

SLES023B – DECEMBER 2001 – REVISED MARCH 2002

## SINGLE-ENDED ANALOG-INPUT 24-BIT, 96-kHz STEREO A/D CONVERTER

### FEATURES

- 24-Bit Delta-Sigma Stereo A/D Converter
- Single-Ended Voltage Input: 3 V p-p
- Antialiasing Filter Included
- Oversampling Decimation Filter
  - Oversampling Frequency:  $\times 64$ ,  $\times 128$
  - Passband Ripple:  $\pm 0.05$  dB
  - Stopband Attenuation:  $-65$  dB
  - On-Chip HPF (Low Cut Filter): 0.84 Hz (44.1 kHz)
- High Performance
  - THD+N: 96 dB (Typical)
  - SNR: 105 dB (Typical)
  - Dynamic Range: 105 dB (Typical)
- PCM Audio Interface
  - Master/Slave Mode Selectable
  - Data Formats: 24-Bit Left-Justified; 24-Bit  $I^2S$ ; 20-, 24-Bit Right-Justified
- Sampling Rate: 16 kHz to 96 kHz
- System Clock: 256 f<sub>S</sub>, 384 f<sub>S</sub>, 512 f<sub>S</sub>, 768 f<sub>S</sub>
- Dual Power Supplies: 5 V for Analog, 3.3 V for Digital
- Package: 20-Pin SSOP
- Lead-Free Product

### APPLICATIONS

- AV Amp Receiver
- MD Player
- CD Recorder
- Multitrack Receiver
- Electric Musical Instrument

### DESCRIPTION

The PCM1802 is a high-performance, low-cost, single-chip stereo analog-to-digital converter with single-ended analog voltage input. The PCM1802 uses a delta-sigma modulator with 64- or 128-times oversampling, and includes a digital decimation filter and HPF (low cut filter) which removes the dc component of the input signal. For various applications, the PCM1802 supports master and slave modes and four data formats in serial interface. The PCM1802 is suitable for a wide variety of cost-sensitive consumer applications where good performance, 5-V analog supply, and 3.3-V digital supply operation is required. The PCM1802 is fabricated using a highly advanced CMOS process and is available in the DB 20-pin SSOP package.



This device contains circuits to protect its inputs and outputs against damage due to high static voltages or electrostatic fields. These circuits have been qualified to protect this device against electrostatic discharges (ESD) of up to 2 kV according to MIL-STD-883C, Method 3015; however, it is advised that precautions be taken to avoid application of any voltage higher than maximum-rated voltages to these high-impedance circuits. During storage or handling, the device leads should be shorted together or the device should be placed in conductive foam. In a circuit, unused inputs should always be connected to an appropriated logic voltage level, preferably either V<sub>CC</sub> or ground. Specific guidelines for handling devices of this type are contained in the publication *Guidelines for Handling Electrostatic-Discharge-Sensitive (ESDS) Devices and Assemblies* available from Texas Instruments.



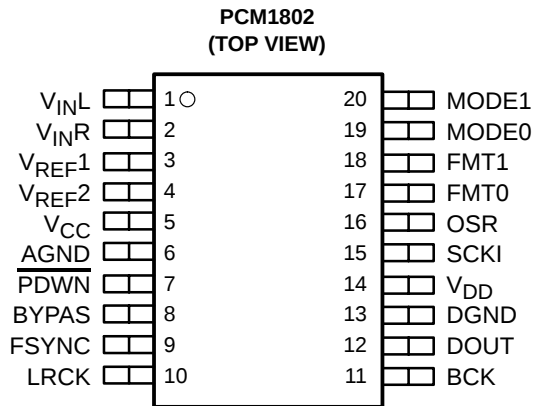
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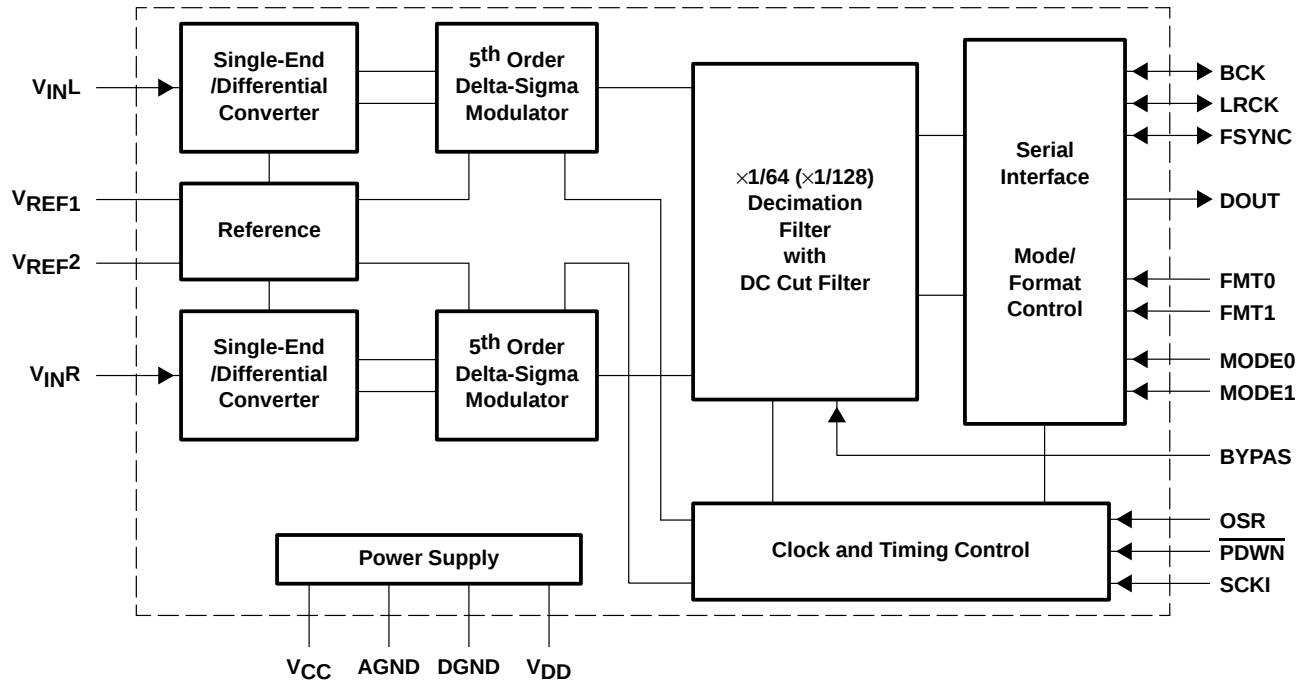
PRODUCTION DATA information is current as of publication date.  
Products conform to specifications per the terms of Texas Instruments  
standard warranty. Production processing does not necessarily include  
testing of all parameters.

| PACKAGE/ORDERING INFORMATION |              |              |                             |                 |                 |                 |
|------------------------------|--------------|--------------|-----------------------------|-----------------|-----------------|-----------------|
| PRODUCT                      | PACKAGE      | PACKAGE CODE | OPERATION TEMPERATURE RANGE | PACKAGE MARKING | ORDERING NUMBER | TRANSPORT MEDIA |
| PCM1802DB                    | 20-Lead SSOP | 20DB         | –40°C to 85°C               | PCM1802         | PCM1802DB       | Tube            |
|                              |              |              |                             |                 | PCM1802DBR      | Tape and reel   |

pin assignments



block diagram



## Terminal Functions

| TERMINAL<br>NAME  | PIN | I/O | DESCRIPTIONS                                                                            |
|-------------------|-----|-----|-----------------------------------------------------------------------------------------|
| AGND              | 6   | –   | Analog GND                                                                              |
| BCK               | 11  | I/O | Bit clock input/output <sup>‡</sup>                                                     |
| BYPAS             | 8   | I   | HPF bypass control. Low: normal mode (dc cut); High: bypass mode (through) <sup>†</sup> |
| DGND              | 13  | –   | Digital GND                                                                             |
| DOUT              | 12  | O   | Audio data output                                                                       |
| FMT0              | 17  | I   | Audio data format select 0. See <i>data format</i> <sup>†</sup>                         |
| FMT1              | 18  | I   | Audio data format select 1. See <i>data format</i> <sup>†</sup>                         |
| FSYNC             | 9   | I/O | Frame synchronous clock input/output <sup>‡</sup>                                       |
| LRCK              | 10  | I/O | Sampling clock input/output <sup>‡</sup>                                                |
| MODE0             | 19  | I   | Mode select 0. See <i>interface mode</i> <sup>†</sup>                                   |
| MODE1             | 20  | I   | Mode select 1. See <i>interface mode</i> <sup>†</sup>                                   |
| OSR               | 16  | I   | Oversampling ratio select. Low: $\times 64 f_S$ ; High: $\times 128 f_S$ <sup>†</sup>   |
| PDWN              | 7   | I   | Power-down control, active low <sup>†</sup>                                             |
| SCKI              | 15  | I   | System clock input; 256 $f_S$ , 384 $f_S$ , 512 $f_S$ or 768 $f_S$ <sup>§</sup>         |
| V <sub>CC</sub>   | 5   | –   | Analog power supply, 5 V                                                                |
| V <sub>DD</sub>   | 14  | –   | Digital power supply, 3.3 V                                                             |
| V <sub>INL</sub>  | 1   | I   | Analog input, L-channel                                                                 |
| V <sub>INR</sub>  | 2   | I   | Analog input, R-channel                                                                 |
| V <sub>REF1</sub> | 3   | –   | Reference 1 decoupling capacitor                                                        |
| V <sub>REF2</sub> | 4   | –   | Reference 2 voltage input, normally connected to V <sub>CC</sub>                        |

<sup>†</sup> Schmitt-trigger input with internal pulldown (50 k $\Omega$  typically), 5-V tolerant

<sup>‡</sup> Schmitt-trigger input

<sup>§</sup> Schmitt-trigger input, 5-V tolerant

absolute maximum ratings over operating free-air temperature (unless otherwise noted)<sup>††</sup>

|                                                                                                   |                                     |
|---------------------------------------------------------------------------------------------------|-------------------------------------|
| Supply voltage: V <sub>CC</sub>                                                                   | 6.5 V                               |
| V <sub>DD</sub>                                                                                   | 4.0 V                               |
| Ground voltage differences: AGND, DGND                                                            | $\pm 0.1$ V                         |
| Digital input voltage: FSYNC, LRCK, BCK, DOUT                                                     | –0.3 V to (V <sub>DD</sub> + 0.3 V) |
| PDWN, BYPAS, SCKI, OSR, FMT0, FMT1, MODE0, MODE1                                                  | –0.3 V to 6.5 V                     |
| Analog input voltage: V <sub>INL</sub> , V <sub>INR</sub> , V <sub>REF1</sub> , V <sub>REF2</sub> | –0.3 V to (V <sub>CC</sub> + 0.3 V) |
| Input current (any pins except supplies)                                                          | $\pm 10$ mA                         |
| Ambient temperature under bias                                                                    | –40°C to 125°C                      |
| Storage temperature                                                                               | –55°C to 150°C                      |
| Junction temperature                                                                              | 150°C                               |
| Lead temperature (soldering)                                                                      | 260°C, 5 s                          |
| Package temperature (IR reflow, peak)                                                             | 260°C                               |

<sup>††</sup> 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.

