BURR-BROWN®

# PCM1710U

## SoundPLUS Stereo Audio DIGITAL-TO-ANALOG CONVERTER

## FEATURES

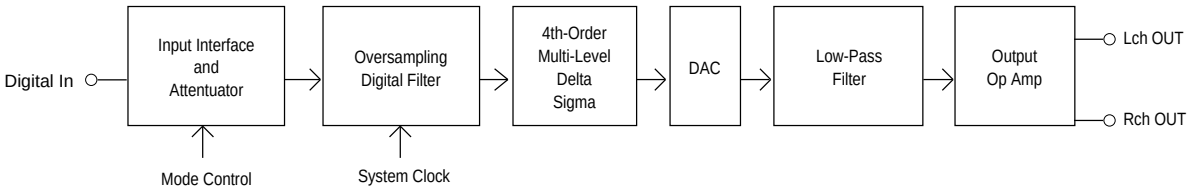
- **COMPLETE STEREO DAC:**
  **8X Oversampling Digital Filter**
  **Multi-Level Delta-Sigma DAC**
  **Analog Low Pass Filter**
  **Output Amplifier**
- **HIGH PERFORMANCE:**
  **–92dB THD+N**
  **98dB Dynamic Range**
  **110dB SNR**
- **ACCEPTS 16 OR 20 BITS INPUT DATA**
- **SYSTEM CLOCK: 256fs or 384fs**
- **SINGLE +5V POWER SUPPLY**
- **ON-CHIP DIGITAL FILTER:**
  **Soft Mute and Attenuator**
  **Digital De-emphasis**
  **Double-Speed Dubbing Mode**
- **SMALL 28-PIN SOIC PACKAGE**

## DESCRIPTION

The PCM1710 is a complete stereo audio digital-to-analog converter, including digital interpolation filter, delta-sigma DAC, and analog voltage output. PCM1710 can accept either 16-bit normal or 20-Bit normal input data (MSB first, right justified), or 16-bit IIS data (32-bits per word, continuous clock).

The digital filter performs an 8X interpolation function, as well as special functions such as soft mute, digital attenuation, de-emphasis and double-speed dubbing. Performance of the digital feature is excellent, featuring –62dB stop band attenuation and ±0.008dB ripple in the pass band.

PCM1710 is suitable for a wide variety of consumer applications where good performance is required. Its low cost, small size and single +5V power supply make it ideal for automotive CD players, bookshelf CD players, BS tuners, keyboards, MPEG audio, MIDI applications, set-top boxes, CD-ROM drives, CD-Interactive and CD-Karaoke systems.




International Airport Industrial Park • Mailing Address: PO Box 11400 • Tucson, AZ 85734 • Street Address: 6730 S. Tucson Blvd. • Tucson, AZ 85706
Tel: (520) 746-1111 • Twx: 910-952-1111 • Cable: BBRCORP • Telex: 066-6491 • FAX: (520) 889-1510 • Immediate Product Info: (800) 548-6132

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# SPECIFICATIONS

All specifications at +25°C, $+V_{CC}$ = $+V_{DD}$ = +5V, $f_S$ = 44.1kHz, $f_{SYS}$ = 384/256fs, and 16-bit data, unless otherwise noted.

