TLV320DAC23
Stereo Audio D/A Converter, 8- to 96-kHz With
Integrated Headphone Amplifier

Data Manual
## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction</td>
<td>1–1</td>
</tr>
<tr>
<td></td>
<td>1.1 Features</td>
<td>1–2</td>
</tr>
<tr>
<td></td>
<td>1.2 Functional Block Diagram</td>
<td>1–3</td>
</tr>
<tr>
<td></td>
<td>1.3 Terminal Assignments</td>
<td>1–4</td>
</tr>
<tr>
<td></td>
<td>1.4 Ordering Information</td>
<td>1–5</td>
</tr>
<tr>
<td></td>
<td>1.5 Terminal Functions</td>
<td>1–6</td>
</tr>
<tr>
<td>2</td>
<td>Specifications</td>
<td>2–1</td>
</tr>
<tr>
<td></td>
<td>2.1 Absolute Maximum Ratings Over Operating Free-Air Temperature Range</td>
<td>2–1</td>
</tr>
<tr>
<td></td>
<td>2.2 Recommended Operating Conditions</td>
<td>2–1</td>
</tr>
<tr>
<td></td>
<td>2.3 Electrical Characteristics Over Recommended Operating Conditions</td>
<td>2–2</td>
</tr>
<tr>
<td></td>
<td>2.3.1 DAC</td>
<td>2–2</td>
</tr>
<tr>
<td></td>
<td>2.3.2 Analog Line Input to Line Output</td>
<td>2–2</td>
</tr>
<tr>
<td></td>
<td>2.3.3 Stereo Headphone Output</td>
<td>2–3</td>
</tr>
<tr>
<td></td>
<td>2.3.4 Analog Reference Levels</td>
<td>2–3</td>
</tr>
<tr>
<td></td>
<td>2.3.5 Digital I/O</td>
<td>2–3</td>
</tr>
<tr>
<td></td>
<td>2.3.6 Supply Current</td>
<td>2–3</td>
</tr>
<tr>
<td></td>
<td>2.4 Digital-Interface Timing</td>
<td>2–4</td>
</tr>
<tr>
<td></td>
<td>2.4.1 Audio Interface (Master Mode)</td>
<td>2–4</td>
</tr>
<tr>
<td></td>
<td>2.4.2 Audio Interface (Slave-Mode)</td>
<td>2–5</td>
</tr>
<tr>
<td></td>
<td>2.4.3 Three-Wire Control Interface (SDI)</td>
<td>2–6</td>
</tr>
<tr>
<td></td>
<td>2.4.4 Two-Wire Control Interface</td>
<td>2–6</td>
</tr>
<tr>
<td>3</td>
<td>How to Use the DAC23</td>
<td>3–1</td>
</tr>
<tr>
<td></td>
<td>3.1 Control Interfaces</td>
<td>3–1</td>
</tr>
<tr>
<td></td>
<td>3.1.1 SPI</td>
<td>3–1</td>
</tr>
<tr>
<td></td>
<td>3.1.2 2-Wire</td>
<td>3–1</td>
</tr>
<tr>
<td></td>
<td>3.1.3 Register Map</td>
<td>3–2</td>
</tr>
<tr>
<td></td>
<td>3.2 Analog Interface</td>
<td>3–4</td>
</tr>
<tr>
<td></td>
<td>3.2.1 Line Inputs</td>
<td>3–4</td>
</tr>
<tr>
<td></td>
<td>3.2.2 Line Outputs</td>
<td>3–5</td>
</tr>
<tr>
<td></td>
<td>3.2.3 Headphone Output</td>
<td>3–5</td>
</tr>
<tr>
<td></td>
<td>3.3 Digital Audio Interface</td>
<td>3–5</td>
</tr>
<tr>
<td></td>
<td>3.3.1 Digital Audio-Interface Modes</td>
<td>3–5</td>
</tr>
<tr>
<td></td>
<td>3.3.2 Audio Sampling Rates</td>
<td>3–7</td>
</tr>
<tr>
<td></td>
<td>3.3.3 Digital Filter Characteristics</td>
<td>3–10</td>
</tr>
<tr>
<td>A</td>
<td>Mechanical Data</td>
<td>A–1</td>
</tr>
</tbody>
</table>
# List of Illustrations

<table>
<thead>
<tr>
<th>Figure</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2–1</td>
<td>System-Clock Timing Requirements</td>
<td>2–4</td>
</tr>
<tr>
<td>2–2</td>
<td>Master-Mode Timing Requirements</td>
<td>2–4</td>
</tr>
<tr>
<td>2–3</td>
<td>Slave-Mode Timing Requirements</td>
<td>2–5</td>
</tr>
<tr>
<td>2–4</td>
<td>Three-Wire Control Interface Timing Requirements</td>
<td>2–6</td>
</tr>
<tr>
<td>2–5</td>
<td>Two-Wire Control Interface Timing Requirements</td>
<td>2–6</td>
</tr>
<tr>
<td>3–1</td>
<td>SPI Timing</td>
<td>3–1</td>
</tr>
<tr>
<td>3–2</td>
<td>2-Wire Compatible Timing</td>
<td>3–2</td>
</tr>
<tr>
<td>3–3</td>
<td>Analog Line Input Circuit</td>
<td>3–5</td>
</tr>
<tr>
<td>3–4</td>
<td>Right Justified Mode Timing</td>
<td>3–6</td>
</tr>
<tr>
<td>3–5</td>
<td>Left Justified Mode Timing</td>
<td>3–6</td>
</tr>
<tr>
<td>3–6</td>
<td>I2S Mode Timing</td>
<td>3–6</td>
</tr>
<tr>
<td>3–7</td>
<td>DSP Mode Timing</td>
<td>3–7</td>
</tr>
<tr>
<td>3–8</td>
<td>Digital De-Emphasis Filter Response – 44.1 kHz Sampling</td>
<td>3–10</td>
</tr>
<tr>
<td>3–9</td>
<td>Digital De-Emphasis Filter Response – 48 kHz Sampling</td>
<td>3–11</td>
</tr>
<tr>
<td>3–10</td>
<td>DAC Digital Filter Response 0: USB Mode</td>
<td>3–11</td>
</tr>
<tr>
<td>3–11</td>
<td>DAC Digital Filter Ripple 0: USB Mode</td>
<td>3–11</td>
</tr>
<tr>
<td>3–12</td>
<td>DAC Digital Filter Response 1: USB Mode Only</td>
<td>3–12</td>
</tr>
<tr>
<td>3–13</td>
<td>DAC Digital Filter Ripple 1: USB Mode Only</td>
<td>3–12</td>
</tr>
<tr>
<td>3–14</td>
<td>DAC Digital Filter Response 2: USB Mode and Normal Modes</td>
<td>3–12</td>
</tr>
<tr>
<td>3–16</td>
<td>DAC Digital Filter Response 3: USB Mode Only</td>
<td>3–13</td>
</tr>
<tr>
<td>3–17</td>
<td>DAC Digital Filter Ripple 3: USB Mode Only</td>
<td>3–13</td>
</tr>
</tbody>
</table>
1 Introduction

The TLV320DAC23 is a high performance stereo DAC with highly integrated analog functionality. The DACs within the TLV320DAC23 are comprised of multibit sigma-delta technology with integrated over-sampling digital interpolation filters. Supported data transfer word lengths are 16, 20, 24, and 32 bits with sample rates from 8 kHz to 96 kHz. The DAC sigma-delta modulator features a second order multibit architecture with up to 100 dBA SNR at audio sample rates up to 96 kHz. This enables high quality digital audio playback capability while consuming less than 19 mW during playback only. The TLV320DAC23 is the ideal choice for portable digital audio player applications such as MP3 digital audio players.

Integrated analog features consist of stereo line inputs with an analog bypass path and a stereo headphone amplifier with analog volume control and mute. The headphone amplifier is capable of delivering 30 mW per channel into 32 Ω. The analog bypass path allows use of the stereo line inputs and the headphone amplifier with analog volume control while completely bypassing the DAC, thus enabling further design flexibility such as integrated FM tuners.