electrical characteristics, all specifications at  $T_A = 25^\circ\text{C}$ ,  $V_{CC} = 5\text{ V}$ ,  $V_{DD} = 3.3\text{ V}$ , master mode,  $f_S = 44.1\text{ kHz}$ , system clock =  $384 f_S$ , over sampling ratio =  $\times 128$ , 24-bit data (unless otherwise noted)

|                                  |                    | TEST CONDITIONS         | PCM1802DB                                         |         |                 | UNIT |     |
|----------------------------------|--------------------|-------------------------|---------------------------------------------------|---------|-----------------|------|-----|
|                                  |                    |                         | MIN                                               | TYP     | MAX             |      |     |
| Resolution                       |                    |                         | 24                                                |         |                 | bits |     |
| DATA FORMAT                      |                    |                         |                                                   |         |                 |      |     |
| Audio data interface format      |                    |                         | Left justified, I <sup>2</sup> S, right justified |         |                 |      |     |
| Audio data bit length            |                    |                         | 20, 24                                            |         |                 | bits |     |
| Audio data format                |                    |                         | MSB first, 2s complement                          |         |                 |      |     |
| f <sub>S</sub>                   | Sampling frequency |                         | 16                                                | 44.1    | 96              | kHz  |     |
| System clock frequency           |                    | 256 f <sub>S</sub>      | 4.096                                             | 11.2896 | 24.576          | MHz  |     |
|                                  |                    | 384 f <sub>S</sub>      | 6.144                                             | 16.9344 | 36.864          |      |     |
|                                  |                    | 512 f <sub>S</sub>      | 8.192                                             | 22.5792 | 49.152          |      |     |
|                                  |                    | 768 f <sub>S</sub>      | 12.288                                            | 33.8688 |                 |      |     |
| INPUT LOGIC                      |                    |                         |                                                   |         |                 |      |     |
| V <sub>IH</sub>                  | See Note 1         | Input logic level       | 2                                                 |         | V <sub>DD</sub> | VDC  |     |
| V <sub>IL</sub>                  |                    |                         | 0                                                 |         | 0.8             |      |     |
| V <sub>IH</sub>                  | See Note 2         |                         | 2                                                 |         | 5.5             |      |     |
| V <sub>IL</sub>                  |                    |                         | 0                                                 |         | 0.8             |      |     |
| I <sub>IH</sub>                  | See Note 3         | Input logic current     | V <sub>IN</sub> = V <sub>DD</sub>                 |         | ±10             | μA   |     |
| I <sub>IL</sub>                  |                    |                         | V <sub>IN</sub> = 0 V                             |         | ±10             |      |     |
| I <sub>IH</sub>                  | See Note 4         |                         | V <sub>IN</sub> = V <sub>DD</sub>                 |         | 65              |      | 100 |
| I <sub>IL</sub>                  |                    |                         | V <sub>IN</sub> = 0 V                             |         |                 |      | ±10 |
| OUTPUT LOGIC                     |                    |                         |                                                   |         |                 |      |     |
| V <sub>OH</sub>                  | See Note 5         | Output logic level      | I <sub>OUT</sub> = −1 mA                          |         | 2.8             | VDC  |     |
| V <sub>OL</sub>                  |                    |                         | I <sub>OUT</sub> = 1 mA                           |         | 0.5             |      |     |
| DC ACCURACY                      |                    |                         |                                                   |         |                 |      |     |
| Gain mismatch channel-to-channel |                    |                         | ±1                                                |         | ±4              | %FSR |     |
| Gain error                       |                    |                         | ±2                                                |         | ±6              | %FSR |     |
| Bipolar zero error               |                    | LCF bypass (see Note 6) | ±2                                                |         |                 | %FSR |     |

- NOTES: 1. Pins 9–11: FSYNC, LRCK, BCK (Schmitt-trigger input, in slave mode)  
 2. Pins 7–8, 15–20: PDWN, BYPAS, SCKI, OSR, FMT0, FMT1, MODE0, MODE1 (Schmitt-trigger input, 5-V tolerant).  
 3. Pins 9–11, 15: FSYNC, LRCK, BCK (Schmitt-trigger input in slave mode), SCKI (Schmitt-trigger input).  
 4. Pins 7–8, 16–20: PDWN, BYPAS, OSR, FMT0, FMT1, MODE0, MODE1 (Schmitt-trigger input, with 50-k $\Omega$  typical pulldown resistor).  
 5. Pins 9–12: FSYNC, LRCK, BCK (in master mode), DOUT  
 6. Low cut filter

electrical characteristics, all specifications at  $T_A = 25^\circ\text{C}$ ,  $V_{CC} = 5\text{ V}$ ,  $V_{DD} = 3.3\text{ V}$ , master mode,  $f_S = 44.1\text{ kHz}$ , system clock =  $384 f_S$ , over sampling ratio =  $\times 128$ , 24-bit data (unless otherwise noted) (continued)

|                                        |                               | TEST CONDITIONS                                                                      | PCM1802DB            |     |        | UNIT             |
|----------------------------------------|-------------------------------|--------------------------------------------------------------------------------------|----------------------|-----|--------|------------------|
|                                        |                               |                                                                                      | MIN                  | TYP | MAX    |                  |
| DYNAMIC PERFORMANCE (see Note 7)       |                               |                                                                                      |                      |     |        |                  |
| THD+N (V <sub>IN</sub> = −0.5 dB)      |                               | f <sub>S</sub> = 44.1 kHz                                                            | 0.0015%              |     | 0.003% |                  |
|                                        |                               | f <sub>S</sub> = 96 kHz (see Note 8)                                                 | 0.0025%              |     |        |                  |
| THD+N (V <sub>IN</sub> = −60 dB)       |                               | f <sub>S</sub> = 44.1 kHz                                                            | 0.7%                 |     |        |                  |
|                                        |                               | f <sub>S</sub> = 96 kHz (see Note 8)                                                 | 1.2%                 |     |        |                  |
| Dynamic range                          |                               | f <sub>S</sub> = 44.1 kHz, A-weighted                                                | 100                  | 105 | dB     |                  |
|                                        |                               | f <sub>S</sub> = 96 kHz, A-weighted (see Note 8)                                     | 103                  |     |        |                  |
| S/N ratio                              |                               | f <sub>S</sub> = 44.1 kHz, A-weighted                                                | 100                  | 105 | dB     |                  |
|                                        |                               | f <sub>S</sub> = 96 kHz, A-weighted (see Note 8)                                     | 103                  |     |        |                  |
| Channel separation                     |                               | f <sub>S</sub> = 44.1 kHz                                                            | 96                   | 103 | dB     |                  |
|                                        |                               | f <sub>S</sub> = 96 kHz (see Note 8)                                                 | 98                   |     |        |                  |
| ANALOG INPUT                           |                               |                                                                                      |                      |     |        |                  |
| Input voltage                          |                               |                                                                                      | 0.6 V <sub>CC</sub>  |     |        | V <sub>p–p</sub> |
| Center voltage (V <sub>REF1</sub> )    |                               |                                                                                      | 0.5 V <sub>CC</sub>  |     |        | V                |
| Input impedance                        |                               |                                                                                      | 20                   |     |        | kΩ               |
| Antialiasing filter frequency response |                               | −3 dB                                                                                | 300                  |     |        | kHz              |
| DIGITAL FILTER PERFORMANCE             |                               |                                                                                      |                      |     |        |                  |
| Passband                               |                               |                                                                                      | 0.454 f <sub>S</sub> |     |        | Hz               |
| Stopband                               |                               |                                                                                      | 0.583 f <sub>S</sub> |     |        | Hz               |
| Passband ripple                        |                               |                                                                                      | ±0.05                |     |        | dB               |
| Stopband attenuation                   |                               |                                                                                      | −65                  |     |        | dB               |
| Delay time                             |                               |                                                                                      | 17.4/f <sub>S</sub>  |     |        | s                |
| HPF frequency response                 |                               | −3 dB                                                                                | 0.019 f <sub>S</sub> |     |        | mHz              |
| POWER SUPPLY REQUIREMENTS              |                               |                                                                                      |                      |     |        |                  |
| V <sub>CC</sub>                        | Voltage range                 |                                                                                      | 4.5                  | 5   | 5.5    | VDC              |
| V <sub>DD</sub>                        |                               |                                                                                      | 2.7                  | 3.3 | 3.6    |                  |
| I <sub>CC</sub>                        | Supply current (see Note 9)   | V <sub>CC</sub> = 5 V, V <sub>DD</sub> = 3.3 V                                       | 24                   |     | 30     | mA               |
| I <sub>DD</sub>                        |                               | f <sub>S</sub> = 44.1 kHz V <sub>CC</sub> = 5 V, V <sub>DD</sub> = 3.3 V             | 8.3                  |     | 10     |                  |
|                                        |                               | f <sub>S</sub> = 96 kHz, V <sub>CC</sub> = 5 V, V <sub>DD</sub> = 3.3 V (see Note 8) | 17                   |     |        |                  |
| P <sub>D</sub>                         | Power dissipation; operation  | f <sub>S</sub> = 44.1 kHz, V <sub>CC</sub> = 5 V, V <sub>DD</sub> = 3.3 V            | 147                  |     | 183    | mW               |
|                                        |                               | f <sub>S</sub> = 96 kHz, V <sub>CC</sub> = 5 V, V <sub>DD</sub> = 3.3 V (see Note 8) | 176                  |     |        |                  |
|                                        | Power dissipation; power down | V <sub>CC</sub> = 5 V, V <sub>DD</sub> = 3.3 V                                       | 0.5                  |     |        | mW               |
| TEMPERATURE RANGE                      |                               |                                                                                      |                      |     |        |                  |
| Operation temperature                  |                               |                                                                                      | −40                  |     | 85     | °C               |
| Thermal resistance (θ <sub>JA</sub> )  |                               | 20-pin SSOP                                                                          | 115                  |     |        | °C/W             |

NOTES: 7. Analog performance specs are tested with System Two™ audio measurement system by Audio Precision™, using 400-Hz HPF, 20-kHz LPF at 44.1-kHz operation, 40-kHz LPF at 96-kHz operation in RMS mode.

8.  $f_S = 96\text{ kHz}$ , system clock =  $256 f_S$ , oversampling ratio =  $\times 64$ .