| PARAMETER | CONDITIONS | PCM1710U MIN | PCM1710U TYP | PCM1710U MAX | UNITS |
|---|---|---|---|---|---|
| **RESOLUTION** | | 16 | | 20 | Bits |
| **DIGITAL INPUT** | | | | | |
| Logic Family | | | | | |
| Input Logic Level (except XTI) | | | | | |
| $V_{IH}$ | | 2.0 | | | VDC |
| $V_{IL}$ | | | | 0.8 | VDC |
| Input Logic Current (except XTI) | | | | –200 | µA |
| Input Logic Level (XTI) | | | | | |
| $V_{IH}$ | | 3.2 | | | VDC |
| $V_{IL}$ | | | | 1.4 | VDC |
| Input Logic Current (XTI) | | | | ±50 | µA |
| Output Logic Level (CLKO): | | | | | |
| $V_{OH}$ | | 4.5 | | | VDC |
| $V_{OL}$ | | | | 0.5 | VDC |
| Output Logic Current (CLKO) | | ±10 | | | mA |
| Data Format | Normal (16/20-bit)/IIS (16-bit) selectable | | | | |
| Sampling Frequency | | 32 | 44.1 | 48 | kHz |
| System Clock Frequency | $384f_S$ | 12.288 | 16.934 | 18.432 | MHz |
| System Clock Frequency | $256f_S$ | 8.192 | 11.2894 | 12.288 | MHz |
| **DC ACCURACY** | | | | | |
| Gain Error | | | ±1.0 | ±5.0 | % of FSR |
| Gain Mis-Match Channel-To-Channel | | | ±1.0 | ±5.0 | % of FSR |
| Bipolar Zero Error | $V_O$ = 1/2$V_{CC}$ at Bipolar Zero | | ±20.0 | | mV |
| Gain Drift | | | ±50 | | ppm of FSR/°C |
| Bipolar Gain Drift | | | ±20 | | ppm of FSR/°C |
| **DYNAMIC PERFORMANCE**(1) | | | | | |
| THD+N at F/S (0dB)(2) | $f_{IN}$ = 991kHz | | –92 | –88 | dB |
| THD+N at –60fdB(2) | $f_{IN}$ = 991kHz | | –36 | –32 | dB |
| Dynamic Range | EIAJ A-weighted | | 98 | | dB |
| S/N Ratio | EIAJ A-weighted | 104 | 110 | | dB |
| Channel Separation | | 90 | 94 | | dB |
| **DIGITAL FILTER PERFORMANCE** | | | | | |
| Pass Band Ripple | Normal Mode | | | ±0.008 | dB |
| Pass Band Ripple | Double Speed Mode | | | ±0.018 | dB |
| Stop Band Attenuation | Normal Mode | –62 | | | dB |
| Stop Band Attenuation | Double Speed Mode | –58 | | | dB |
| Pass Band | Normal Mode | | | 0.4535 | fs |
| Pass Band | Double Speed Mode | | | 0.4535 | fs |
| Stop Band | Normal Mode | | | 0.5465 | fs |
| Stop Band | Double Speed Mode | | | 0.5465 | fs |
| De-emphasis Error | ($f_S$ 32kHz ~ 48kHz) | –0.05 | | +0.03 | dB |
| **ANALOG OUTPUT** | | | | | |
| Voltage Range | | | 3.2 | | Vp-p |
| Load Impedance | | 5 | | | kΩ |
| Center Voltage | | | +1/2$V_{CC}$ | | V |
| **POWER SUPPLY REQUIREMENTS** | | | | | |
| Voltage Range: $+V_{CC}$ | | +4.5 | +5.0 | +5.5 | VDC |
| $+V_{DD}$ | | +4.5 | +5.0 | +5.5 | VDC |
| Supply Current ($+I_{CC}$) + ($+I_{DD}$) | | | 45 | 70 | mA |
| **TEMPERATURE RANGE** | | | | | |
| Operation | | –25 | | +85 | °C |
| Storage | | –55 | | +100 | °C |

NOTE: (1) Dynamic performance specs are tested with external 20kHz low pass filter. (2) 30kHz LPF, 400Hz HPF, Average Mode. Shibusoku #725 THD Meter.

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## PIN ASSIGNMENTS

| PIN NAME | NUMBER | FUNCTION |
|---|---|---|
| **Input Interface Pins** | | |
| LRCIN | 1 | Sample Rate Clock Input. Controls the update rate (fs). |
| DIN | 2 | Serial Data Input. MSB first, right justified format contains a frame of 16-bit or 20-bit data. |
| BCKIN | 3 | Bit Clock Input. Clocks in the data present on DIN input. |
| **Mode Controls and Clock Signals** | | |
| CLKO | 4 | Buffered Output of Oscillator. Equivalent to fs. |
| XTI | 5 | Oscillator Input (External Clock Input). For an internal clock, tie XTI to one side of the crystal oscillator. For an external clock, tie XTI to the output of the chosen external clock. |
| XTO | 6 | Oscillator Output. When using the internal clock, tie to the opposite side (from pin 5) of the crystal oscillator. When using an external clock, leave XTO open. |
| CKSL | 23 | System Clock Select. For 384fs, tie CKSL “High”. For 256fs, tie CKSL “Low”. |
| MODE | 24 | Operation Mode Select. For serial mode, tie MODE “High”. For parallel mode, tie MODE “Low”. |
| MUTE | 25 | Mute Control. To disable soft mute, tie MUTE “High”. To enable soft mute, tie MUTE “Low”. |
| MD/DM1 | 26 | Mode Control for Data/De-emphasis. See “Mode Control Functions” on page 11. |
| MC/DM2 | 27 | Mode Control for BCKIN/De-emphasis. See “Mode Control Functions” on page 11. |
| ML/DSD | 28 | Mode Control for WDCK/Double speed dubbing. See “Mode Control Functions” on page 11. |
| **Analog Functions** | | |
| $V_{OUT}R$ | 13 | Right Channel Analog Output. |
| $V_{OUT}L$ | 16 | Left Channel Analog Output. |
| **Power Supply Connections** | | |
| DGND | 7, 22 | Digital Ground. |
| $V_{DD}$ | 8, 21 | Digital Power Supply (+5V). |
| $V_{CC}2R$ | 9 | Analog Power Supply (+5V), Right Channel DAC. |
| AGND2R | 10 | Analog Ground (DAC), Right Channel. |
| EXT1R | 11 | Output Amplifier Common, Right Channel. Bypass to ground with a 10µF capacitor. |
| EXT2R | 12 | Output Amplifier Bias, Right Channel. Connect to EXT1R. |
| AGND | 14 | Analog Ground. |
| $V_{CC}$ | 15 | Analog Power Supply (+5V). |
| EXT2L | 17 | Output Amplifier Bias, Left Channel. Connect to EXT1L. |
| EXT1L | 18 | Output Amplifier Common, Left Channel. Bypass to ground with a 10µF capacitor. |
| AGND2L | 19 | Analog Ground (DAC), Left Channel. |
| $V_{CC}2L$ | 20 | Analog Power Supply (+5V), Left Channel DAC. |