While the TLV320DAC23 supports the industry standard over-sample rates of 256 fₛ and 384 fₛ, unique over-sample rates of 250 fₛ and 272 fₛ are provided which optimize interface considerations in designs using TI C54x DSPs and USB data interfaces. A single 12-MHz crystal can be used to supply clocking to the DSP, USB, and DAC. The TLV320DAC23 features an internal oscillator which, when connected to a 12-MHz external crystal, will provide a system clock to the DSP and other peripherals at either 12 MHz or 6 MHz using an internal clock buffer and selectable divider. Audio sample rates of 48 kHz and CD standard rates of 44.1 kHz are directly supported from a 12-MHz master clock with 250 fₛ and 272 fₛ over-sample rates.

Low power consumption and flexible power management allow selective shutdown of DAC functions, thus extending battery life in portable applications. Couple this design solution with the industry’s smallest package, the TI proprietary MicroStar Junior™ using only 25 mm² of board area, powerful portable stereo audio designs are easily realizable in a cost effective, space saving total analog solution.

MicroStar Junior is a trademark of Texas Instruments.
1.1 Features

- **High-Performance Stereo DAC**
  - 100-dB SNR multibit sigma-delta ADC (A-weighted at 48 kHz)
  - 1.42 V – 3.6 V digital supply: compatible with TI C54x DSP core voltages
  - 2.7 V – 3.6 V analog supply: compatible TI C54x DSP buffer voltages
  - 8-kHz – 96-kHz sampling-frequency support

- **Software control via TI McBSP-compatible multiprotocol serial port**
  - 2-wire-compatible and SPI-compatible serial port protocols
  - Glueless interface to TI McBSPs

- **Audio data input/output via TI McBSP compatible programmable audio interface**
  - I²S-compatible interface
  - Standard I²S, MSB, or LSB justified data transfers
  - 16/20/24/32-bit word lengths
  - Audio master/slave timing capability optimized for TI DSPs (250/272 fs)
  - Industry-standard master/slave support also provided (256/384 fs)
  - Glueless interface to TI McBSPs

- **Stereo line inputs**

- **Stereo line outputs**
  - Analog stereo mixer for DAC and analog bypass path

- **Analog volume control with mute**

- **Highly efficient linear headphone amplifier**
  - 30 mW into 32 Ω from a 3.3-V analog supply voltage

- **Flexible power management under total software control**
  - 18-mW power consumption during playback mode
  - Standby power consumption <150 µW
  - Power-down power consumption <15 µW

- **Industry’s smallest package: 32-Pin TI proprietary MicroStar Junior**
  - 25 mm² total board area
  - 28-Pin TSSOP available (62 mm² total board area)
  - 28-Pin QFN available (25 mm² total board area)

- **Ideally suitable for portable solid-state audio players and recorders**
1.2 Functional Block Diagram

The Functional Block Diagram shows the components and connections of the TLV320DAC23 audio DAC chip. Key features include:

- **AVDD** and **AGND** for power supply.
- **VMID** and **50 kΩ resistors** for grounding.
- **DAC Select** for selecting the output DAC.
- **Bypass** switch for signal path.
- **Headphone Drivers** for low and high frequencies.
- **6 to −73 dB, 1-dB Steps** for volume adjustment.
- **CLKIN Divider** for clock signals.
- **Oscillator (OSC)** for generating clock signals.
- **CLKOUT (1x, 1/2x)** for output clock signals.
- **Digital Interface** for controlling the DAC.
- **Control Interface** for input signals (CS, SDI, SCLK, MODE).

The diagram illustrates the flow of signals through the chip, emphasizing the integration of analog and digital components.
1.3 Terminal Assignments

GQE PACKAGE (TOP VIEW)

PW PACKAGE (TOP VIEW)

NC – No internal connection
### 1.4 Ordering Information

<table>
<thead>
<tr>
<th>$T_A$</th>
<th>32-Pin MicroStar Junior GQE</th>
<th>28-Pin TSSOP PW</th>
<th>28-Pin QFN RHD</th>
</tr>
</thead>
<tbody>
<tr>
<td>−10°C to 70°C</td>
<td>TLV320DAC23GQE</td>
<td>TLV320DAC23PW</td>
<td>TLV320DAC23RHD</td>
</tr>
<tr>
<td>−40°C to 85°C</td>
<td>TLV320DAC23IGQE</td>
<td>TLV320DAC23PW</td>
<td>TLV320DAC23RHD</td>
</tr>
</tbody>
</table>
## 1.5 Terminal Functions

<table>
<thead>
<tr>
<th>TERMINAL</th>
<th>NAME</th>
<th>NUMBER</th>
<th>I/O</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AGND</td>
<td>5 15 12</td>
<td>–</td>
<td>Analog supply return</td>
</tr>
<tr>
<td></td>
<td>AVDD</td>
<td>4 14 11</td>
<td>–</td>
<td>Analog supply input. Voltage level is 3.3 V nominal.</td>
</tr>
<tr>
<td></td>
<td>BCLK</td>
<td>23 3 28</td>
<td>I/O</td>
<td>I²S serial-bit clock. In audio master mode, the DAC23 generates this signal and sends it to the DSP. In audio slave mode, the signal is generated by the DSP.</td>
</tr>
<tr>
<td></td>
<td>BVDD</td>
<td>21 1 26</td>
<td>–</td>
<td>Buffer supply input. Voltage range is from 2.7 V to 3.6 V.</td>
</tr>
<tr>
<td></td>
<td>CLKOUT</td>
<td>22 2 27</td>
<td>O</td>
<td>Clock output. This is a buffered version of the XTI input and is available in 1X or 1/2X frequencies of XTI. Frequency selection is controlled by bit X in control register XX.</td>
</tr>
<tr>
<td></td>
<td>CS</td>
<td>12 21 18</td>
<td>I</td>
<td>Control port input latch/address select. For SPI control mode this input acts as the data latch control. For 2-wire control mode this input defines the seventh bit in the device address field. See Section 3.1 for details.</td>
</tr>
<tr>
<td></td>
<td>DIN</td>
<td>24 4 1</td>
<td>I</td>
<td>I²S format serial data input to the sigma-delta stereo DAC</td>
</tr>
<tr>
<td></td>
<td>DGN D</td>
<td>20 28 25</td>
<td>–</td>
<td>Digital supply return</td>
</tr>
<tr>
<td></td>
<td>DVDD</td>
<td>19 27 24</td>
<td>–</td>
<td>Digital supply input. Voltage range is 1.4 V to 3.6 V.</td>
</tr>
<tr>
<td></td>
<td>HPGND</td>
<td>32 11 8</td>
<td>–</td>
<td>Buffer supply input. Voltage range is from 2.7 V to 3.6 V.</td>
</tr>
<tr>
<td></td>
<td>HPVDD</td>
<td>29 8 5</td>
<td>–</td>
<td>Analog headphone amplifier supply input. Voltage level is 3.3 V nominal.</td>
</tr>
<tr>
<td></td>
<td>LHPOUT</td>
<td>30 9 6</td>
<td>O</td>
<td>Left stereo mixer-channel amplified headphone output. Nominal 0-dB output level is 1.0 V RMS. Gain of –73 dB to 6 dB is provided in 1-dB steps.</td>
</tr>
<tr>
<td></td>
<td>LLINEIN</td>
<td>11 20 17</td>
<td>I</td>
<td>Left stereo-line input channel</td>
</tr>
<tr>
<td></td>
<td>LOUT</td>
<td>2 12 9</td>
<td>O</td>
<td>Left stereo mixer-channel line output. Nominal output level is 1.0 V RMS.</td>
</tr>
<tr>
<td></td>
<td>LRCIN</td>
<td>26 5 2</td>
<td>I/O</td>
<td>I²S DAC-word clock signal. In audio master mode, the DAC23 generates this framing signal and sends it to the DSP. In audio slave mode, the signal is generated by the DSP.</td>
</tr>
<tr>
<td></td>
<td>MODE</td>
<td>13 22 19</td>
<td>I</td>
<td>Serial interface mode input. See Section 3.1 for details.</td>
</tr>
<tr>
<td></td>
<td>NC</td>
<td>1, 7, 8, 9, 17, 25, 27, 28</td>
<td>–</td>
<td>Not Used—No internal connection</td>
</tr>
<tr>
<td></td>
<td>RHP OUT</td>
<td>31 10 7</td>
<td>O</td>
<td>Right stereo mixer-channel amplified headphone output. Nominal 0-dB output level is 1.0 V RMS. Gain of –73 dB to 6 dB is provided in 1-dB steps.</td>
</tr>
<tr>
<td></td>
<td>RL INEIN</td>
<td>10 19 16</td>
<td>I</td>
<td>Right stereo-line input channel</td>
</tr>
<tr>
<td></td>
<td>ROUT</td>
<td>3 13 10</td>
<td>O</td>
<td>Right stereo mixer-channel line output. Nominal output level is 1.0 V RMS.</td>
</tr>
<tr>
<td></td>
<td>SCLK</td>
<td>15 24 21</td>
<td>I</td>
<td>Control port serial data clock. For both SPI and 2-wire control modes this is the serial clock input. See Section 3.1 for details.</td>
</tr>
<tr>
<td></td>
<td>SDIN</td>
<td>14 23 20</td>
<td>I</td>
<td>Control port serial data input. For both SPI and 2-wire control modes this is the serial data input and also is used to select the control protocol after reset. See Section 3.1 for details.</td>
</tr>
<tr>
<td></td>
<td>VMID</td>
<td>6 16 13</td>
<td>I</td>
<td>Midrail voltage decoupling input. 10-μF and 0.1-μF capacitors should be connected in parallel to this terminal for noise filtering. Voltage level is 1/2 AVDD nominal.</td>
</tr>
<tr>
<td></td>
<td>XTI/MCLK</td>
<td>16 25 22</td>
<td>I</td>
<td>Crystal or external clock input. Used for derivation of all internal clocks on the DAC23.</td>
</tr>
<tr>
<td></td>
<td>XTO</td>
<td>18 26 23</td>
<td>O</td>
<td>Crystal output. Connect to external crystal for applications where the DAC23 is the audio timing master. Not used in applications where external clock source is used.</td>
</tr>
</tbody>
</table>
2 Specifications