9. Minimum load on DOUT (pin 12), BCK (pin 11), LRCK (pin 10), FSYNC (pin 9).

## TYPICAL PERFORMANCE CURVES OF INTERNAL FILTER

digital filter—decimation filter frequency response

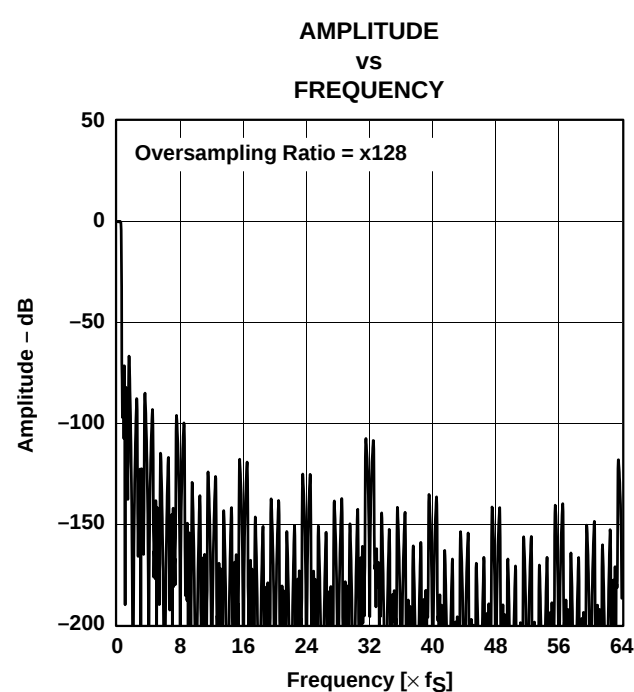


Figure 1. Overall Characteristics

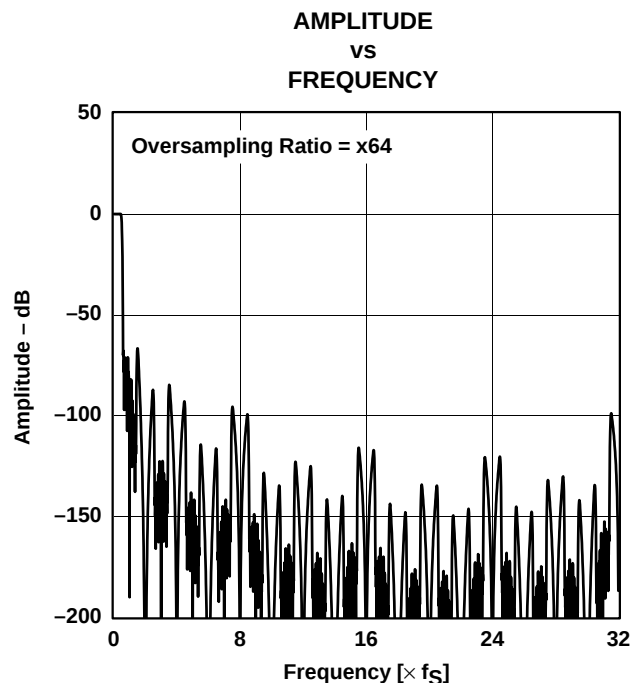


Figure 2. Overall Characteristics

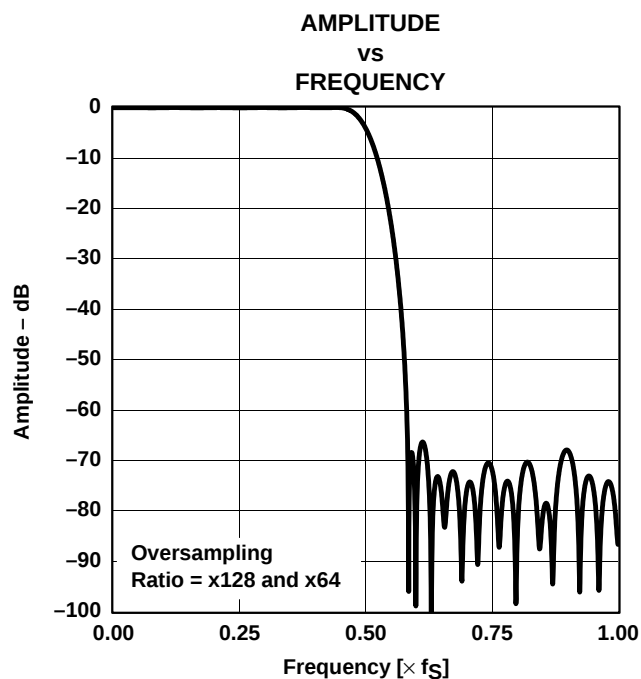


Figure 3. Stopband Attenuation Characteristics

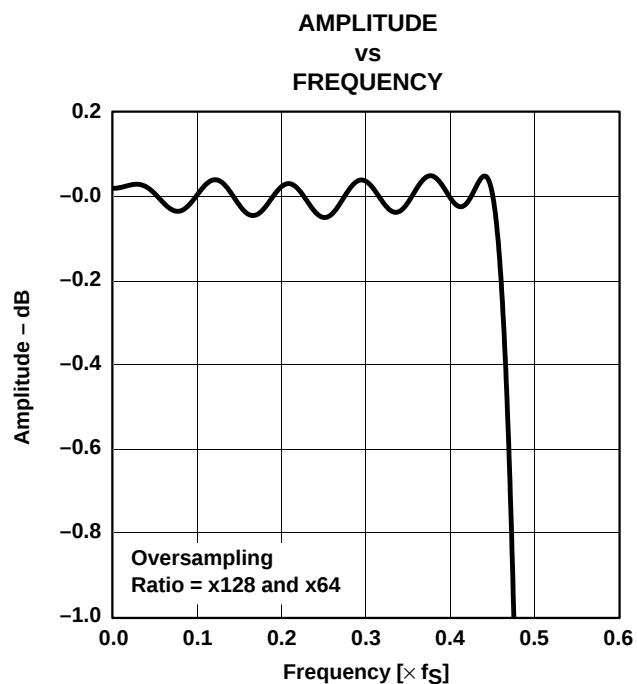


Figure 4. Passband Ripple Characteristics

All specifications at  $T_A = 25^\circ\text{C}$ ,  $V_{CC} = 5\text{ V}$ ,  $V_{DD} = 3.3\text{ V}$ , master mode,  $f_s = 44.1\text{ kHz}$ , system clock =  $384 f_s$ , oversampling ratio =  $\times 128$ , 24-bit data, unless otherwise noted.

## TYPICAL PERFORMANCE CURVES OF INTERNAL FILTER

## HPF (low cut filter) frequency response

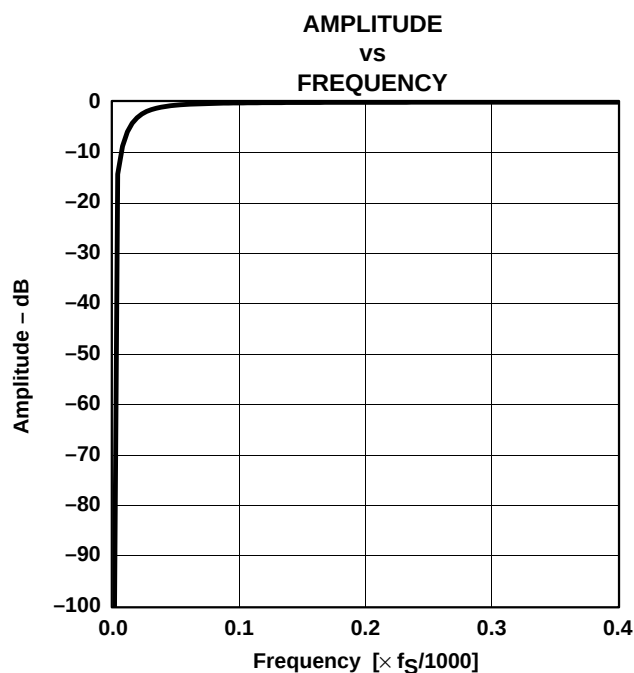


Figure 5. LCF Stopband Characteristics

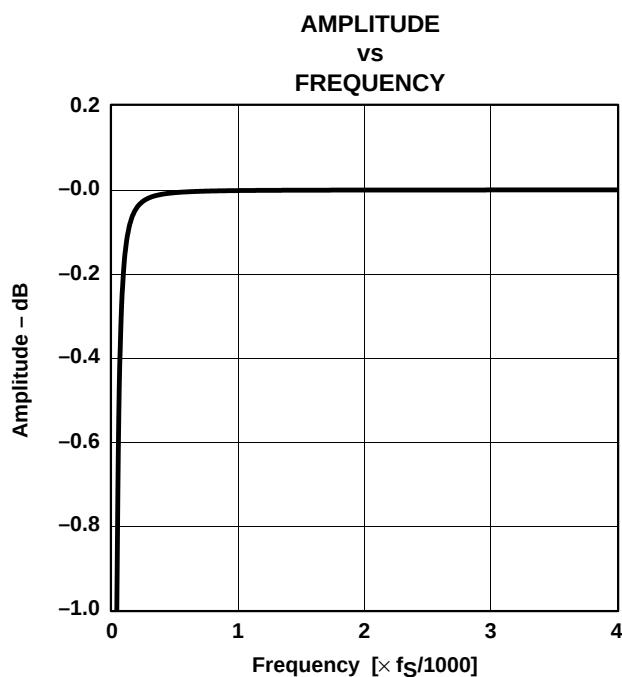


Figure 6. LCF Passband Characteristics

## analog filter—antialiasing filter frequency response

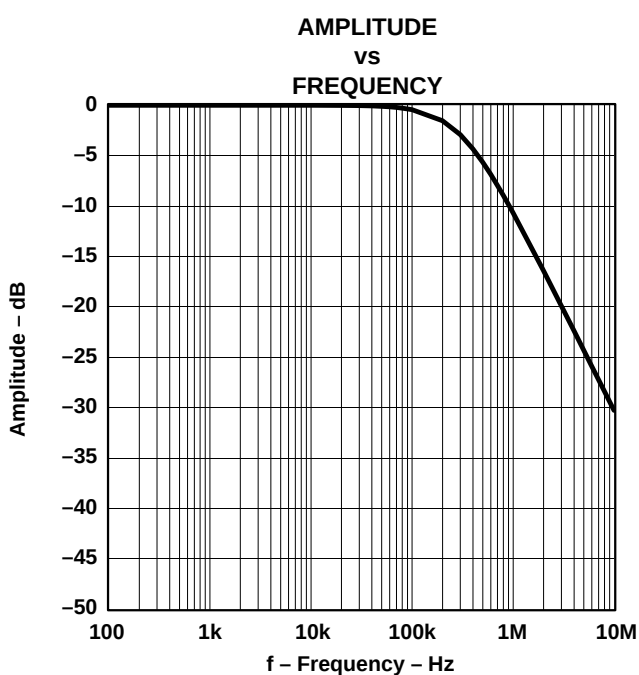


Figure 7. Antialias Filter Stopband Characteristics

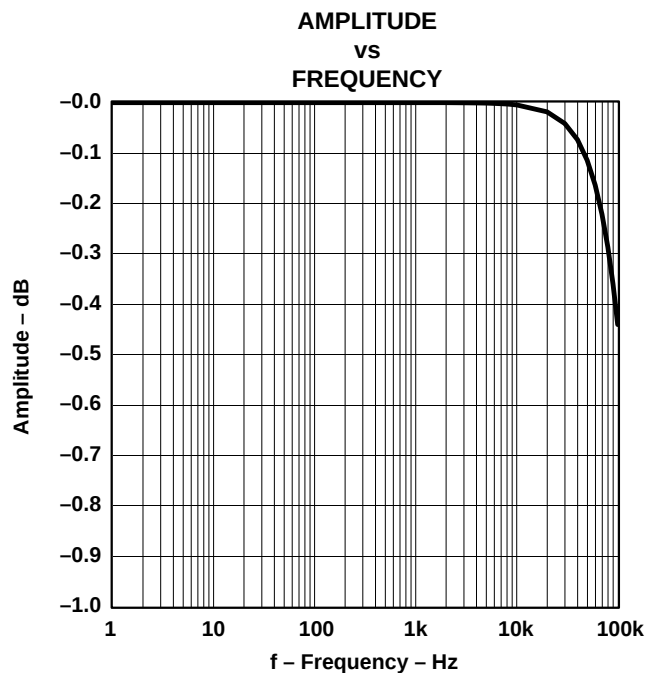


Figure 8. Antialias Filter Passband Characteristics

All specifications at  $T_A = 25^\circ\text{C}$ ,  $V_{CC} = 5\text{ V}$ ,  $V_{DD} = 3.3\text{ V}$ , master mode,  $f_S = 44.1\text{ kHz}$ , system clock =  $384 f_S$ , oversampling ratio =  $\times 128$ , 24-bit data, unless otherwise noted.

