line may be kept LOW or brought HIGH. In either case, it must be brought HIGH for a minimum of 33ns before the next write sequence so that a falling edge of SYNC can initiate the next write sequence. Since the SYNC buffer draws more current when the SYNC signal is HIGH than it does when it is LOW, SYNC should be idled LOW between write sequences for lowest power operation of the part. As mentioned above, however, it must be brought HIGH again just before the next write sequence.

INPUT SHIFT REGISTER

The input shift register is 16 bits wide, as shown in Figure 3. The first two bits are “don’t care”. The next two bits (PD1 and PD0) are control bits that control which mode of operation the part is in (normal mode or one of three power-down modes). There is a more complete description of the various modes in the Power-Down Modes section. The next 12 bits are the data bits. These are transferred to the DAC register on the 16th falling edge of SCLK.

SYNC INTERRUPT

In a normal write sequence, the SYNC line is kept LOW for at least 16 falling edges of SCLK and the DAC is updated on the 16th falling edge. However, if the SYNC is brought HIGH before the 16th falling edge, this acts as an interrupt to the write sequence. The shift register is reset and the write sequence is seen as invalid. Neither an update of the DAC register contents or a change in the operating mode occurs, as shown in Figure 4.

POWER-ON RESET

The DAC7512 contains a power-on reset circuit that controls the output voltage during power-up. On power-up, the DAC register is filled with zeros and the output voltage is 0V; it remains there until a valid write sequence is made to the DAC. This is useful in applications where it is important to know the state of the output of the DAC while it is in the process of powering up.

POWER-DOWN MODES

The DAC7512 contains four separate modes of operation. These modes are programmable by setting two bits (PD1 and PD0) in the control register. Table I shows how the state of the bits corresponds to the mode of operation of the device.

<table>
<thead>
<tr>
<th>DB13</th>
<th>DB12</th>
<th>OPERATING MODE</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>Normal Operation</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>Output 1k to GND</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>Output 100k to GND</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>High-Z</td>
</tr>
</tbody>
</table>

TABLE I. Modes of Operation for the DAC7512.

When both bits are set to 0, the part works normally with its normal power consumption of 135µA at 5V. However, for the three power-down modes, the supply current falls to 200nA at 5V (50nA at 3V). Not only does the supply current fall, but the output stage is also internally switched from the output of the amplifier to a resistor network of known values. This has the advantage that the output impedance of the part is known while the part is in power-down mode. There are three different options. The output is connected internally to GND through a 1kΩ resistor, a 100kΩ resistor, or it is left open-circuited (High-Z). See Figure 5 for the output stage.
All linear circuitry is shut down when the power-down mode is activated. However, the contents of the DAC register are unaffected when in power-down. The time to exit power-down is typically 2.5µs for VDD = 5V and 5µs for VDD = 3V. See the Typical Characteristics for more information.

**MICROPROCESSOR INTERFACING**

**DAC7512 TO 8051 INTERFACE**

Figure 6 shows a serial interface between the DAC7512 and a typical 8051-type microcontroller. The setup for the interface is as follows: TXD of the 8051 drives SCLK of the DAC7512, while RXD drives the serial data line of the part. The SYNC signal is derived from a bit programmable pin on the port. In this case, port line P3.3 is used. When data is to be transmitted to the DAC7512, P3.3 is taken LOW. The 8051 transmits data only in 8-bit bytes; thus only eight falling clock edges occur in the transmit cycle. To load data to the DAC, P3.3 is left LOW after the first eight bits are transmitted, and a second write cycle is initiated to transmit the second byte of data. P3.3 is taken HIGH following the completion of this cycle. The 8051 outputs the serial data in a format which has the LSB first. The DAC7512 requires its data with the MSB as the first bit received. The 8051 transmit routine must therefore take this into account, and “mirror” the data as needed.

**DAC7512 TO MICROWIRE™ INTERFACE**

Figure 7 shows an interface between the DAC7512 and any Microwire compatible device. Serial data is shifted out on the falling edge of the serial clock and is clocked into the DAC7512 on the rising edge of the SK signal.

**APPLICATIONS**

**USING REF02 AS A POWER SUPPLY FOR THE DAC7512**

Due to the extremely low supply current required by the DAC7512, an alternative option is to use a REF02 +5V precision voltage reference to supply the required voltage to the part, see Figure 9. This is especially useful if the power supply is too noisy or if the system supply voltages are at some value other than 5V. The REF02 will output a steady supply voltage for the DAC7512. If the REF02 is used, the current it needs to supply to the DAC7512 is 135µA. This is with no load on the output of the DAC. When the DAC output
is loaded, the REF02 also needs to supply the current to the load. The total current required (with a 5kΩ load on the DAC output) is:

\[ 135µA + \left( \frac{5V}{5kΩ} \right) = 1.14mA \]

The load regulation of the REF02 is typically 0.005%/mA, which results in an error of 285µV for the 1.14mA current drawn from it. This corresponds to a 0.2LSB error.