2.1 Absolute Maximum Ratings Over Operating Free-Air Temperature Range (unless otherwise noted)†
Supply voltage range, \( \text{AV}_{\text{DD}} \) to \( \text{AGND} \), \( \text{DV}_{\text{DD}} \) to \( \text{DGND} \), \( \text{BV}_{\text{DD}} \) to \( \text{DGND} \), \( \text{HPV}_{\text{DD}} \) to \( \text{HPGND} \) (see Note 1) \(-0.3 \text{ V} \) to +3.63 V
Analog supply return to digital supply return, \( \text{AGND} \) to \( \text{DGND} \) \(-0.3 \text{ V} \) to +0.3 V
Input voltage range, all input signals: Digital \(-0.3 \text{ V} \) to \( \text{DV}_{\text{DD}} + 0.3 \text{ V} \)
Analog \(-0.3 \text{ V} \) to \( \text{AV}_{\text{DD}} + 0.3 \text{ V} \)
Operating free-air temperature range, \( T_A \) \(-10 ^\circ \text{C} \) to 70°C
Storage temperature range, \( T_{\text{stg}} \) \(-65 ^\circ \text{C} \) to 150°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 under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTE 1: \( \text{DV}_{\text{DD}} \) may not exceed \( \text{BV}_{\text{DD}} + 0.3 \text{ V} \); \( \text{BV}_{\text{DD}} \) may not exceed \( \text{AV}_{\text{DD}} + 0.3 \text{ V} \) or \( \text{HPV}_{\text{DD}} + 0.3 \text{ V} \).

2.2 Recommended Operating Conditions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MIN</th>
<th>NOM</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog supply voltage, ( \text{AV}<em>{\text{DD}} ), ( \text{HPV}</em>{\text{DD}} ) (see Note 2)</td>
<td>2.7</td>
<td>3.3</td>
<td>3.6</td>
<td>V</td>
</tr>
<tr>
<td>Digital buffer supply voltage, ( \text{BV}_{\text{DD}} ) (see Note 2)</td>
<td>2.7</td>
<td>3.3</td>
<td>3.6</td>
<td>V</td>
</tr>
<tr>
<td>Digital core supply voltage, ( \text{DV}_{\text{DD}} ) (see Note 2)</td>
<td>1.42</td>
<td>1.5</td>
<td>3.6</td>
<td>V</td>
</tr>
<tr>
<td>Analog input voltage, ( \text{AV}_{\text{DD}} = 3.3 \text{ V} )</td>
<td>1</td>
<td>V RMS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stereo line output load resistance</td>
<td>10</td>
<td>kΩ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Headphone amplifier output load resistance</td>
<td>0</td>
<td>Ω</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLKOUT digital output load capacitance</td>
<td>20</td>
<td>pF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All other digital output load capacitance</td>
<td>10</td>
<td>pF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stereo-line output load capacitance</td>
<td>50</td>
<td>pF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>XTI master clock Input</td>
<td>18.43</td>
<td>MHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DAC conversion rate</td>
<td>96</td>
<td>kHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating free-air temperature, ( T_A )</td>
<td>−10</td>
<td>70</td>
<td>^°C</td>
<td></td>
</tr>
</tbody>
</table>

NOTE 2: Digital voltage values are with respect to DGND; analog voltage values are with respect to AGND.
### 2.3 Electrical Characteristics Over Recommended Operating Conditions, $AV_{DD}$, $HPV_{DD}$, $BV_{DD}$ = 3.3 V, $DV_{DD}$ = 1.5 V, Master Mode, XTI = 12 MHz, (unless otherwise stated)

#### 2.3.1 DAC

**2.3.1.1 Load = 10 k$\Omega$, 50 pF**

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-dB full-scale output voltage</td>
<td>$AV_{DD}$ = 3.3 V</td>
<td>1.0</td>
<td></td>
<td></td>
<td>V RMS</td>
</tr>
<tr>
<td>Signal-to-noise ratio, A-weighted, 0-dB gain (see Notes 3, 4, and 5)</td>
<td>$AV_{DD}$ = 3.3 V</td>
<td>$f_s = 44.1kHz$</td>
<td>90</td>
<td>100</td>
<td>dB</td>
</tr>
<tr>
<td></td>
<td>$AV_{DD}$ = 3.3 V</td>
<td>$f_s = 96 kHz$</td>
<td>98</td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Dynamic range, A-weighted (see Note 5)</td>
<td>$AV_{DD}$ = 3.3 V</td>
<td>85</td>
<td>90</td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Total harmonic distortion (THD)</td>
<td>$AV_{DD}$ = 3.3 V</td>
<td>1 kHz, 0 dB</td>
<td>−88</td>
<td>−80</td>
<td>dB</td>
</tr>
<tr>
<td></td>
<td>$AV_{DD}$ = 3.3 V</td>
<td>1 kHz, −3 dB</td>
<td>−92</td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Power supply rejection ratio</td>
<td>$AV_{DD}$ = 3.3 V</td>
<td>1 kHz, 0 dB</td>
<td>−88</td>
<td>−80</td>
<td>dB</td>
</tr>
<tr>
<td></td>
<td>$AV_{DD}$ = 3.3 V</td>
<td>1 kHz, −3 dB</td>
<td>−92</td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Mute attenuation</td>
<td>1 kHz, 100 mV$_{pp}$</td>
<td></td>
<td>50</td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>DAC channel separation</td>
<td>$AV_{DD} = 3.3 V, 1 kHz, 0dB$</td>
<td></td>
<td>100</td>
<td></td>
<td>dB</td>
</tr>
</tbody>
</table>

#### 2.3.2 Analog Line Input to Line Output

**2.3.2.1 Load = 10 k$\Omega$, 50 pF, no gain on input**

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-dB full-scale output voltage</td>
<td>$AV_{DD}$ = 3.3 V</td>
<td>1.0</td>
<td></td>
<td></td>
<td>V RMS</td>
</tr>
<tr>
<td>Signal-to-noise ratio, (SNR) A-weighted, 0-dB gain (see Notes 3, 5)</td>
<td>$AV_{DD}$ = 3.3 V</td>
<td>1 kHz, 0 dB</td>
<td>−86</td>
<td>−80</td>
<td>dB</td>
</tr>
<tr>
<td>Total harmonic distortion (THD)</td>
<td>$AV_{DD}$ = 3.3 V</td>
<td>1 kHz, −3 dB</td>
<td>−92</td>
<td>−86</td>
<td>dB</td>
</tr>
<tr>
<td>Power supply rejection ratio</td>
<td>1 kHz, 100 mV$_{pp}$</td>
<td></td>
<td>50</td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Mute attenuation</td>
<td>1 kHz, 0 dB</td>
<td>80</td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Input resistance</td>
<td>10 k</td>
<td>24 k</td>
<td></td>
<td></td>
<td>Ω</td>
</tr>
</tbody>
</table>
### 2.3.3 Stereo Headphone Output