## ABSOLUTE MAXIMUM RATINGS

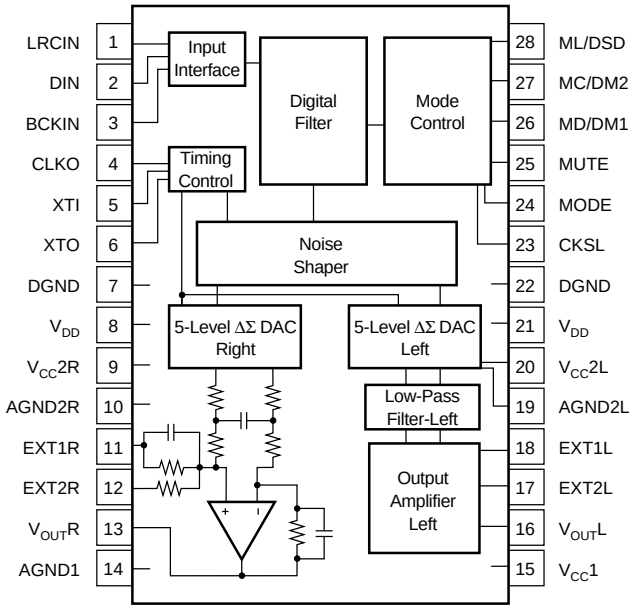
Power Supply Voltages ..... ±6.5VDC
$+V_{CC}$ to $V_{DD}$ Voltage ..... ±0.1V
Input Logic Voltage ..... –0.3V to $V_{DD}$ +0.3V
Power Dissipation ..... 400mW
Operating Temperature Range ..... –25°C to +85°C
Storage Temperature Range ..... –55°C to +125°C
Lead Temperature (soldering, 5s) ..... +260°C

## PACKAGE INFORMATION

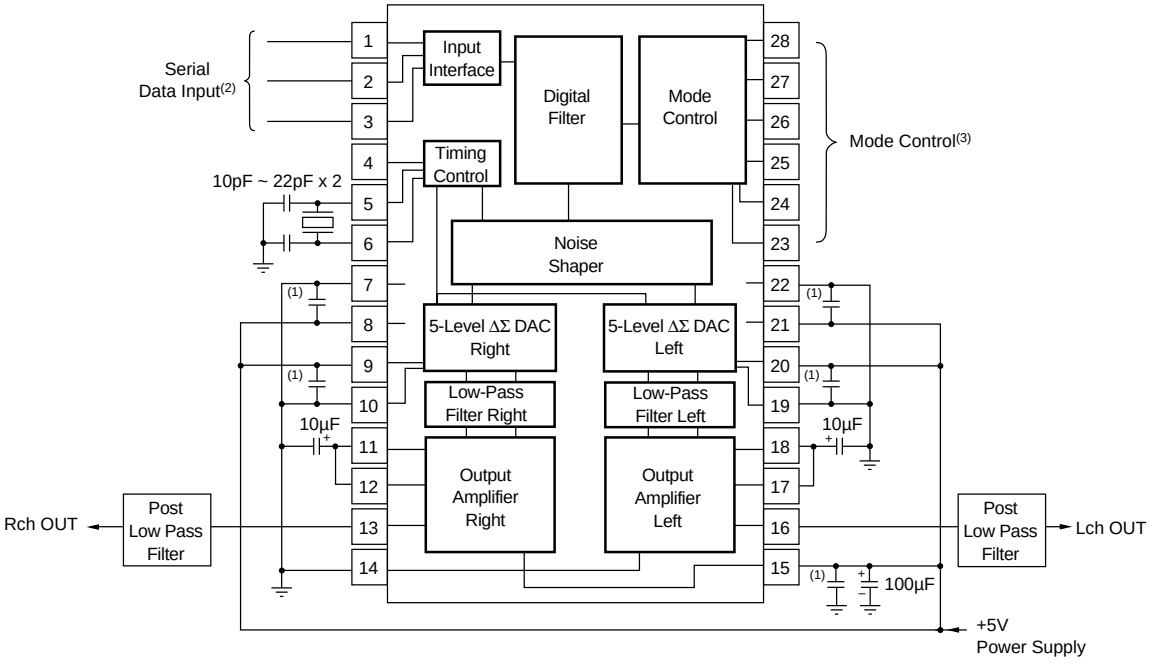
| MODEL | PACKAGE | PACKAGE DRAWING NUMBER(1) |
|---|---|---|
| PCM1710U | 28-Pin SOIC | 217 |