TYPICAL PERFORMANCE CURVES

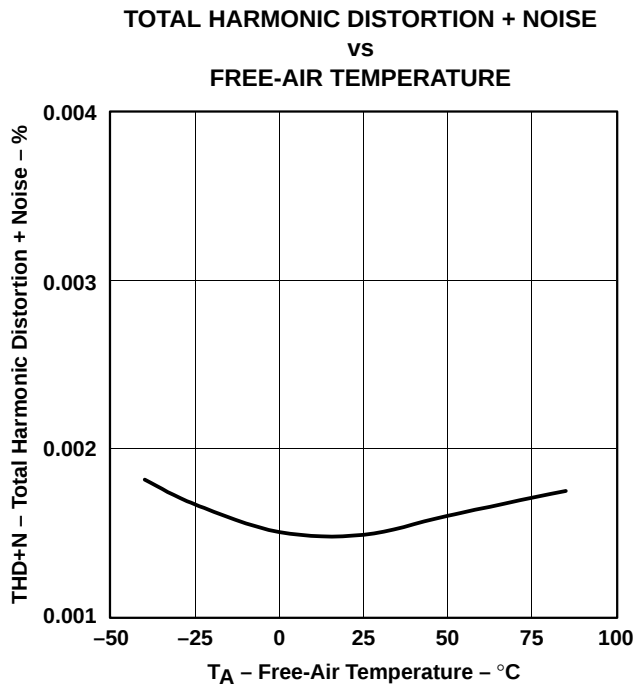


Figure 9

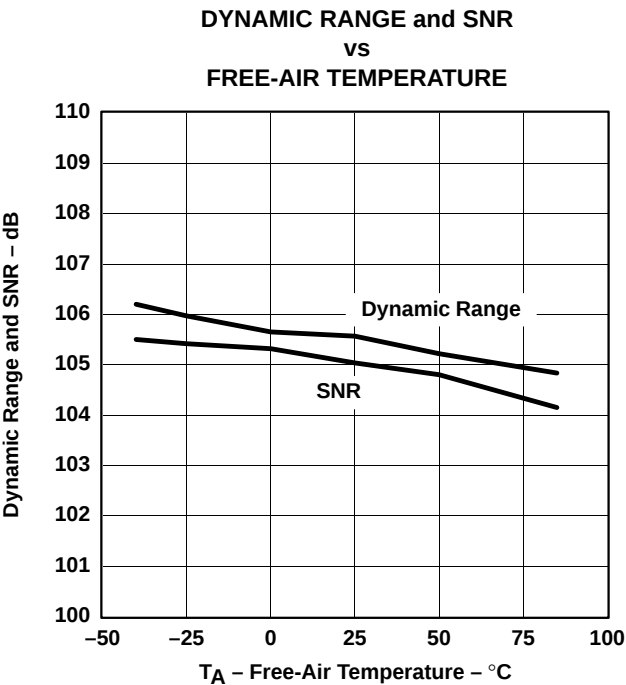


Figure 10

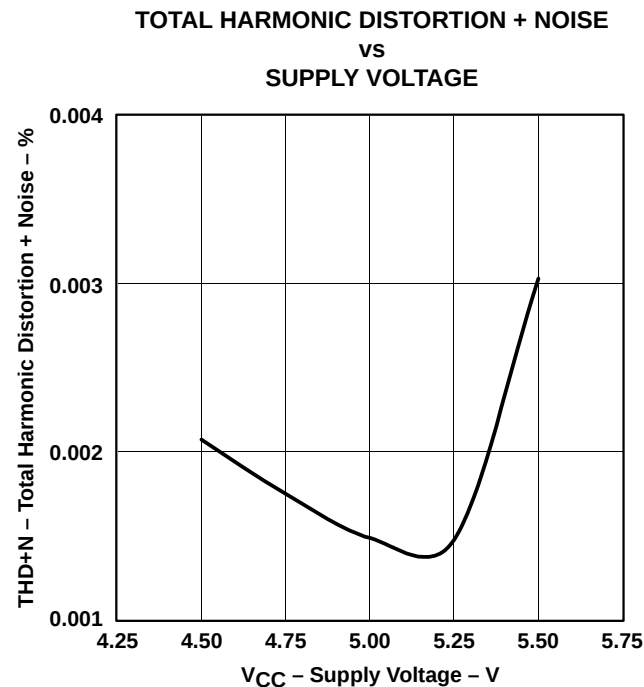


Figure 11

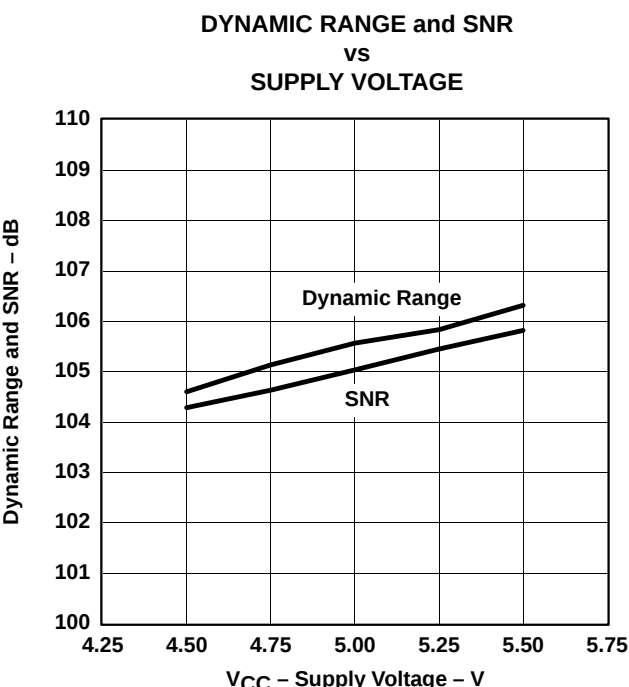


Figure 12

All specifications at T<sub>A</sub> = 25°C, V<sub>CC</sub> = 5.0 V, V<sub>DD</sub> = 3.3 V, master mode, f<sub>S</sub> = 44.1 kHz, system clock = 384 f<sub>S</sub>, oversampling ratio = ×128, 24-bit data, unless otherwise noted.

## TYPICAL PERFORMANCE CURVES

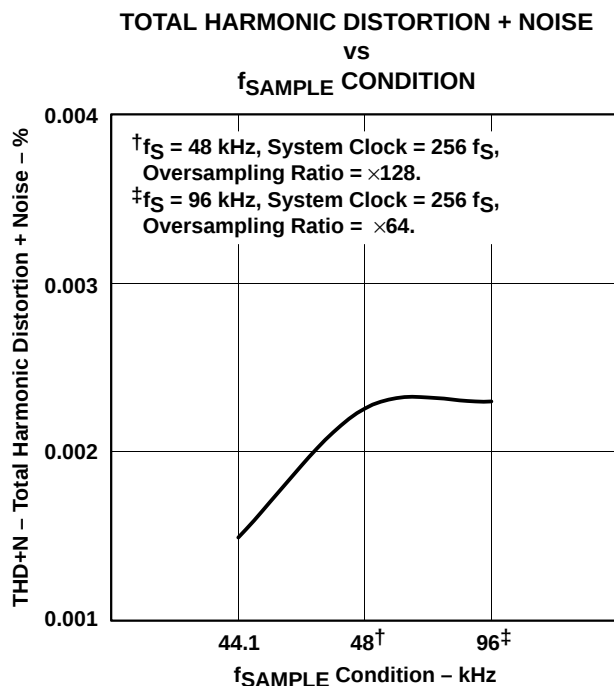


Figure 13

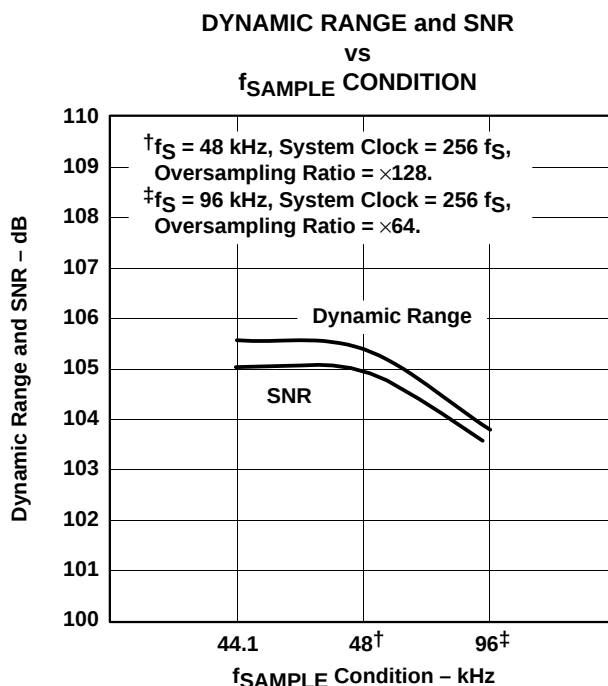


Figure 14

## output spectrum

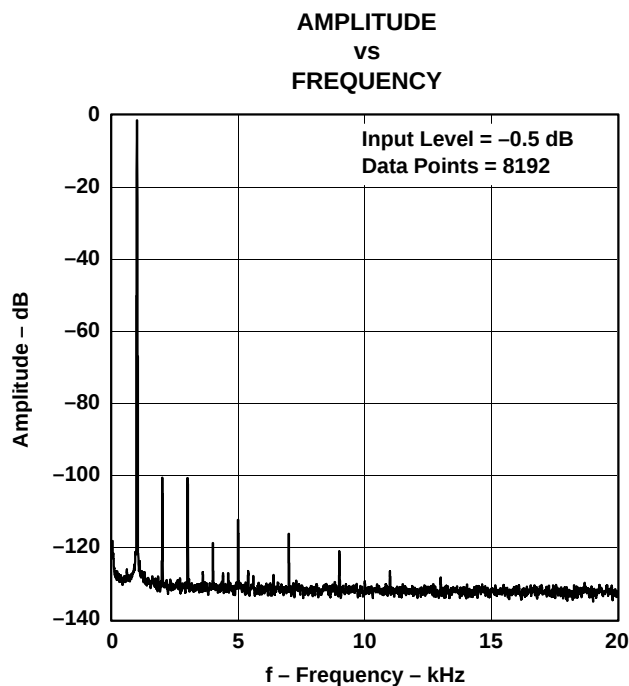


Figure 15

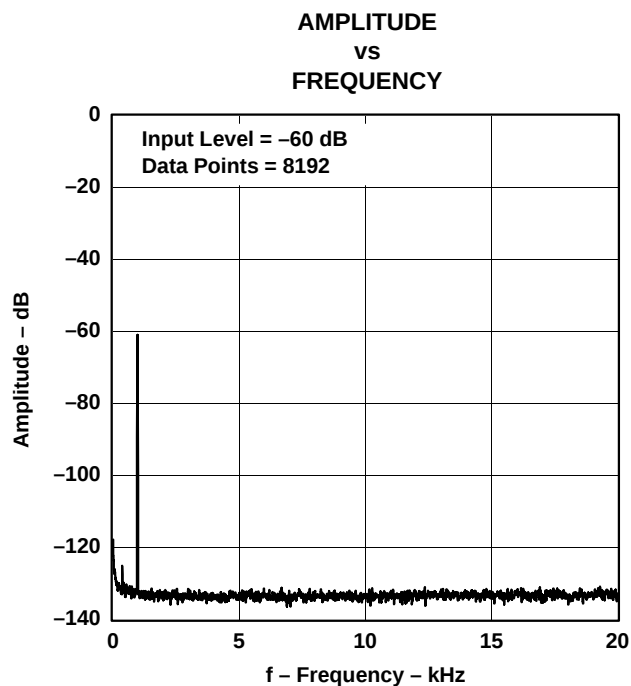


Figure 16

All specifications at T<sub>A</sub> = 25°C, V<sub>CC</sub> = 5 V, V<sub>DD</sub> = 3.3 V, master mode, f<sub>S</sub> = 44.1 kHz, system clock = 384 f<sub>S</sub>, oversampling ratio = ×128, 24-bit data, unless otherwise noted.

TYPICAL PERFORMANCE CURVES  
TOTAL HARMONIC DISTORTION + NOISE  
VS  
SIGNAL LEVEL

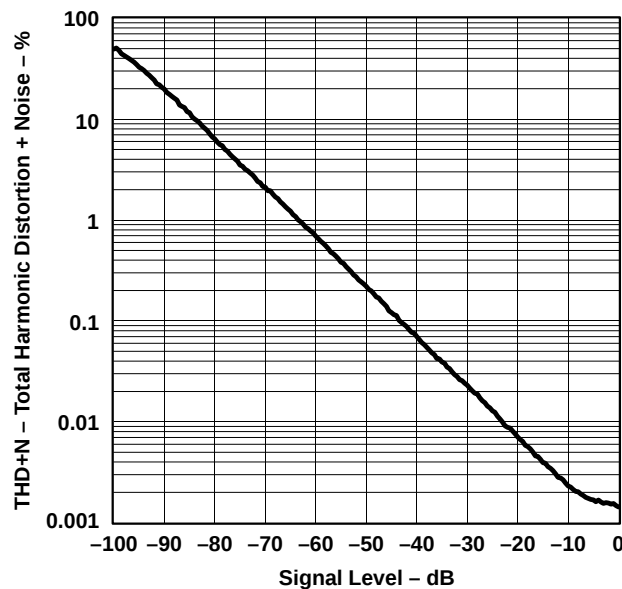


Figure 17

supply current

SUPPLY CURRENT  
VS  
f<sub>SAMPLE</sub> CONDITION

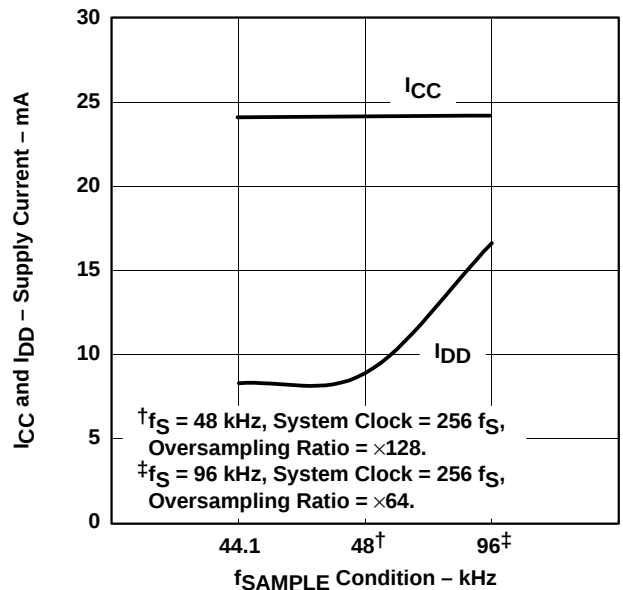


Figure 18

All specifications at T<sub>A</sub> = +25°C, V<sub>CC</sub> = 5 V, V<sub>DD</sub> = 3.3 V, Master Mode, f<sub>S</sub> = 44.1 kHz, system clock = 384f<sub>S</sub>, oversampling ratio = ×128, 24-bit data, unless otherwise noted.