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-dB full-scale output voltage</td>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
<td>V RMS</td>
</tr>
<tr>
<td>Maximum output power, $P_O$</td>
<td>$R_L = 32 , \Omega$</td>
<td>30</td>
<td></td>
<td></td>
<td>mW</td>
</tr>
<tr>
<td></td>
<td>$R_L = 16 , \Omega$</td>
<td>40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signal-to-noise ratio, A-weighted (see Note 4)</td>
<td>$AVDD = 3.3 , V$</td>
<td>90</td>
<td>97</td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Total harmonic distortion</td>
<td>$AVDD = 3.3 , V$, 1 kHz output, into $32 , \Omega$</td>
<td>$P_O = 10 , mW$</td>
<td>-60</td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power supply rejection ratio</td>
<td>1 kHz, 100 mV$_{pp}$</td>
<td>50</td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Programmable gain</td>
<td>1 kHz output</td>
<td>-73</td>
<td>6</td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Programmable-gain step size</td>
<td>1 kHz output</td>
<td></td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Mute attenuation</td>
<td>1 kHz output</td>
<td>80</td>
<td></td>
<td></td>
<td>dB</td>
</tr>
</tbody>
</table>

**NOTES:**
3. Ratio of output level with 1-kHz full-scale input, to the output level with the input short circuited, measured A-weighted over a 20-Hz to 20-kHz bandwidth using an audio analyzer.
4. All performance measurements done with 20-kHz low-pass filter and, where noted, A-weighted filter. Failure to use such a filter results in higher THD + N and lower SNR and dynamic range readings than shown in the electrical characteristics. The low-pass filter removes out-of-band noise, which, although not audible, may affect dynamic specification values.
5. Ratio of output level with 1-kHz full-scale input, to the output level with all zeros into the digital input, measured A-weighted over a 20-Hz to 20-kHz bandwidth.

### 2.3.4 Analog Reference Levels

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference voltage, $V_{MID}$</td>
<td>$AVDD/2 - 50 , mV$</td>
<td>$AVDD/2 + 50 , mV$</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Divider resistance, $R_{VMID}$</td>
<td>40</td>
<td>50</td>
<td>60</td>
<td>kΩ</td>
</tr>
</tbody>
</table>

### 2.3.5 Digital I/O

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{IL}$ Input low level</td>
<td></td>
<td></td>
<td>$0.3 \times BVDD$</td>
<td>V</td>
</tr>
<tr>
<td>$V_{IH}$ Input high level</td>
<td></td>
<td></td>
<td>$0.7 \times BVDD$</td>
<td>V</td>
</tr>
<tr>
<td>$V_{OL}$ Output low level</td>
<td></td>
<td></td>
<td>$0.1 \times BVDD$</td>
<td>V</td>
</tr>
<tr>
<td>$V_{OH}$ Output high level</td>
<td></td>
<td></td>
<td>$0.9 \times BVDD$</td>
<td>V</td>
</tr>
</tbody>
</table>

### 2.3.6 Supply Current

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_{TOT}$ Total supply current, no input signal (3.3 V supply)</td>
<td>Line playback only (Clk power off, 50 Ω)</td>
<td>6</td>
<td>8</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td>Line playback only (Clk power on, 50 Ω)</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Analog bypass (line in to line out)</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Power down Oscillator enabled</td>
<td>1.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Oscillator disabled</td>
<td>0.01</td>
<td>0.025</td>
<td></td>
</tr>
</tbody>
</table>
2.4 Digital-Interface Timing

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_{w(1)} )</td>
<td></td>
<td></td>
<td>18</td>
<td>ns</td>
</tr>
<tr>
<td>( t_{w(2)} )</td>
<td></td>
<td></td>
<td>18</td>
<td>ns</td>
</tr>
<tr>
<td>( t_{c(1)} )</td>
<td>54</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>Duty cycle, MCLK/XTI</td>
<td>40/60%</td>
<td>60/40%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( t_{pd(1)} )</td>
<td>0</td>
<td>10</td>
<td>ns</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2–1. System-Clock Timing Requirements

2.4.1 Audio Interface (Master Mode)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_{pd(2)} )</td>
<td>0</td>
<td>10</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>( t_{su(1)} )</td>
<td>10</td>
<td></td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>( t_{h(1)} )</td>
<td>10</td>
<td></td>
<td>ns</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2–2. Master-Mode Timing Requirements
### 2.4.2 Audio Interface (Slave-Mode)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_w(3) )</td>
<td>20</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>( t_w(4) )</td>
<td>20</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>( t_c(2) )</td>
<td>50</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>( t_su(2) )</td>
<td>10</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>( t_h(2) )</td>
<td>10</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>( t_su(3) )</td>
<td>10</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>( t_h(3) )</td>
<td>10</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BCLK</th>
<th>LRCIN</th>
<th>DIN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Figure 2–3. Slave-Mode Timing Requirements*
2.4.3 Three-Wire Control Interface (SDI)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_{W(5)} ) Clock pulse duration, SCLK</td>
<td>20</td>
<td></td>
<td>20</td>
<td>ns</td>
</tr>
<tr>
<td>( t_{W(6)} ) Clock pulse duration, SCLK</td>
<td>20</td>
<td></td>
<td>20</td>
<td>ns</td>
</tr>
<tr>
<td>( t_{C(3)} ) Clock period, SCLK</td>
<td>80</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>( t_{SU(4)} ) Clock rising edge to CS rising edge, SCLK</td>
<td>60</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>( t_{SU(5)} ) Setup time, SDIN to SCLK</td>
<td>20</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>( t_{H(4)} ) Hold time, SCLK to SDIN</td>
<td>20</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>( t_{W(7)} ) Pulse duration, CS</td>
<td>High</td>
<td>20</td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>( t_{W(8)} ) Pulse duration, CS</td>
<td>Low</td>
<td>20</td>
<td></td>
<td>ns</td>
</tr>
</tbody>
</table>

Figure 2-4. Three-Wire Control Interface Timing Requirements

2.4.4 Two-Wire Control Interface

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_{W(9)} ) Clock pulse duration, SCLK</td>
<td>1.3</td>
<td></td>
<td></td>
<td>µs</td>
</tr>
<tr>
<td>( t_{W(10)} ) Clock pulse duration, SCLK</td>
<td>Low</td>
<td>600</td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>( f_{SF} ) Clock frequency, SCLK</td>
<td>0</td>
<td>400</td>
<td></td>
<td>kHz</td>
</tr>
<tr>
<td>( t_{H(5)} ) Hold time (start condition)</td>
<td>600</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>( t_{SU(6)} ) Setup time (start condition)</td>
<td>600</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>( t_{H(6)} ) Data hold time</td>
<td>900</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>( t_{SU(7)} ) Data setup time</td>
<td>100</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>( t_{R} ) Rise time, SDIN, SCLK</td>
<td>300</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>( t_{F} ) Fall time, SDIN, SCLK</td>
<td>300</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>( t_{SU(8)} ) Setup time (stop condition)</td>
<td>600</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
</tbody>
</table>

Figure 2-5. Two-Wire Control Interface Timing Requirements
3 How to Use the DAC23

3.1 Control Interfaces

The TLV320DAC23 has many programmable features. The control interface is used to program the registers of the device. The control interface complies with SPI (three-wire operation) and two-wire operation specifications. The state of the MODE terminal selects the control interface type. The MODE pin must be hardwired to the required level.

<table>
<thead>
<tr>
<th>MODE</th>
<th>INTERFACE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2-wire</td>
</tr>
<tr>
<td>1</td>
<td>SPI</td>
</tr>
</tbody>
</table>

3.1.1 SPI

In SPI mode, SDI carries the serial data, SCLK is the serial clock and CS latches the data word into the TLV320DAC23. The interface is compatible with microcontrollers and DSPs with an SPI interface.