NOTE: (1) For detailed drawing and dimension table, please see end of data sheet, or Appendix D of Burr-Brown IC Data Book.

## PIN CONFIGURATION




## CONNECTION DIAGRAM




NOTES: (1) Bypass Capacitor :1µF ~ 10µF.
(2) Input pins require pull-up resistors. (3) Mode control pins require pull-up resistors.

## DATA INPUT TIMING

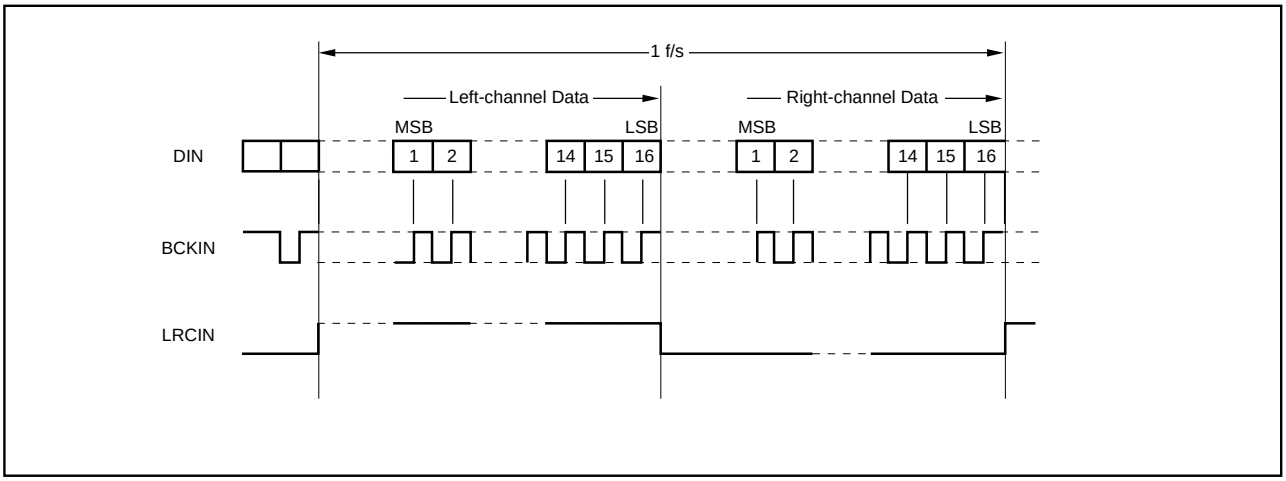



FIGURE 1. Normal Format, 16-Bit (LRCIN H: Lch).