## PRINCIPLES OF OPERATION

PCM1802 consists of a reference circuit, two channels of single-ended-to-differential converter, fifth-order delta-sigma modulator with full differential architecture, decimation filter with low cut filter, and a serial interface circuit. Figure 19 illustrates the total architecture of PCM1802, Figure 20 illustrates the architecture of single-ended-to-differential converter and antialiasing filter, and Figure 21 illustrates the block diagram of fifth-order delta-sigma modulator and transfer function. An on-chip high-precision reference with one external capacitor provides all reference voltages that are needed in the PCM1802, and defines the full scale voltage range for both channels. On-chip single-ended-to-differential signal converters save the design, space, and extra parts cost for external signal converters. Full differential architecture provides a wide dynamic range and excellent power supply rejection performance. The input signal is sampled at a  $\times 64$  or  $\times 128$  oversampling rate, thus eliminating an external sample-and-hold amplifier. A fifth-order delta-sigma noise shaper, which consists of five integrators using the switched capacitor technique and a comparator, shapes the quantization noise generated by the comparator and 1-bit DAC outside of the audio signal band. The high-order delta-sigma modulation randomizes the modulator outputs and reduces the idle tone level. The  $64\text{-}f_s$  or  $128\text{-}f_s$ , 1-bit stream from the delta-sigma modulator is converted to a  $1\text{-}f_s$ , 24-bit or 20-bit digital signal by removing high-frequency noise components with a decimation filter. The dc component of the signal is removed by the LCF, and the LCF output is converted to a time-multiplexed serial signal through the serial interface, which provides flexible serial formats.

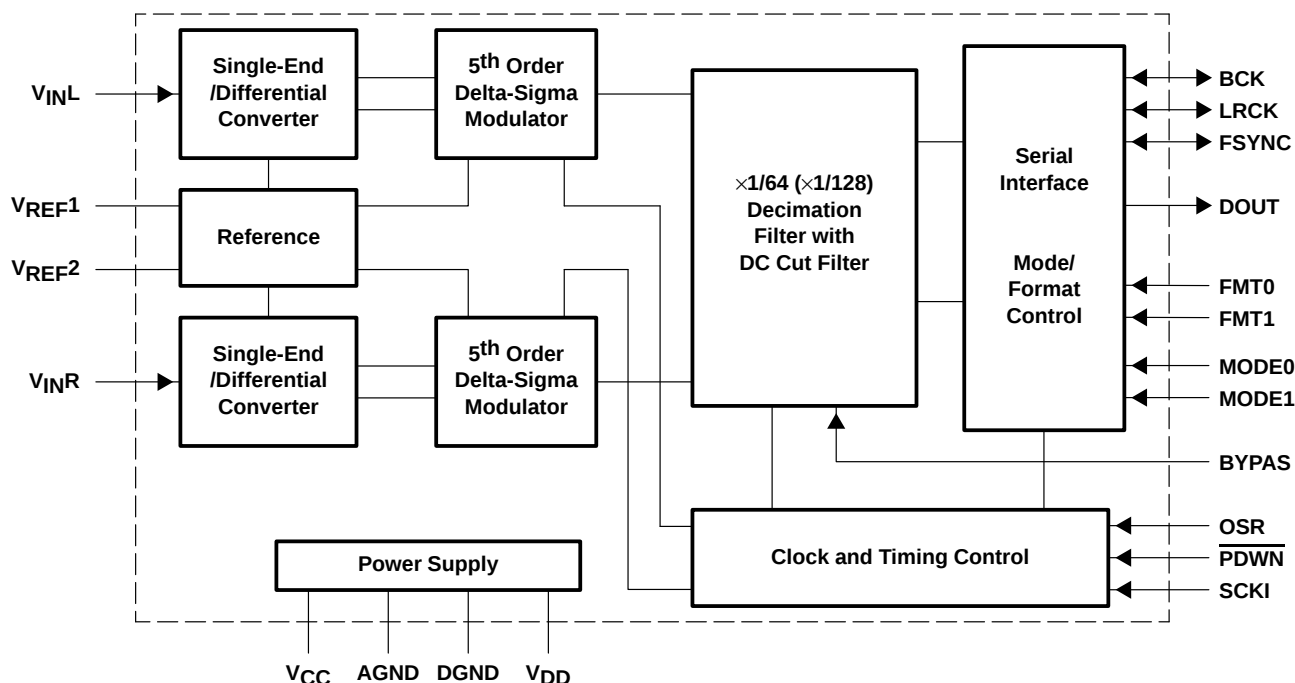
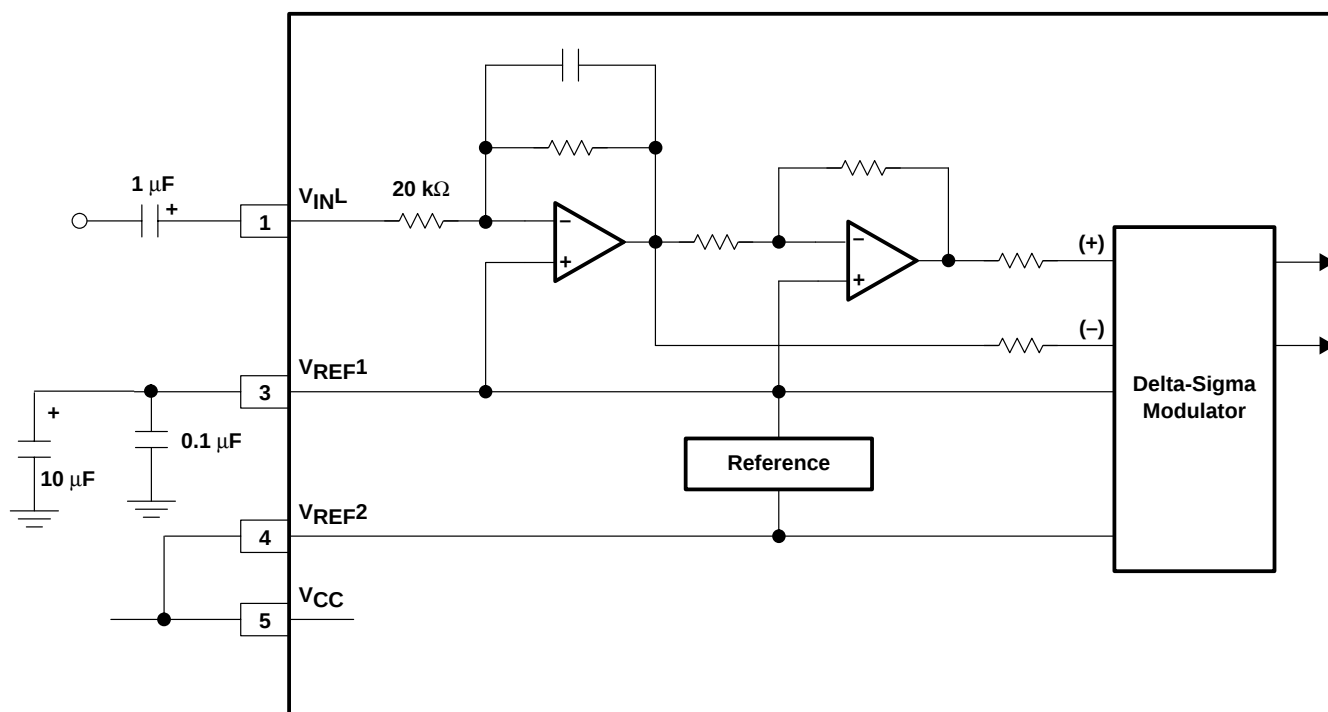
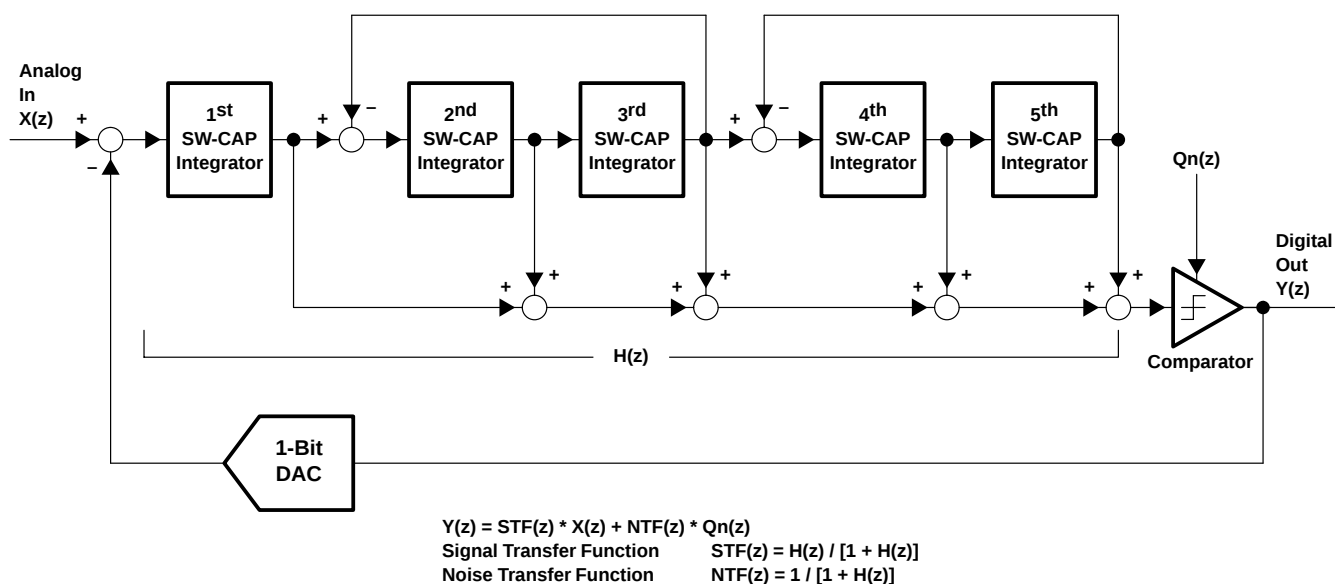


Figure 19. Block Diagram

## PRINCIPLES OF OPERATION



**Figure 20. Analog Front End (Left Channel)**



**Figure 21. Block Diagram of Fifth-Order Delta-Sigma Modulator**

## PRINCIPLES OF OPERATION

### system clock

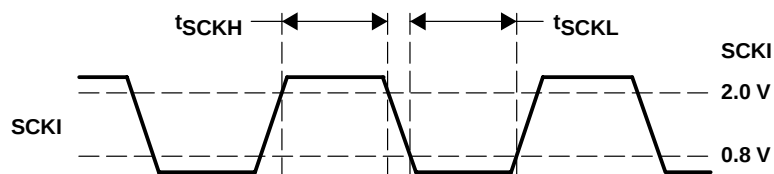
The PCM1802 supports  $256 f_S$ ,  $384 f_S$ ,  $512 f_S$ , and  $768 f_S$  as the system clock, where  $f_S$  is the audio sampling frequency. The system clock must be supplied on SCKI (pin 15).

The PCM1802 has a system clock detection circuit which automatically senses if the system clock is operating at  $256 f_S$ ,  $384 f_S$ ,  $512 f_S$ , or  $768 f_S$  in slave mode. In master mode, the system clock frequency must be selected by MODE0 (pin 19) and MODE1 (pin 20), and  $768 f_S$  is not available. For system clock inputs of  $384 f_S$ ,  $512 f_S$ , and  $768 f_S$ , the system clock is divided to  $256 f_S$  automatically, and the  $256 f_S$  clock is used to operate the delta-sigma modulator and the digital filter.

Table 1 shows the relationship of typical sampling frequencies and system clock frequencies, and Figure 22 shows system clock timing.

**Table 1. Sampling Frequency and System Clock Frequency**

| SAMPLING RATE<br>FREQUENCY<br>(kHz) | SYSTEM CLOCK FREQUENCY (MHz) |           |           |           |
|-------------------------------------|------------------------------|-----------|-----------|-----------|
|                                     | $256 f_S$                    | $384 f_S$ | $512 f_S$ | $768 f_S$ |
| 32                                  | 8.192                        | 12.288    | 16.384    | 24.576    |
| 44.1                                | 11.2896                      | 16.9344   | 22.5792   | 33.8688   |
| 48                                  | 12.288                       | 18.432    | 24.576    | 36.864    |
| 64                                  | 16.384                       | 24.576    | 32.768    | 49.152    |
| 88.2                                | 22.5792                      | 33.8688   | 45.1584   | —         |
| 96                                  | 24.576                       | 36.864    | 49.152    | —         |



| PARAMETER  |                                | MIN | MAX | UNIT |
|------------|--------------------------------|-----|-----|------|
| $t_{SCKH}$ | System clock pulse width, high | 7   |     | ns   |
| $t_{SCKL}$ | System clock pulse width, low  | 7   |     | ns   |

**Figure 22. System Clock Timing**

## PRINCIPLES OF OPERATION

### power-on reset sequence

The PCM1802 has an internal power-on reset circuit and initialization (reset) is performed automatically when the power supply ( $V_{DD}$ ) exceeds 2.2 V (typ). While  $V_{DD} < 2.2$  V (typ), and for 1024 system-clock counts after  $V_{DD} > 2.2$  V (typ), the PCM1802 stays in the reset state and the digital output is forced to zero. The digital output is valid after the reset state is released and the time of  $4480/f_S$  has passed. Figure 23 illustrates the internal power-on reset timing and the digital output for power-on reset.