A control word consists of 16 bits, starting with the MSB. The data bits are latched on the rising edge of SCLK. A rising edge on CS after the sixteenth rising clock edge latches the data word into the DAC (see Figure 3-1).

The control word is divided into two parts. The first part is the address block, the second part is the data block:

\[
\begin{array}{c|c}
B[15:9] & \text{Control address bits} \\
B[8:0] & \text{Control data bits} \\
\end{array}
\]

\[
\begin{array}{c|c|c|c|c|c|c|c|c|c|c}
\text{CS} & B15 & B14 & B13 & B12 & B11 & B10 & B9 & B8 & B7 & B6 & B5 & B4 & B3 & B2 & B1 & B0 \\
\text{SCLK} & & & & & & & & & & & & & & & & \\
\text{SDI} & MSB & B15 & B14 & B13 & B12 & B11 & B10 & B9 & B8 & B7 & B6 & B5 & B4 & B3 & B2 & B1 & B0 \\
\end{array}
\]

**Figure 3–1. SPI Timing**

3.1.2 2-Wire

In 2-wire mode, the data transfer uses SDI for the serial data and SCLK for the serial clock. The start condition is a falling edge on SDIN while SCLK is high. The seven bits following the start condition determine the device on the 2-wire bus that receives the data. R/W determines the direction of the data transfer. The TLV320DAC23 is a write only device and responds only if R/W is 0. The device operates only as a slave device whose address is selected by setting the state of the CS pin as follows.

<table>
<thead>
<tr>
<th>CS STATE (Default = 0)</th>
<th>ADDRESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0011010</td>
</tr>
<tr>
<td>1</td>
<td>0011011</td>
</tr>
</tbody>
</table>

The device that recognizes the address responds by pulling SDI low during the ninth clock cycle, acknowledging the data transfer. The control follows in the next two eight-bit blocks. The stop condition after the data transfer is a rising edge on SDI when SCLK is high (see Figure 3-2).
The 16-bit control word is divided into two parts. The first part is the address block, the second part is the data block:

- \( B[15:9] \) Control address bits
- \( B[8:0] \) Control data bits

![2-Wire Compatible Timing Diagram](image)

### 3.1.3 Register Map

The TLV320DAC23 has the following set of registers, which are used to program the modes of operation.

<table>
<thead>
<tr>
<th>ADDRESS</th>
<th>REGISTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000000</td>
<td>Left line input channel control</td>
</tr>
<tr>
<td>0000001</td>
<td>Right line input channel control</td>
</tr>
<tr>
<td>0000010</td>
<td>Left channel headphone volume control</td>
</tr>
<tr>
<td>0000011</td>
<td>Right channel headphone volume control</td>
</tr>
<tr>
<td>0000100</td>
<td>Analog audio path control</td>
</tr>
<tr>
<td>0000101</td>
<td>Digital audio path control</td>
</tr>
<tr>
<td>0000110</td>
<td>Power down control</td>
</tr>
<tr>
<td>0000111</td>
<td>Digital audio interface format</td>
</tr>
<tr>
<td>0001000</td>
<td>Sample rate control</td>
</tr>
<tr>
<td>0001001</td>
<td>Digital interface activation</td>
</tr>
<tr>
<td>0001111</td>
<td>Reset register</td>
</tr>
</tbody>
</table>

#### Left Line Input Channel Control (Address: 0000000)

<table>
<thead>
<tr>
<th>BIT</th>
<th>D8</th>
<th>D7</th>
<th>D6</th>
<th>D5</th>
<th>D4</th>
<th>D3</th>
<th>D2</th>
<th>D1</th>
<th>D0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>LRS</td>
<td>LIM</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

- **LRS** Left/right line simultaneous volume/mute update
  - Simultaneous update: 0 = Disabled, 1 = Enabled
- **LIM** Left line input mute
  - 0 = Normal, 1 = Muted
- **X** Reserved

#### Right Line Input Channel Control (Address: 0000001)

<table>
<thead>
<tr>
<th>BIT</th>
<th>D8</th>
<th>D7</th>
<th>D6</th>
<th>D5</th>
<th>D4</th>
<th>D3</th>
<th>D2</th>
<th>D1</th>
<th>D0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>RLS</td>
<td>RIM</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

- **RLS** Right/left line simultaneous volume/mute update
  - Simultaneous update: 0 = Disabled, 1 = Enabled
- **RIM** Right line input mute
  - 0 = Normal, 1 = Muted
- **X** Reserved
### Left Channel Headphone Volume Control (Address: 0000010)

<table>
<thead>
<tr>
<th>BIT</th>
<th>D8</th>
<th>D7</th>
<th>D6</th>
<th>D5</th>
<th>D4</th>
<th>D3</th>
<th>D2</th>
<th>D1</th>
<th>D0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>LRS</td>
<td>LZC</td>
<td>LHV6</td>
<td>LHV5</td>
<td>LHV4</td>
<td>LHV3</td>
<td>LHV2</td>
<td>LHV1</td>
<td>LHV0</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

- **LRS**: Left/right headphone channel simultaneous volume/mute update
  - Simultaneous update: 0 = Disabled, 1 = Enabled
- **LZC**: Left-channel zero-cross detect
  - Zero-cross detect: 0 = Off, 1 = On
- **LHV[6:0]**: Left Headphone volume control (1111001 = 0 dB default)
  - 111111 = +6 dB, 79 steps between +6 dB and −73 dB (mute), 0110000 = −73 dB (mute), any thing below 0110000 does nothing – you are still muted

### Right Channel Headphone Volume Control (Address: 0000111)

<table>
<thead>
<tr>
<th>BIT</th>
<th>D8</th>
<th>D7</th>
<th>D6</th>
<th>D5</th>
<th>D4</th>
<th>D3</th>
<th>D2</th>
<th>D1</th>
<th>D0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>RLS</td>
<td>RZC</td>
<td>RHV6</td>
<td>RHV5</td>
<td>RHV4</td>
<td>RHV3</td>
<td>RHV2</td>
<td>RHV1</td>
<td>RHV0</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

- **RLS**: Right/left headphone channel simultaneous volume/mute update
  - Simultaneous update: 0 = Disabled, 1 = Enabled
- **RZC**: Right-channel zero-cross detect
  - Zero-cross detect: 0 = Off, 1 = On
- **RHV[6:0]**: Right Headphone volume control (1111001 = 0 dB default)
  - 111111 = +6 dB, 79 steps between +6 dB and −73 dB (mute), 0110000 = −73 dB (mute), any thing below 0110000 does nothing – you are still muted

### Analog Audio Path Control (Address: 0000100)

<table>
<thead>
<tr>
<th>BIT</th>
<th>D8</th>
<th>D7</th>
<th>D6</th>
<th>D5</th>
<th>D4</th>
<th>D3</th>
<th>D2</th>
<th>D1</th>
<th>D0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>DAC</td>
<td>BYP</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

- **DAC**: DAC select
  - 0 = DAC off, 1 = DAC selected
- **BYP**: Bypass
  - 0 = Disabled, 1 = Enabled
- **X**: Reserved

### Digital Audio Path Control (Address: 0000101)

<table>
<thead>
<tr>
<th>BIT</th>
<th>D8</th>
<th>D7</th>
<th>D6</th>
<th>D5</th>
<th>D4</th>
<th>D3</th>
<th>D2</th>
<th>D1</th>
<th>D0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>DACM</td>
<td>DEEMP1</td>
<td>DEEMP0</td>
<td>X</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

- **DACM**: DAC soft mute
  - 0 = Disabled, 1 = Enabled
- **DEEMP[1:0]**: De-emphasis control
  - 00 = Disabled, 01 = 32 kHz, 10 = 44.1 kHz, 11 = 48 kHz
- **X**: Reserved

### Power Down Control (Address: 0000110)

<table>
<thead>
<tr>
<th>BIT</th>
<th>D8</th>
<th>D7</th>
<th>D6</th>
<th>D5</th>
<th>D4</th>
<th>D3</th>
<th>D2</th>
<th>D1</th>
<th>D0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>X</td>
<td>OFF</td>
<td>CLK</td>
<td>OSC</td>
<td>OUT</td>
<td>DAC</td>
<td>X</td>
<td>X</td>
<td>LINE</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