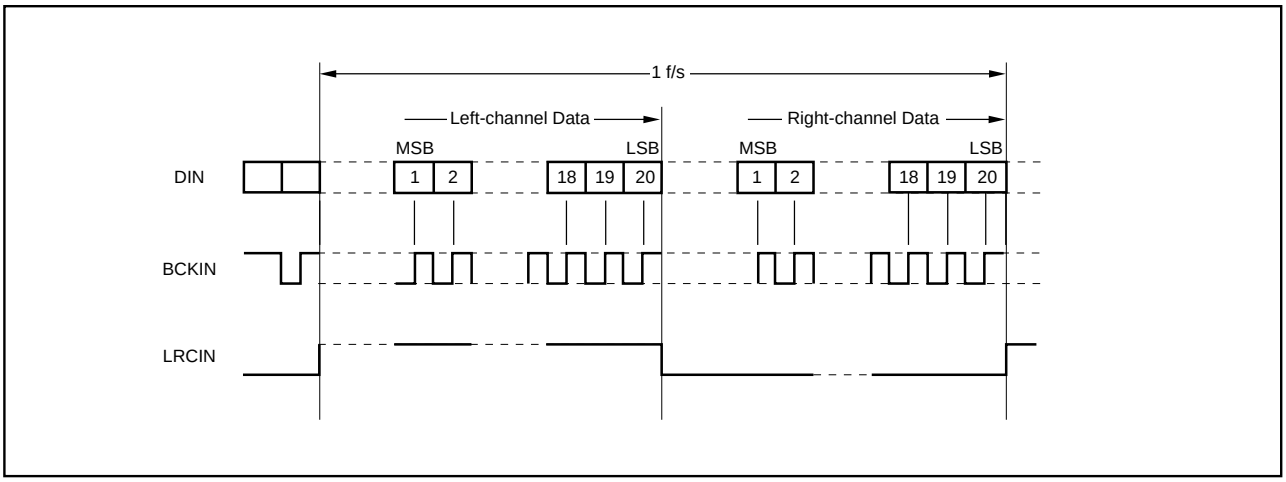



FIGURE 2. Normal Format, 20-Bit (LRCIN H: Lch).

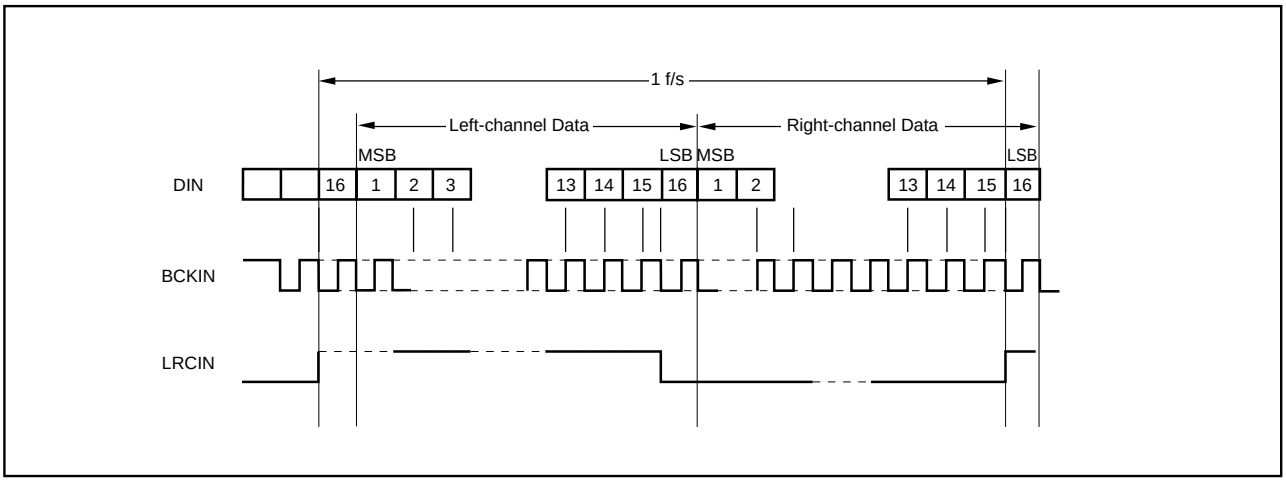



FIGURE 3. IIS Format, (16-Bit, 32 BCKIN Clock Cycles Per fs Interval).