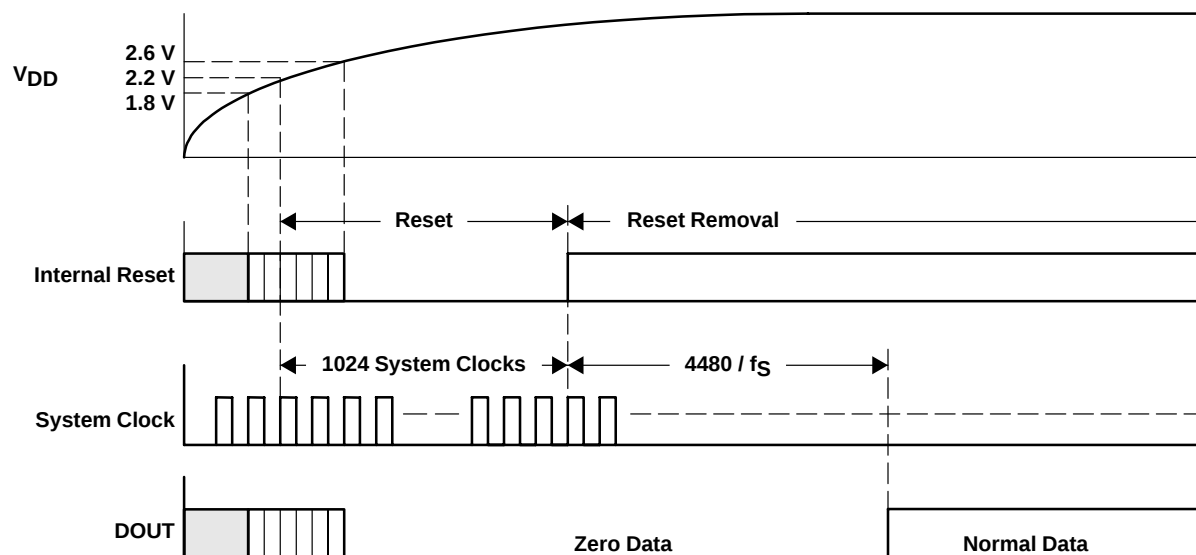


Figure 23. Internal Power-On Reset Timing

### serial audio data interface

The PCM1802 interfaces with the audio system through BCK (pin 11), LRCK (pin 10), FSYNC (pin 9), and DOUT (pin 12).

## PRINCIPLES OF OPERATION

### interface mode

The PCM1802 supports master mode and slave mode as interface modes, and they are selected by MODE1 (pin 20) and MODE0 (pin 19) as shown in Table 2.

In master mode, the PCM1802 provides the timing for serial audio data communications between the PCM1802 and the digital audio processor or external circuit. In slave mode, the PCM1802 receives the timing for data transfer from an external controller.

**Table 2. Interface Mode**

| MODE1 | MODE0 | INTERFACE MODE                                                                                  |
|-------|-------|-------------------------------------------------------------------------------------------------|
| 0     | 0     | Slave mode (256 f <sub>S</sub> , 384 f <sub>S</sub> , 512 f <sub>S</sub> , 768 f <sub>S</sub> ) |
| 0     | 1     | Master mode (512 f <sub>S</sub> )                                                               |
| 1     | 0     | Master mode (384 f <sub>S</sub> )                                                               |
| 1     | 1     | Master mode (256 f <sub>S</sub> )                                                               |

#### (1) Master mode

In master mode, BCK, LRCK and FSYNC work as output pins, and these pins are controlled by timing which is generated in the clock circuit of the PCM1802. FSYNC is used to designate the valid data from the PCM1802. The rising edge of FSYNC indicates the starting point of the converted audio data and the falling edge of this signal indicates the ending point of the data. The frequency of this signal is fixed at  $2 \times \text{LRCK}$ . The duty cycle ratio depends on data bit length. The frequency of BCK is fixed at  $64 \times \text{LRCK}$ . The 768 f<sub>S</sub> system clock is not available in master mode.

#### (2) Slave mode

In slave mode, BCK, LRCK and FSYNC work as input pins. FSYNC is used to enable the BCK signal, and the PCM1802 can shift out the converted data while FSYNC is HIGH. The PCM1802 accepts either the 64 BCK/LRCK or the 48 BCK/LRCK format. The delay of FSYNC from the LRCK transition must be within 16 BCKs for the 64 BCK/LRCK format and within 12 BCKs for the 48 BCK/LRCK format.

### data format

The PCM1802 supports four audio data formats in both master and slave modes, and they are selected by FMT1 (pin 18) and FMT0 (pin 17) as shown in Table 3. Figure 24 and Figure 26 illustrate the data formats in slave mode and master mode, respectively.

**Table 3. Data Format**

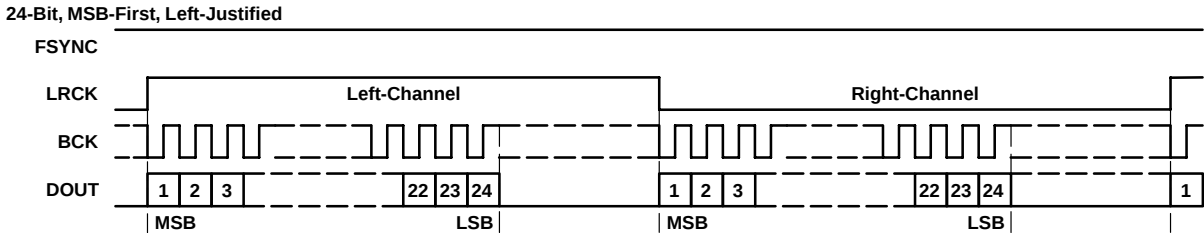
| FORMAT# | FMT1 | FMT0 | FORMAT                   |
|---------|------|------|--------------------------|
| 0       | 0    | 0    | Left justified, 24 bit   |
| 1       | 0    | 1    | I <sup>2</sup> S, 24 bit |
| 2       | 1    | 0    | Right justified, 24 bit  |
| 3       | 1    | 1    | Right justified, 20 bit  |

PRINCIPLES OF OPERATION

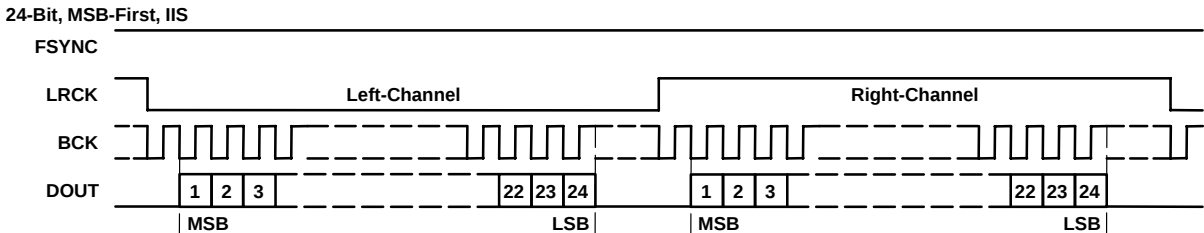
interface timing

Figure 25 and Figure 27 illustrate the interface timing in slave mode and master mode, respectively.

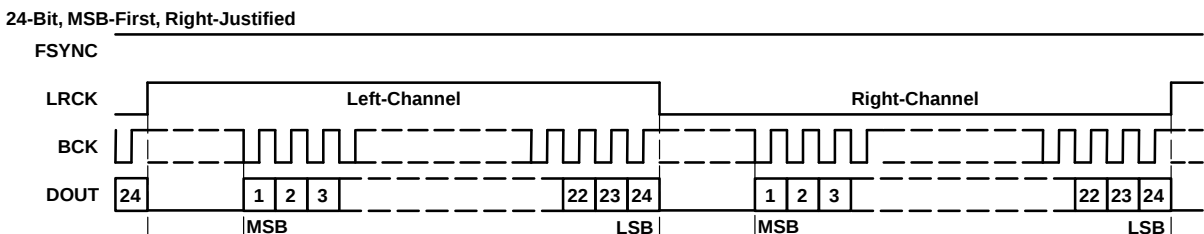
FORMAT 0: FMT[1:0] = 00



FORMAT 1: FMT[1:0] = 01



FORMAT 2: FMT[1:0] = 10



FORMAT 3: FMT[1:0] = 11

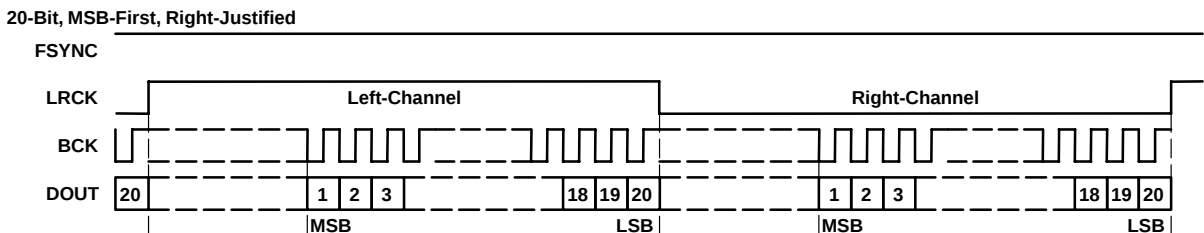
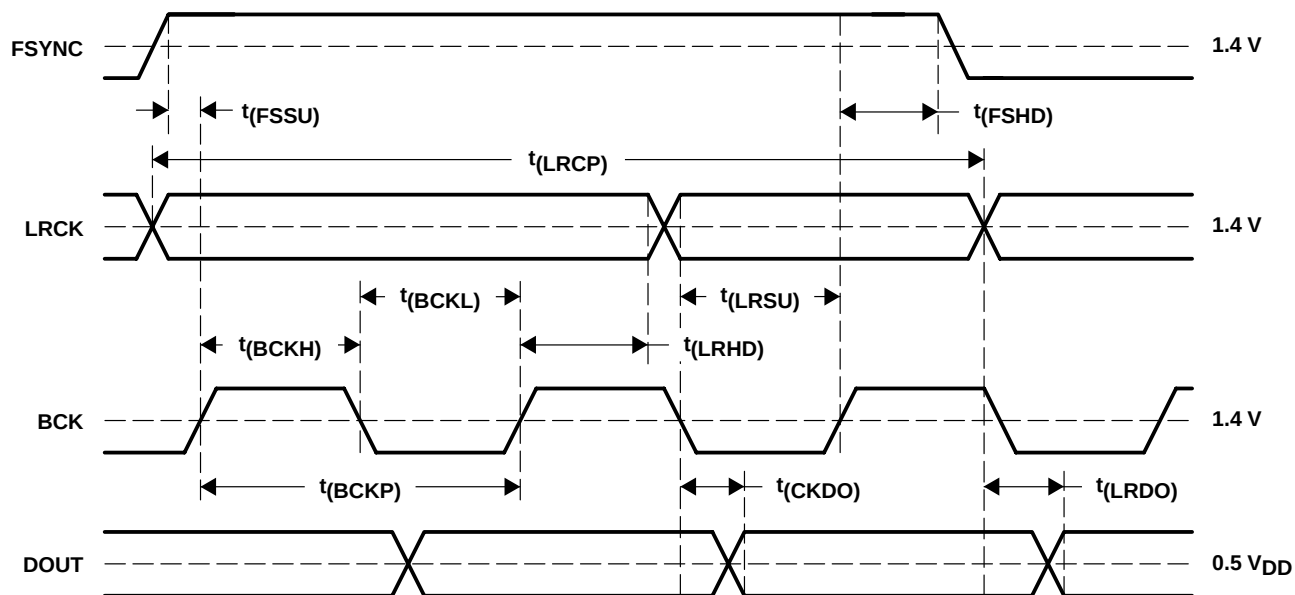