- **OFF**: Power
  - 0 = On, 1 = Off
- **CLK**: Clock
  - 0 = On, 1 = Off
- **OSC**: Oscillator
  - 0 = On, 1 = Off
- **OUT**: Outputs
  - 0 = On, 1 = Off
- **DAC**: DAC
  - 0 = On, 1 = Off
- **LINE**: Line input
  - 0 = On, 1 = Off
- **X**: Reserved
Digital Audio Interface Format (Address: 0000111)

<table>
<thead>
<tr>
<th>BIT</th>
<th>D8</th>
<th>D7</th>
<th>D6</th>
<th>D5</th>
<th>D4</th>
<th>D3</th>
<th>D2</th>
<th>D1</th>
<th>D0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>X</td>
<td>X</td>
<td>MS</td>
<td>LRSWAP</td>
<td>LRP</td>
<td>IWL1</td>
<td>IWL0</td>
<td>FOR1</td>
<td>FOR0</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

- **MS**: Master/slave mode  
  0 = Slave  
  1 = Master
- **LRSWAP**: DAC left/right swap  
  0 = Disabled  
  1 = Enabled
- **LRP**: DAC left/right phase  
  0 = Right channel on, LRCIN high  
  1 = Right channel on, LRCIN low
- **IWL[1:0]**: Input bit length  
  00 = 16 bit  
  01 = 20 bit  
  10 = 24 bit  
  11 = 32 bit
- **FOR[1:0]**: Data format  
  11 = DSP format, frame sync followed by two data words  
  10 = I2S format, MSB first, left – 1 aligned  
  01 = MSB first, left aligned  
  00 = MSB first, right aligned

**X**: Reserved

**NOTES:**  
1. In Master mode, the TLV320AIC23 supplies the BCLK and LRCIN. In Slave mode, BCLK and LRCIN are supplied to the TLV320AIC23.  
2. In normal mode, BCLK = MCLK/4 for all sample rates except for 88.2 kHz and 96 kHz. For 88.2 kHz and 96 kHz sample rate, BCLK = MCLK.  
3. In USB mode, bit BCLK = MCLK

Sample Rate Control (Address: 0001000)

<table>
<thead>
<tr>
<th>BIT</th>
<th>D8</th>
<th>D7</th>
<th>D6</th>
<th>D5</th>
<th>D4</th>
<th>D3</th>
<th>D2</th>
<th>D1</th>
<th>D0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>X</td>
<td>CLKOUT</td>
<td>CLKIN</td>
<td>SR3</td>
<td>SR2</td>
<td>SR1</td>
<td>SR0</td>
<td>BOSR</td>
<td>USB/Normal</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

- **CLKOUT**: Clock output divider  
  0 = MCLK  
  1 = MCLK/2
- **CLKIN**: Clock input divider  
  0 = MCLK  
  1 = MCLK/2
- **SR[3:0]**: Sampling rate control (see Sections 3.3.2.1 AND 3.3.2.2)
- **BOSR**: Base oversampling rate  
  USB mode:  
  0 = 250 f_s  
  1 = 272 f_s  
  Normal mode:  
  0 = 256 f_s  
  1 = 384 f_s
- **USB/Normal**: Clock mode select:  
  0 = Normal  
  1 = USB
- **X**: Reserved

Digital Interface Activation (Address: 0001001)

<table>
<thead>
<tr>
<th>BIT</th>
<th>D8</th>
<th>D7</th>
<th>D6</th>
<th>D5</th>
<th>D4</th>
<th>D3</th>
<th>D2</th>
<th>D1</th>
<th>D0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>ACT</td>
<td>ACT</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

- **ACT**: Activate interface  
  0 = Inactive  
  1 = Active
- **X**: Reserved

Reset Register (Address: 0001111)

<table>
<thead>
<tr>
<th>BIT</th>
<th>D8</th>
<th>D7</th>
<th>D6</th>
<th>D5</th>
<th>D4</th>
<th>D3</th>
<th>D2</th>
<th>D1</th>
<th>D0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>RES</td>
<td>RES</td>
<td>RES</td>
<td>RES</td>
<td>RES</td>
<td>RES</td>
<td>RES</td>
<td>RES</td>
<td>RES</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

- **RES**: Write to this register triggers reset

### 3.2 Analog Interface

#### 3.2.1 Line Inputs

The TLV320DAC23 has line inputs for the left and the right audio channels (RLINEIN and LLINEIN). Both line inputs have independently programmable mutes. Active and passive filters for the two channels prevent high frequencies from folding back into the audio band.
The line inputs are biased internally to VMID. When the line inputs are muted or the device is set to standby mode, the line inputs are kept biased to VMID using special antithump circuitry. This reduces audible clicks that otherwise might be heard when reactivating the inputs.

For interfacing to a CD system, the line input should be scaled to 1 V\(_{RMS}\) to avoid clipping, using the circuit shown in Figure 3-3.

![Figure 3-3. Analog Line Input Circuit](image)

Where:

- \( R_1 = 5 \, k\Omega \)
- \( R_2 = 5 \, k\Omega \)
- \( C_1 = 47 \, pF \)
- \( C_2 = 470 \, nF \)

R1 and R2 divide the input signal by two, reducing the 2 V\(_{RMS}\) from the CD player to the nominal 1 V\(_{RMS}\) of the DAC23 inputs. C1 filters high-frequency noise, and C2 removes any dc component from the signal.

### 3.2.2 Line Outputs

The TLV320DAC23 has two low-impedance line outputs (LLINEOUT and RLINEOUT) capable of driving line loads with 10-k\(\Omega\) and 50-pF impedances.

The DAC full-scale output voltage is 1.0 V\(_{RMS}\) at \(AV_{DD} = 3.3\) V. The full-scale range tracks linearly with the analog supply voltage \(AV_{DD}\). The DAC is connected to the line outputs via a low-pass filter that removes out-of-band components. No further external filtering is required in most applications.

The DAC outputs and the line inputs are summed into the line outputs. The line outputs are muted by either muting the DAC (analog) or soft muting (digital) and disabling the bypass path (see Section 3.1.3). 

### 3.2.3 Headphone Output

The TLV320DAC23 has stereo headphone outputs (LHPOUT and RHPOUT), and is designed to drive 16-\(\Omega\) or 32-\(\Omega\) headphones. The headphone output includes a high-quality volume control and mute function.

The headphone volume is logarithmically adjustable from 6 dB to –73 dB in 1-dB steps. Writing 000000 to the volume-control registers (see Section 3.1.3) mutes the headphone output. When the headphone output is muted or the device is placed in standby mode, the dc voltage is maintained at the outputs to prevent audible clicks.

A zero-cross detection circuit is provided under the control of the LZC and RZC bits. If this circuit is enabled, the volume-control values are updated only when the input signal to the gain stage is close to the analog ground level. This minimizes audible clicks as the volume is changed or the device is muted. This circuit has no time-out, so if only dc levels are being applied to the gain stage input of more than 20 mV, the gain is not updated.

The gain is independently programmable on the left and right channels. Both channels can be locked to the same value by setting the RLS and LRS bits (see Section 3.1.3).

### 3.3 Digital Audio Interface

#### 3.3.1 Digital Audio-Interface Modes

The TLV320DAC23 supports four audio-interface modes.

- Right justified
- Left justified
- \(\text{I}^2\text{S} \) mode
- DSP mode
The four modes are MSB first and operate with a variable word width between 16 to 32 bits (except right-justified mode, which does not support 32 bits).

The digital audio interface consists of clock signal BCLK, data signals DIN and and the synchronization signal LRCIN. BCLK is an output in master mode and an input in slave mode.

### 3.3.1.1 Right-Justified Mode

In right-justified mode, the LSB is available on the rising edge of BCLK, preceding a falling edge on LRCIN (see Figure 3-4).

![Figure 3-4. Right Justified Mode Timing](image)

### 3.3.1.2 Left-Justified Mode

In left-justified mode, the MSB is available on the rising edge of BCLK, following a rising edge on LRCIN (see Figure 3-5).