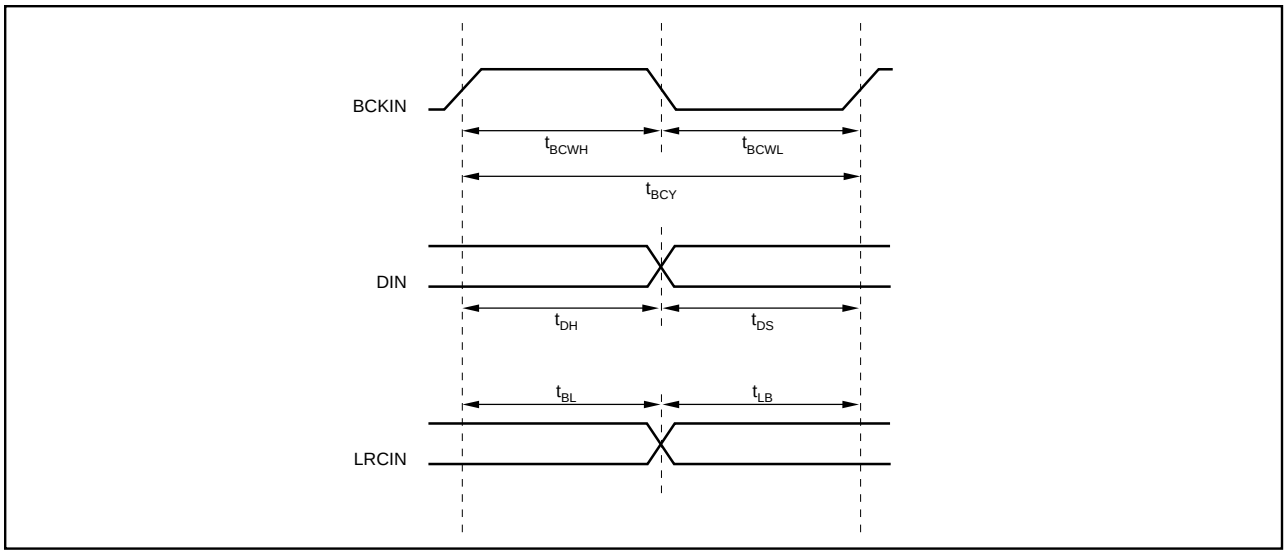



FIGURE 4. Data Input Timing.

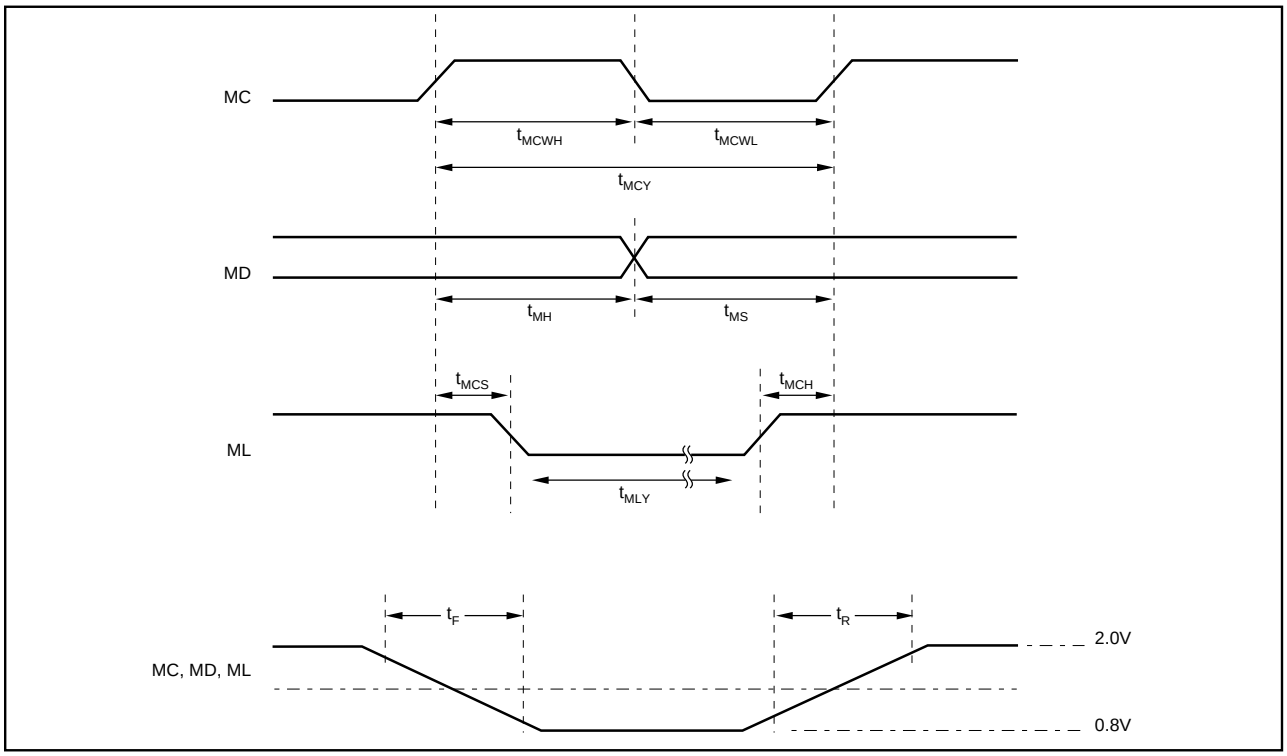



FIGURE 5. Serial Mode Control Timing.