Figure 24. Audio Data Format (Slave Mode: FSYNC, LRCK, BCK Work as Inputs)

## PRINCIPLES OF OPERATION

## interface timing (continued)



| PARAMETER |                                            | MIN | TYP | MAX | UNIT    |
|-----------|--------------------------------------------|-----|-----|-----|---------|
| $t(BCKP)$ | BCK period                                 | 150 |     |     | ns      |
| $t(BCKH)$ | BCK pulse duration high                    | 60  |     |     | ns      |
| $t(BCKL)$ | BCK pulse duration low                     | 60  |     |     | ns      |
| $t(LRSU)$ | LRCK setup time to BCK rising edge         | 40  |     |     | ns      |
| $t(LRHD)$ | LRCK hold time to BCK rising edge          | 20  |     |     | ns      |
| $t(LRCP)$ | LRCK period                                | 10  |     |     | $\mu$ s |
| $t(FSSU)$ | FSYNC setup time to BCK rising edge        | 20  |     |     | ns      |
| $t(FSHD)$ | FSYNC hold time to BCK rising edge         | 20  |     |     | ns      |
| $t(CKDO)$ | Delay time, BCK falling edge to DOUT valid | -10 |     | 20  | ns      |
| $t(LRDO)$ | Delay time, LRCK edge to DOUT valid        | -10 |     | 20  | ns      |
| $t_r$     | Rise time of all signals                   |     |     | 10  | ns      |
| $t_f$     | Fall time of all signals                   |     |     | 10  | ns      |

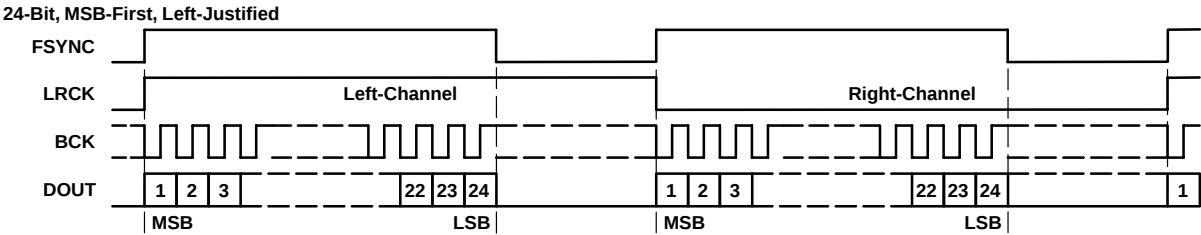
NOTE: Timing measurement reference level is  $(V_{IH}/V_{IL})/2$ . Rise and fall times are measured from 10% to 90% of IN/OUT signal swing. Load capacitance of DOUT is 20 pF.

**Figure 25. Audio Data Interface Timing (Slave Mode: FSYNC, LRCK, BCK Work as Inputs)**

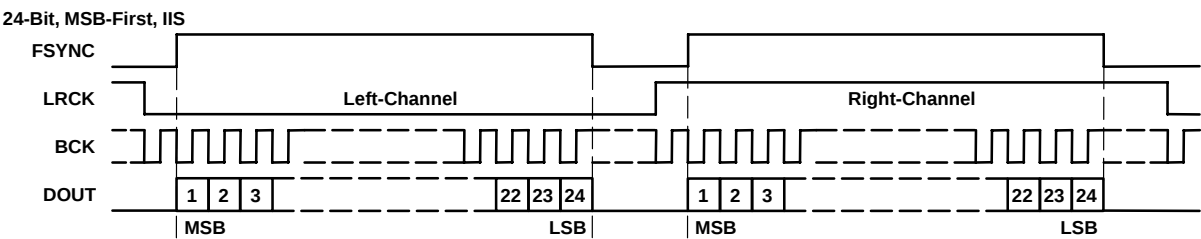
PRINCIPLES OF OPERATION

interface timing (continued)

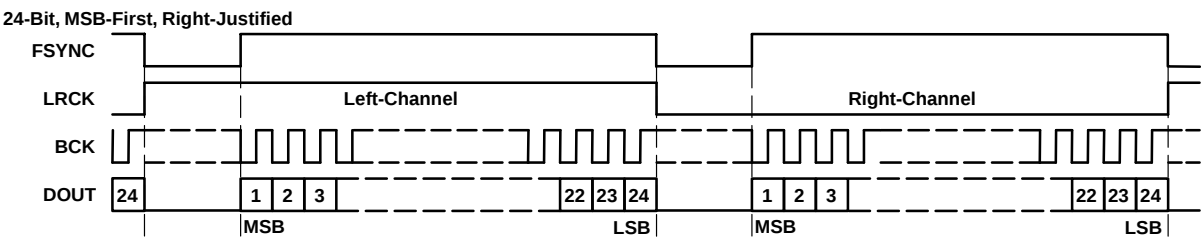
FORMAT 0: FMT[1:0] = 00



FORMAT 1: FMT[1:0] = 01



FORMAT 2: FMT[1:0] = 10



FORMAT 3: FMT[1:0] = 11

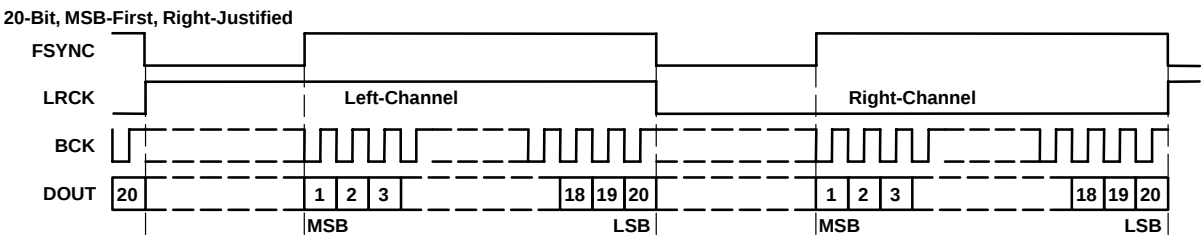
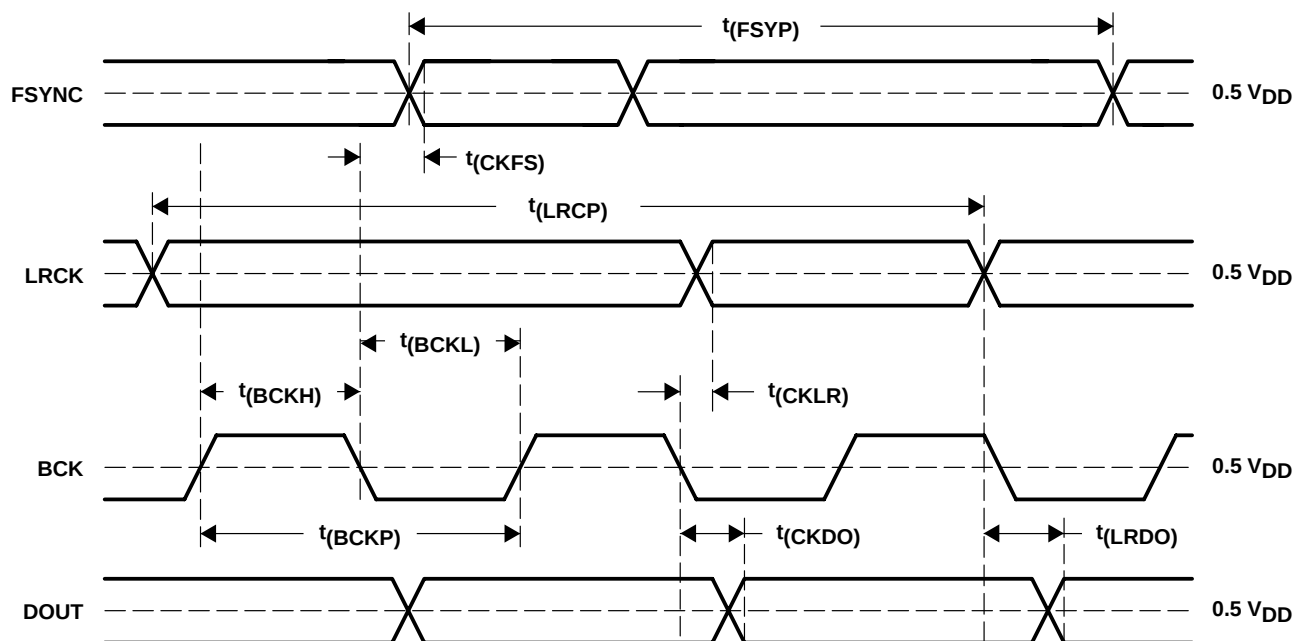


Figure 26. Audio Data Format (Master Mode: FSYNC, LRCK, BCK Work as Outputs)

## PRINCIPLES OF OPERATION

## interface timing (continued)



| PARAMETER         |                                            | MIN | TYP          | MAX  | UNIT          |
|-------------------|--------------------------------------------|-----|--------------|------|---------------|
| $t_{\text{BCKP}}$ | BCK period                                 | 150 | $1/(64 f_S)$ | 1200 | ns            |
| $t_{\text{BCKH}}$ | BCK pulse width high                       | 75  |              | 600  | ns            |
| $t_{\text{BCKL}}$ | BCK pulse width low                        | 75  |              | 600  | ns            |
| $t_{\text{CKLR}}$ | Delay time BCK falling edge to LRCK valid  | -10 |              | 20   | ns            |
| $t_{\text{LRCP}}$ | LRCK period                                | 10  | $1/f_S$      | 80   | $\mu\text{s}$ |
| $t_{\text{CKFS}}$ | Delay time BCK falling edge to FSYNC valid | -10 |              | 20   | ns            |
| $t_{\text{FSYP}}$ | FSYNC period                               | 5   | $1/(2 f_S)$  | 40   | $\mu\text{s}$ |
| $t_{\text{CKDO}}$ | Delay time, BCK falling edge to DOUT valid | -10 |              | 20   | ns            |
| $t_{\text{LRDO}}$ | Delay time, LRCK edge to DOUT valid        | -10 |              | 20   | ns            |
| $t_r$             | Rise time of all signals                   |     |              | 10   | ns            |
| $t_f$             | Fall time of all signals                   |     |              | 10   | ns            |

NOTE: Timing measurement reference level is  $(V_{\text{IH}}/V_{\text{IL}}) / 2$ . Rise and fall times are measured from 10% to 90% of IN/OUT signal swing. Load capacitance of all signals is 20 pF.

**Figure 27. Audio Data Interface Timing (Master Mode: FSYNC, LRCK, BCK Work as Outputs)**

## PRINCIPLES OF OPERATION

### synchronization with digital audio system

In slave mode, the PCM1802 operates under LRCK, synchronized with system clock SCKI. The PCM1802 does not need a specific phase relationship between LRCK and SCKI, but does require the synchronization of LRCK and SCKI.

If the relationship between LRCK and SCKI changes more than  $\pm 6$  BCKs for 64 BCK/frame ( $\pm 5$  BCKs for 48 BCK/frame) during one sample period due to LRCK or SCKI jitter, internal operation of the ADC halts within  $1/f_S$  and digital output is forced into BPZ code until re-synchronization between LRCK and SCKI is completed.

In the case of changes less than  $\pm 5$  BCKs for 64 BCK/frame ( $\pm 4$  BCKs for 48 BCK/frame), resynchronization does not occur.

Figure 28 illustrates digital output response for loss of synchronization and resynchronization. During undefined data, some noise might be generated in the audio signal. Also, the transition of normal to undefined data and undefined or zero data to normal creates a data discontinuity in the digital output, which can generate some noise in the audio signal.

It is recommended to set  $\overline{\text{PDWN}}$  low to get stable analog performance when the sampling rate, interface mode, data format, or oversampling control is changed.