![Figure 3-5. Left Justified Mode Timing](image)

### 3.3.1.3 I²S Mode

In I²S mode, the MSB is available on the second rising edge of BCLK, after the falling edge on LRCIN (see Figure 3-6).

![Figure 3-6. I²S Mode Timing](image)
3.3.1.4 DSP Mode

The DSP mode is compatible with the McBSP ports of TI DSPs. LRCIN must be connected to the Frame Sync signal of the McBSP. A falling edge on LRCIN starts the data transfer. The left-channel data consists of the first data word, which is immediately followed by the right channel data word (see Figure 3-7).

![DSP Mode Timing Diagram](image)

Figure 3–7. DSP Mode Timing

3.3.2 Audio Sampling Rates

The TLV320DAC23 can operate in master or slave clock mode. In the master mode, the TLV320DAC23 clock and sampling rates are derived from a 12-MHz MCLK signal. This 12-MHz clock signal is compatible with the USB specification. The TLV320DAC23 can be used directly in a USB system.

In the slave mode, the TLV320DAC23 clock and sample rates are controlled by using an appropriate MCLK or crystal frequency and the sample rate control register settings.

The settings in the sample rate control register control the clock mode and sampling rates.

Sample Rate Control (Address: 0001000)

<table>
<thead>
<tr>
<th>BIT</th>
<th>D8</th>
<th>D7</th>
<th>D6</th>
<th>D5</th>
<th>D4</th>
<th>D3</th>
<th>D2</th>
<th>D1</th>
<th>D0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>X</td>
<td>CLKOUT</td>
<td>CLKIN</td>
<td>SR3</td>
<td>SR2</td>
<td>SR1</td>
<td>SR0</td>
<td>BOSR</td>
<td>USB/Normal</td>
</tr>
<tr>
<td>Default</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

CLKOUT: Clock output divider
0 = MCLK
1 = MCLK/2

CLKIN: Clock input divider
0 = MCLK
1 = MCLK/2

SR[3:0]: Sample rate control (see Sections 3.3.2.1 and 3.3.2.2)

BOSR: Base oversampling rate

USB mode:
0 = 250 fS
1 = 272 fS

Normal mode:
0 = 256 fS
1 = 384 fS

USB/Normal: Clock mode select:
0 = Normal
1 = USB

X: Reserved

The clock circuit of the DAC23 has two internal dividers. The first, controlled by CLKIN, applies to the sampling-rate generator of the DAC. The second, controlled by CLKOUT, applies only to the CLKOUT terminal. By setting CLKIN to 1, the entire DAC is clocked with half the frequency, effectively dividing the resulting sampling rates by two.
3.3.2.1 USB-Mode Sampling Rates

In the USB mode, the following DAC sampling rates are available:

(MCLK = 12 MHz)

<table>
<thead>
<tr>
<th>SAMPLING RATE</th>
<th>FILTER TYPE</th>
<th>FILTER TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>kHz</td>
<td>SR3</td>
<td>SR2</td>
</tr>
<tr>
<td>96</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>88.235</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>48</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>44.118</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>32</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8.021</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>48</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>44.118</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>24</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>22.059</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>16</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4.0105</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

(MCLK = 6 MHz)

<table>
<thead>
<tr>
<th>SAMPLING RATE</th>
<th>FILTER TYPE</th>
<th>FILTER TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>kHz</td>
<td>SR3</td>
<td>SR2</td>
</tr>
<tr>
<td>48</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>44.118</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>24</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>22.059</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>16</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4.0105</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>22.059</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11.029</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2.005</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
3.3.2.2 Normal-Mode Sampling Rates

In Normal mode, the following DAC sampling rates, depending on the MCLK frequency, are available:

### MCLK = 12.288 MHz

<table>
<thead>
<tr>
<th>SAMPLING RATE kHz</th>
<th>FILTER TYPE</th>
<th>SAMPLING-RATE CONTROL SETTINGS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>96</td>
<td>2</td>
<td>0 1 1 1 0 0 0 0 0 0 0 0 0 0</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>1</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>1</td>
<td>0 1 1 1 0 0 0 0 0 0 0 0 0 0</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>2</td>
<td>0 1 1 1 1 1 0 0 0 0 0 0 0 0</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>1</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>1</td>
<td>0 1 1 1 0 0 0 0 0 0 0 0 0 0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>0 0 0 0 1 1 1 0 0 0 0 0 0 0</td>
<td></td>
</tr>
</tbody>
</table>

### MCLK = 11.2896 MHz

<table>
<thead>
<tr>
<th>SAMPLING RATE kHz</th>
<th>FILTER TYPE</th>
<th>SAMPLING-RATE CONTROL SETTINGS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>88.2</td>
<td>2</td>
<td>1 1 1 1 1 1 0 0 0 0 0 0 0 0</td>
<td></td>
</tr>
<tr>
<td>44.1</td>
<td>1</td>
<td>1 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td></td>
</tr>
<tr>
<td>8.021</td>
<td>1</td>
<td>1 0 1 1 1 1 0 0 0 0 0 0 0 0</td>
<td></td>
</tr>
<tr>
<td>44.1</td>
<td>2</td>
<td>1 1 1 1 1 1 0 0 0 0 0 0 0 0</td>
<td></td>
</tr>
<tr>
<td>22.05</td>
<td>1</td>
<td>1 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td></td>
</tr>
<tr>
<td>4.0105</td>
<td>1</td>
<td>1 0 1 1 1 0 0 0 0 0 0 0 0 0</td>
<td></td>
</tr>
</tbody>
</table>

### MCLK = 18.432 MHz

<table>
<thead>
<tr>
<th>SAMPLING RATE kHz</th>
<th>FILTER TYPE</th>
<th>SAMPLING-RATE CONTROL SETTINGS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>96</td>
<td>2</td>
<td>0 1 1 1 1 1 1 1 1 0 0 0 0 0</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>1</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>1</td>
<td>0 1 1 1 0 0 0 0 0 0 0 0 0 0</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>2</td>
<td>0 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>1</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>1</td>
<td>0 1 1 1 0 0 0 0 0 0 0 0 0 0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>0 0 0 0 1 1 1 1 1 1 1 1 1 1</td>
<td></td>
</tr>
</tbody>
</table>

### MCLK = 16.9344 MHz

<table>
<thead>
<tr>
<th>SAMPLING RATE kHz</th>
<th>FILTER TYPE</th>
<th>SAMPLING-RATE CONTROL SETTINGS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>88.2</td>
<td>2</td>
<td>1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td></td>
</tr>
<tr>
<td>44.1</td>
<td>1</td>
<td>1 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td></td>
</tr>
<tr>
<td>8.021</td>
<td>1</td>
<td>1 0 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td></td>
</tr>
<tr>
<td>44.1</td>
<td>2</td>
<td>1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td></td>
</tr>
<tr>
<td>22.05</td>
<td>1</td>
<td>1 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td></td>
</tr>
<tr>
<td>4.0105</td>
<td>1</td>
<td>1 0 1 1 1 1 1 1 1 1 1 1 1 1</td>
<td></td>
</tr>
</tbody>
</table>

---

3-9
### 3.3.3 Digital Filter Characteristics

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DAC Filter Characteristics (48-kHz Sampling Rate)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passband</td>
<td>±0.03 dB</td>
<td>0.416 f_s</td>
<td></td>
<td></td>
<td>Hz</td>
</tr>
<tr>
<td>Stopband</td>
<td>−6 dB</td>
<td>0.5 f_s</td>
<td></td>
<td></td>
<td>Hz</td>
</tr>
<tr>
<td>Passband ripple</td>
<td>±0.03 dB</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stopband attenuation</td>
<td>f &gt; 0.584 f_s</td>
<td>−50</td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td><strong>DAC Filter Characteristics (44.1-kHz Sampling Rate)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passband</td>
<td>±0.03 dB</td>
<td>0.4535 f_s</td>
<td></td>
<td></td>
<td>Hz</td>
</tr>
<tr>
<td>Stopband</td>
<td>−6 dB</td>
<td>0.5 f_s</td>
<td></td>
<td></td>
<td>Hz</td>
</tr>
<tr>
<td>Passband ripple</td>
<td>±0.03 dB</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stopband attenuation</td>
<td>f &gt; 0.5465 f_s</td>
<td>−50</td>
<td></td>
<td></td>
<td>dB</td>
</tr>
</tbody>
</table>