| | | |
|---|---|---|
| BCK Pulsewidth (H Level) | $t_{BCWH}$ | 70ns (min) |
| BCK Pulsewidth (L Level) | $t_{BCWL}$ | 70ns (min) |
| BCK Pulse Cycle Time | $t_{BCY}$ | 140ns (min) |
| DIN Setup Time | $t_{DS}$ | 30ns (min) |
| DIN Hold Time | $t_{DH}$ | 30ns (min) |
| BCK Rising Edge → LRCI Edge | $t_{BL}$ | 30ns (min) |
| LRC I Edge → BCK Rising Edge | $t_{LB}$ | 30ns (min) |

TABLE I. Data Input Timing Specifications (Refer to Figure 4).

| | | |
|---|---|---|
| MC Pulsewidth (H Level) | $t_{MCWH}$ | 50ns (min) |
| MC Pulsewidth (L Level) | $t_{MCWL}$ | 50ns (min) |
| MC Pulse Cycle Time | $t_{MCY}$ | 100ns (min) |
| MD Setup Time | $t_{MS}$ | 30ns (min) |
| MD Hold Time | $t_{MH}$ | 30ns (min) |
| ML Setup Time | $t_{MCS}$ | 30ns (min) |
| ML Hold Time | $t_{MCH}$ | 30ns (min) |
| ML Low-Level Time | $t_{MLY}$ | 1/sysclk + 20ns (min) |
| MC, MD, ML Rise Time | $t_R$ | 15ns (max) |
| MC, MD, ML Fall Time | $t_F$ | 15ns (max) |

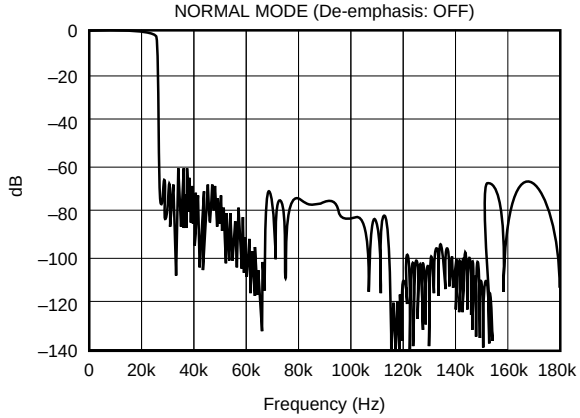
TABLE II. Serial Mode Control Timing Specifications (Refer to Figure 5).

# TYPICAL PERFORMANCE CURVES

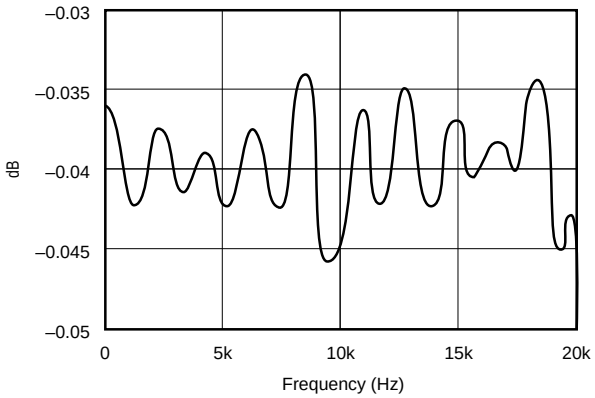
All specifications at +25°C, $+V_{CC}$ = + $V_{DD}$ + 5V, $f_S$ = 44.1kHz, $f_{SYS}$ = 384/256fs, and 16-bit data, unless otherwise noted.

## DIGITAL FILTER

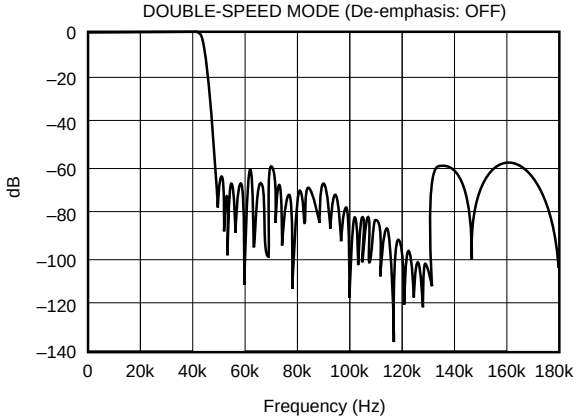
OVERALL FREQUENCY CHARACTERISTIC
NORMAL MODE (De-emphasis: OFF)