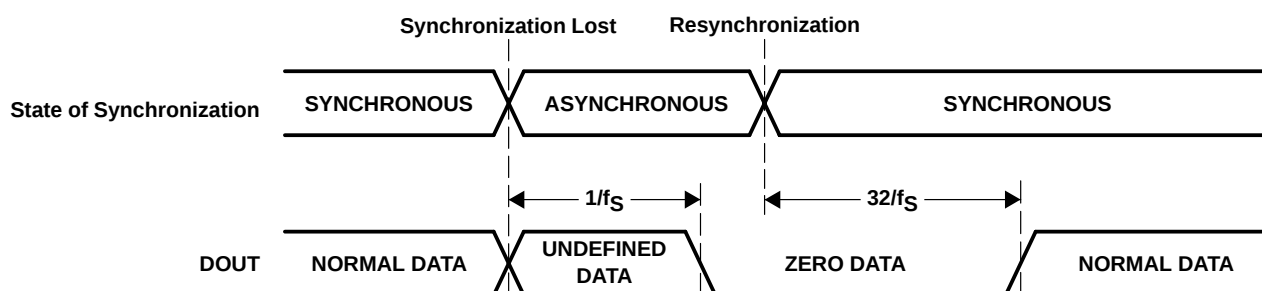


Figure 28. ADC Digital Output for Loss of Synchronization and Resynchronization

### power down, LCF bypass, oversampling control

$\overline{\text{PDWN}}$  (pin 7) controls the entire ADC operation. During power-down mode, both the supply current for the analog portion and the clock signal for the digital portion are shut down, and power dissipation is minimized. Also, DOUT (pin 12) is disabled and no system clock is accepted during power-down mode.

Table 4. Power-Down Control

|                          |                       |
|--------------------------|-----------------------|
| $\overline{\text{PDWN}}$ | Power-down mode       |
| LOW                      | Power-down mode       |
| HIGH                     | Normal operation mode |

The built-in function for dc component rejection can be bypassed using the BYPAS (pin 8) control. In bypass mode, the dc components of the analog input signal, internal dc offset, etc., are also converted and included in the digital output data.

Table 5. LCF Bypass Control

|       |                                       |
|-------|---------------------------------------|
| BYPAS | LCF (low-cut filter) mode             |
| LOW   | Normal (no dc component on DOUT) mode |
| HIGH  | Bypass (dc component on DOUT) mode    |

## PRINCIPLES OF OPERATION

### power down, LCF bypass, oversampling control (continued)

OSR (pin 16) controls the oversampling ratio of the delta-sigma modulator,  $\times 64$  or  $\times 128$ . The  $\times 128$  mode is available for  $f_S < 50$  kHz, and must be used carefully as performance is affected by the duty cycle of the  $384 f_S$  system clock.

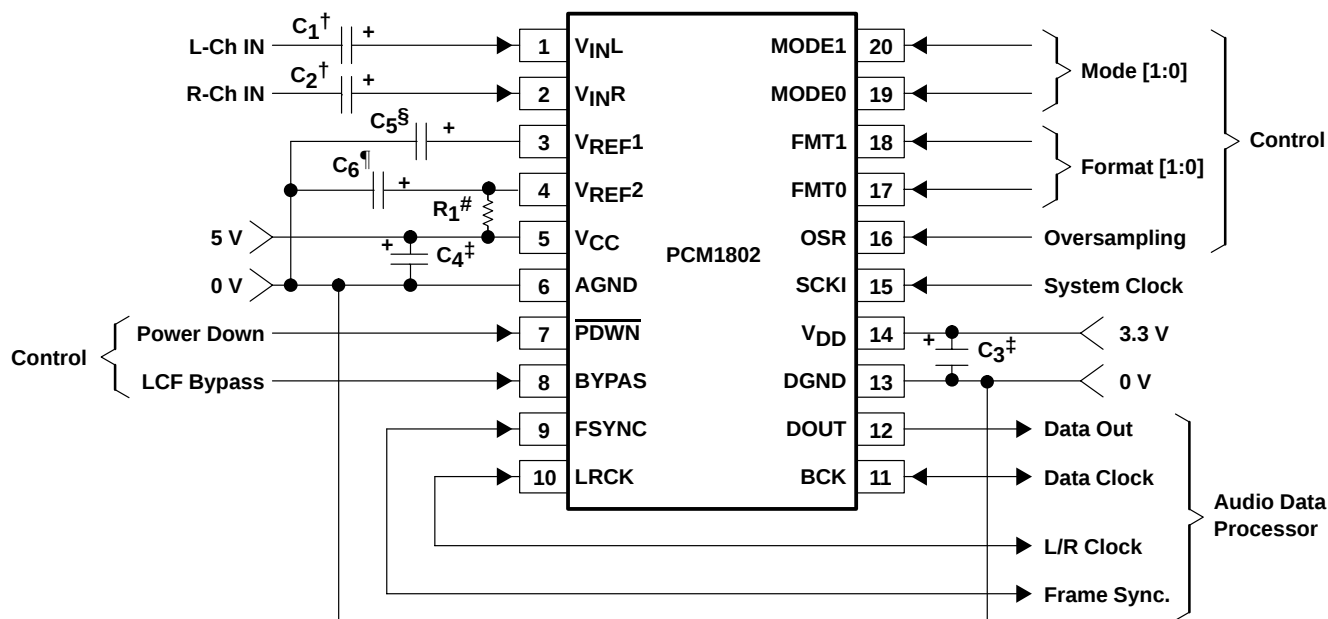
**Table 6. Oversampling Control**

| OSR  | Oversampling ratio             |
|------|--------------------------------|
| LOW  | $\times 64$                    |
| HIGH | $\times 128$ ( $f_S < 50$ kHz) |

## APPLICATION INFORMATION

### typical circuit connection diagram

Figure 29 illustrates a typical circuit connection diagram in which the cutoff frequency of the input HPF is about 8 Hz.



†  $C_1, C_2$ : A 1- $\mu$ F capacitor gives 8-Hz ( $\tau = 1 \mu\text{F} \times 20 \text{ k}\Omega$ ) cutoff frequency for input HPF in normal operation, and requires a power-on settling time with 20-ms time constant in the power-on initialization period.

‡  $C_3, C_4$ : Bypass capacitors, 0.1- $\mu$ F ceramic and 10- $\mu$ F tantalum, depending on layout and power supply.

§  $C_5$ : 0.1- $\mu$ F ceramic and 4.7- $\mu$ F tantalum capacitors are recommended.

¶  $C_6$ : 0.1- $\mu$ F ceramic and 4.7- $\mu$ F tantalum capacitors are recommended for using a noisy analog power supply. These capacitors are not required for clean analog supply.

#  $R_1$ : 1-k $\Omega$  resistor is recommended for using a noisy analog power supply. This resistor is shorted for a clean analog supply.

**Figure 29. Typical Circuit Connection**

## APPLICATION INFORMATION

### board design and layout considerations

#### $V_{CC}$ , $V_{DD}$ pins

The digital and analog power supply lines to the PCM1802 should be bypassed to the corresponding ground pins with 0.1- $\mu$ F ceramic and 10- $\mu$ F tantalum capacitors as close to the pins as possible to maximize the dynamic performance of the ADC.

#### AGND, DGND pins

To maximize the dynamic performance of the PCM1802, the analog and digital grounds are not connected internally. These grounds should have very low impedance to avoid digital noise feeding back into the analog ground. They should be connected directly to each other under the parts to reduce the potential noise problem.

#### $V_{IN}$ pins

A 1- $\mu$ F capacitor is recommended as an ac-coupling capacitor which gives 8-Hz cutoff frequency. If a higher full-scale input voltage is required, it can be accommodated by adding only one series resistor to each  $V_{IN}$  pin.

#### $V_{REF1}$ pin

A 0.1- $\mu$ F ceramic and 10- $\mu$ F chemical capacitors are recommended between  $V_{REF1}$  and AGND to insure low source impedance of ADC references. These capacitors should be located as close as possible to the  $V_{REF1}$  pin to reduce the dynamic errors on ADC references.

#### $V_{REF2}$ pin

The differential voltage between  $V_{REF2}$  and AGND sets the analog input full-scale range. A 0.1- $\mu$ F ceramic and 10- $\mu$ F chemical capacitors are recommended between  $V_{REF2}$  and AGND with insertion of a 1-k $\Omega$  resistor between  $V_{CC}$  and  $V_{REF2}$  for using a noisy analog power supply. These capacitors and resistor are not required for clean analog supply. These capacitors should be located as close as possible to the  $V_{REF2}$  pin to reduce the dynamic errors on ADC references. Full-scale input level is affected by this 1-k $\Omega$  resistor and decreases by 3%.

#### DOUT pin

The DOUT pin has enough load drive capability, but locating a buffer near the PCM1802 and minimizing load capacitance is recommended if the DOUT line is long, in order to minimize the digital-analog crosstalk and maximize the dynamic performance of the ADC.

#### system clock

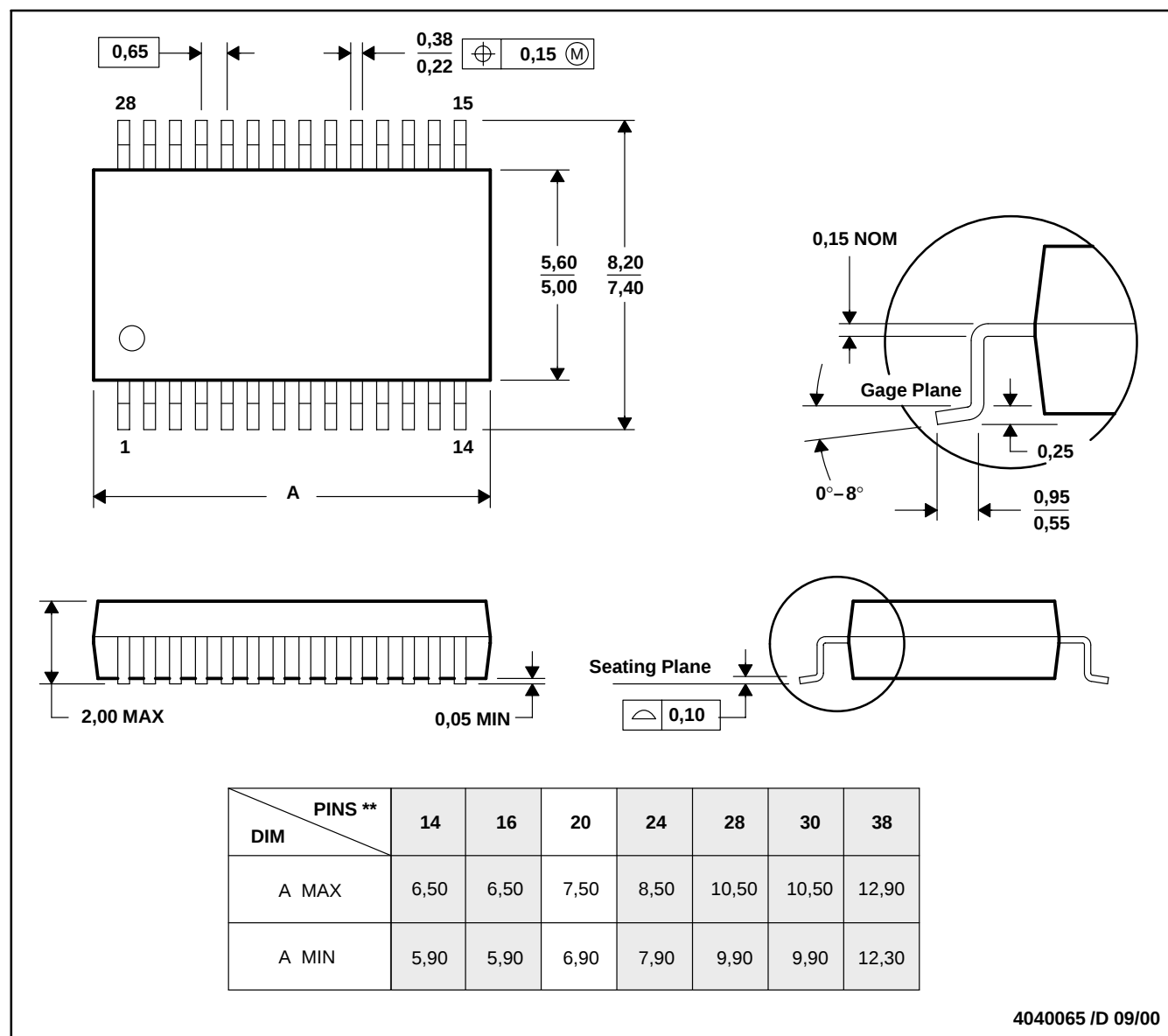
The quality of the system clock can influence dynamic performance, as the PCM1802 operates based on the system clock. In slave mode, it may be necessary to consider the system-clock duty cycle, jitter, and the time difference between the system clock transition and the BCK or LRCK transition.

## MECHANICAL DATA

DB (R-PDSO-G\*\*)

PLASTIC SMALL-OUTLINE

28 PINS SHOWN



- 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 not to exceed 0,15.  
 D. Falls within JEDEC MO-150

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