**BIPOLAR OPERATION USING THE DAC7512**

The DAC7512 has been designed for single-supply operation but a bipolar output range is also possible using the circuit in Figure 10. The circuit shown will give an output voltage range of ±5V. Rail-to-rail operation at the amplifier output is achievable using an OPA340 as the output amplifier.

The output voltage for any input code can be calculated as follows:

\[
V_O = V \cdot \left( \frac{D}{4096} \right) \bullet \left( \frac{R_1 + R_2}{R_1} \right) - V_{DD} \cdot \left( \frac{R_2}{R_1} \right)
\]

where D represents the input code in decimal (0 - 4095).

With \( V_{DD} = 5V \), \( R_1 = R_2 = 10kΩ \):

\[
V_O = \left( \frac{10 \cdot D}{4096} \right) - 5V
\]

This is an output voltage range of ±5V with 000\(_H\) corresponding to a –5V output and FFF\(_H\) corresponding to a +5V output.

**LAYOUT**

A precision analog component requires careful layout, adequate bypassing, and clean, well-regulated power supplies.

As the DAC7512 offers single-supply operation, it will often be used in close proximity with digital logic, microcontrollers, microprocessors, and digital signal processors. The more digital logic present in the design and the higher the switching speed, the more difficult it will be to achieve good performance from the converter.

Due to the single ground pin of the DAC7512, all return currents, including digital and analog return currents, must flow through the GND pin. Ideally, GND would be connected directly to an analog ground plane. This plane would be separate from the ground connection for the digital components until they were connected at the power entry point of the system.

The power applied to \( V_{DD} \) should be well regulated and low noise. Switching power supplies and DC/DC converters will often have high-frequency glitches or spikes riding on the output voltage. In addition, digital components can create similar high-frequency spikes as their internal logic switches states. This noise can easily couple into the DAC output voltage through various paths between the power connections and analog output. This is particularly true for the DAC7512, as the power supply is also the reference voltage for the DAC.

As with the GND connection, \( V_{DD} \) should be connected to a +5V power supply plane or trace that is separate from the connection for digital logic until they are connected at the power entry point. In addition, the 1µF to 10µF and 0.1µF bypass capacitors are strongly recommended. In some situations, additional bypassing may be required, such as a 100µF electrolytic capacitor or even a “Pi” filter made up of inductors and capacitors—all designed to essentially low-pass filter the +5V supply, removing the high-frequency noise.
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion.
D. Falls within JEDEC MO-187
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion.
D. Leads 1, 2, 3 may be wider than leads 4, 5, 6 for package orientation.
## PACKAGING INFORMATION

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<th>Status (1)</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>Package Qty</th>
<th>Eco Plan (2)</th>
<th>Lead finish/Ball material</th>
<th>MSL Peak Temp (3)</th>
<th>Op Temp (°C)</th>
<th>Device Marking (4/5)</th>
<th>Samples</th>
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(1) The marketing status values are defined as follows:
**ACTIVE**: Product device recommended for new designs.
**LIFEBUY**: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
**NRND**: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
**PREVIEW**: Device has been announced but is not in production. Samples may or may not be available.
**OBSOLETE**: TI has discontinued the production of the device.

(2) **RoHS**: TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
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(3) **MSL, Peak Temp.** - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.
8 Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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**Tape and Reel Information**

**Reel Dimensions**
- **Reel Diameter**
- **Reel Width (W1)**

**Tape Dimensions**
- **A0**: Dimension designed to accommodate the component width
- **B0**: Dimension designed to accommodate the component length
- **K0**: Dimension designed to accommodate the component thickness
- **W**: Overall width of the carrier tape
- **P1**: Pitch between successive cavity centers

**Quadrant Assignments for Pin 1 Orientation in Tape**

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<tr>
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<th>B0 (mm)</th>
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*All dimensions are nominal*
## TAPE AND REEL BOX DIMENSIONS

*All dimensions are nominal*

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NOTES:

A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
   ▶ Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 per end.
   ▶ Body width does not include interlead flash. Interlead flash shall not exceed 0.50 per side.
E. Falls within JEDEC MO-187 variation AA, except interlead flash.
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC-7351 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.
NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.25 per side.
4. Leads 1,2,3 may be wider than leads 4,5,6 for package orientation.
5. Refernce JEDEC MO-178.
NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.
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