**Figure 3–8. Digital De-Emphasis Filter Response – 44.1 kHz Sampling**
Figure 3-9. Digital De-Emphasis Filter Response – 48 kHz Sampling

Figure 3-10. DAC Digital Filter Response 0: USB Mode

Figure 3-11. DAC Digital Filter Ripple 0: USB Mode
Figure 3–12. DAC Digital Filter Response 1: USB Mode Only

Figure 3–13. DAC Digital Filter Ripple 1: USB Mode Only

Figure 3–14. DAC Digital Filter Response 2: USB Mode and Normal Modes
Figure 3–15. DAC Digital Filter Ripple 2: USB Mode and Normal Modes

Figure 3–16. DAC Digital Filter Response 3: USB Mode Only

Figure 3–17. DAC Digital Filter Ripple 3: USB Mode Only
## PACKAGING INFORMATION

<table>
<thead>
<tr>
<th>Orderable Device</th>
<th>Status</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>Pin Count</th>
<th>Eco Plan</th>
<th>Lead/Ball Finish</th>
<th>MSL Peak Temp</th>
<th>Op Temp (°C)</th>
<th>Device Marking</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLV320DAC23GQE</td>
<td>LIFEBUY</td>
<td>BGA</td>
<td>MICROSTAR JUNIOR</td>
<td>80</td>
<td>360</td>
<td>TBD</td>
<td>SNPB</td>
<td>Level-2A-235C-4 WKS</td>
<td>0 to 0</td>
<td>320DAC23</td>
<td></td>
</tr>
<tr>
<td>TLV320DAC23IPW</td>
<td>ACTIVE</td>
<td>TSSOP</td>
<td>PW</td>
<td>28</td>
<td>50</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>CU NIPDAU</td>
<td>Level-1-260C-UNLIM</td>
<td>-40 to 85</td>
<td>320DAC23I</td>
<td></td>
</tr>
<tr>
<td>TLV320DAC23IPWG4</td>
<td>ACTIVE</td>
<td>TSSOP</td>
<td>PW</td>
<td>28</td>
<td>50</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>CU NIPDAU</td>
<td>Level-1-260C-UNLIM</td>
<td>-40 to 85</td>
<td>320DAC23I</td>
<td></td>
</tr>
<tr>
<td>TLV320DAC23IPWR</td>
<td>ACTIVE</td>
<td>TSSOP</td>
<td>PW</td>
<td>28</td>
<td>2000</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>CU NIPDAU</td>
<td>Level-1-260C-UNLIM</td>
<td>-40 to 85</td>
<td>320DAC23I</td>
<td></td>
</tr>
<tr>
<td>TLV320DAC23IRHD</td>
<td>ACTIVE</td>
<td>VQFN</td>
<td>RHD</td>
<td>28</td>
<td>73</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>CU NIPDAU</td>
<td>Level-2-260C-1 YEAR</td>
<td>-40 to 85</td>
<td>DAC23I</td>
<td></td>
</tr>
<tr>
<td>TLV320DAC23IPW</td>
<td>ACTIVE</td>
<td>TSSOP</td>
<td>PW</td>
<td>28</td>
<td>50</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>CU NIPDAU</td>
<td>Level-1-260C-UNLIM</td>
<td>-10 to 70</td>
<td>320DAC23</td>
<td></td>
</tr>
<tr>
<td>TLV320DAC23IPWR</td>
<td>ACTIVE</td>
<td>TSSOP</td>
<td>PW</td>
<td>28</td>
<td>2000</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>CU NIPDAU</td>
<td>Level-1-260C-UNLIM</td>
<td>-10 to 70</td>
<td>320DAC23</td>
<td></td>
</tr>
<tr>
<td>TLV320DAC23RHD</td>
<td>ACTIVE</td>
<td>VQFN</td>
<td>RHD</td>
<td>28</td>
<td>73</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>CU NIPDAU</td>
<td>Level-2-260C-1 YEAR</td>
<td>-10 to 70</td>
<td>DAC23</td>
<td></td>
</tr>
<tr>
<td>TLV320DAC23RHDRI</td>
<td>ACTIVE</td>
<td>VQFN</td>
<td>RHD</td>
<td>28</td>
<td>3000</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>CU NIPDAU</td>
<td>Level-2-260C-1 YEAR</td>
<td>-10 to 70</td>
<td>DAC23</td>
<td></td>
</tr>
</tbody>
</table>

(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".
- **RoHS Exempt**: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
- **Green**: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(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.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.
## TAPE AND REEL INFORMATION

*All dimensions are nominal*

<table>
<thead>
<tr>
<th>Device</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>SPQ</th>
<th>Reel Diameter (mm)</th>
<th>Reel Width W1 (mm)</th>
<th>A0 (mm)</th>
<th>B0 (mm)</th>
<th>K0 (mm)</th>
<th>P1 (mm)</th>
<th>W (mm)</th>
<th>Pin 1 Quadrant</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLV320DAC23IPWR</td>
<td>TSSOP</td>
<td>PW</td>
<td>28</td>
<td>2000</td>
<td>330.0</td>
<td>16.4</td>
<td>6.9</td>
<td>10.2</td>
<td>1.8</td>
<td>12.0</td>
<td>16.0</td>
<td>Q1</td>
</tr>
<tr>
<td>TLV320DAC23PWR</td>
<td>TSSOP</td>
<td>PW</td>
<td>28</td>
<td>2000</td>
<td>330.0</td>
<td>16.4</td>
<td>6.9</td>
<td>10.2</td>
<td>1.8</td>
<td>12.0</td>
<td>16.0</td>
<td>Q1</td>
</tr>
<tr>
<td>TLV320DAC23RHDR</td>
<td>VQFN</td>
<td>RHD</td>
<td>28</td>
<td>3000</td>
<td>330.0</td>
<td>12.4</td>
<td>5.3</td>
<td>5.3</td>
<td>1.5</td>
<td>8.0</td>
<td>12.0</td>
<td>Q2</td>
</tr>
</tbody>
</table>
## TAPE AND REEL BOX DIMENSIONS

*All dimensions are nominal*

<table>
<thead>
<tr>
<th>Device</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>SPQ</th>
<th>Length (mm)</th>
<th>Width (mm)</th>
<th>Height (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLV320DAC23IPWR</td>
<td>TSSOP</td>
<td>PW</td>
<td>28</td>
<td>2000</td>
<td>350.0</td>
<td>350.0</td>
<td>43.0</td>
</tr>
<tr>
<td>TLV320DAC23PWR</td>
<td>TSSOP</td>
<td>PW</td>
<td>28</td>
<td>2000</td>
<td>350.0</td>
<td>350.0</td>
<td>43.0</td>
</tr>
<tr>
<td>TLV320DAC23RHDR</td>
<td>VQFN</td>
<td>RHD</td>
<td>28</td>
<td>3000</td>
<td>350.0</td>
<td>350.0</td>
<td>43.0</td>
</tr>
</tbody>
</table>

Pack Materials-Page 2
Images above are just a representation of the package family, actual package may vary. Refer to the product data sheet for package details.
NOTES:
A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
B. This drawing is subject to change without notice.
C. QFN (Quad Flatpack No-Lead) Package configuration.
D. The package thermal pad must be soldered to the board for thermal and mechanical performance.
E. See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.
F. Falls within JEDEC MO-220.
THERMAL INFORMATION

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No-Lead (QFN) package and its advantages, refer to Application Report, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at www.ti.com.

The exposed thermal pad dimensions for this package are shown in the following illustration.

NOTE: All linear dimensions are in millimeters.
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. This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, Quad Flat-Pack Packages, Texas Instruments Literature No. SLLA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at www.ti.com <http://www.ti.com>.
E. 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 stencil design considerations.
F. Customers should contact their board fabrication site for recommended solder mask tolerances and via tenting recommendations for vias placed in thermal pad.
NOTES:

A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 each side.
D. Body width does not include interlead flash. Interlead flash shall not exceed 0.25 each side.
E. Falls within JEDEC MO-153
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 design.
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:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Falls within JEDEC MO-225
IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to TI's Terms of Sale (www.ti.com/legal/termsofsale.html) or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2019, Texas Instruments Incorporated