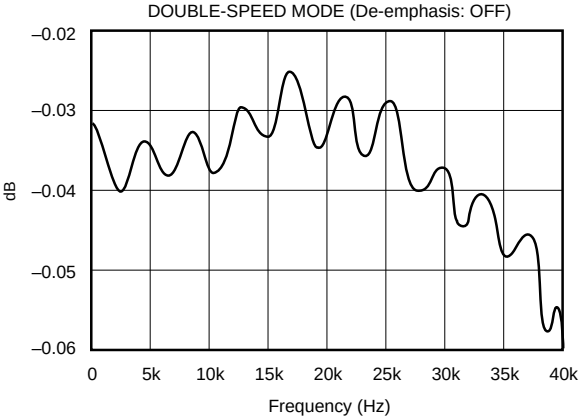

PASSBAND RIPPLE CHARACTERISTIC
NORMAL MODE (De-emphasis: OFF)



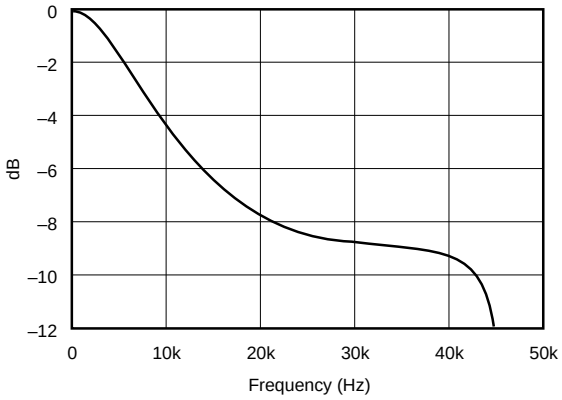

OVERALL FREQUENCY CHARACTERISTIC
DOUBLE-SPEED MODE (De-emphasis: OFF)



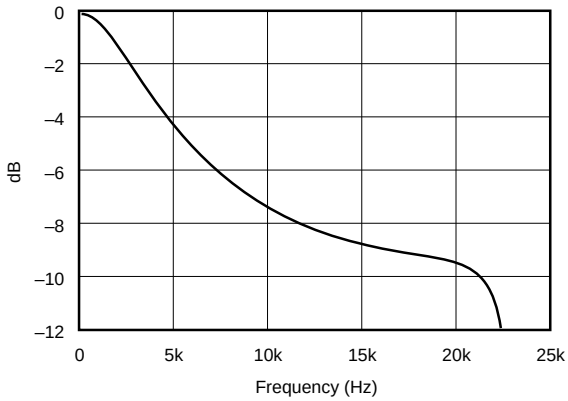

PASSBAND RIPPLE FREQUENCY CHARACTERISTIC
DOUBLE-SPEED MODE (De-emphasis: OFF)




DE-EMPHASIS CHARACTERISTIC
DOUBLE-SPEED MODE




DE-EMPHASIS CHARACTERISTIC, NORMAL MODE

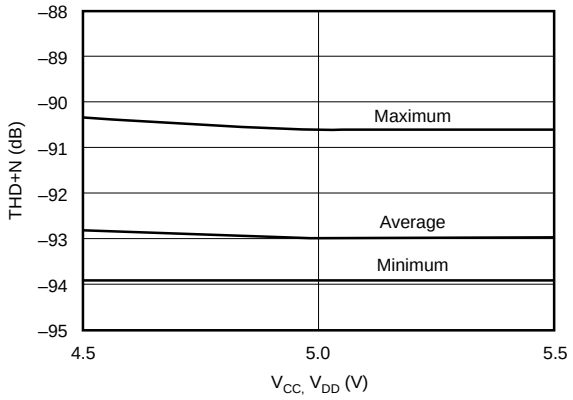


# TYPICAL PERFORMANCE CURVES (CONT)

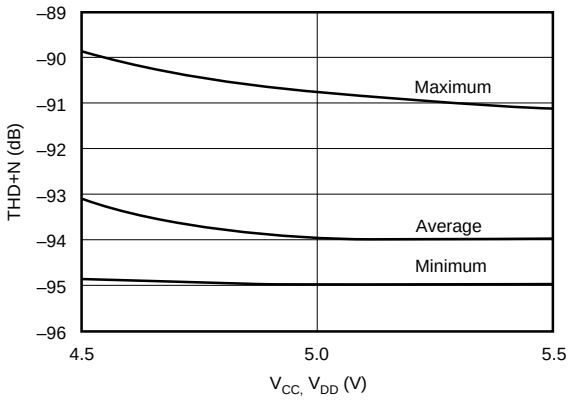
At $T_A$ = +25°C, $V_S$ = ±5V, $R_L$ = 100Ω, $C_L$ = 2pF, and $R_{FB}$ = 402Ω, unless otherwise noted. Based on 200 piece sample from 3 diffusion runs.

## DYNAMIC PERFORMANCE

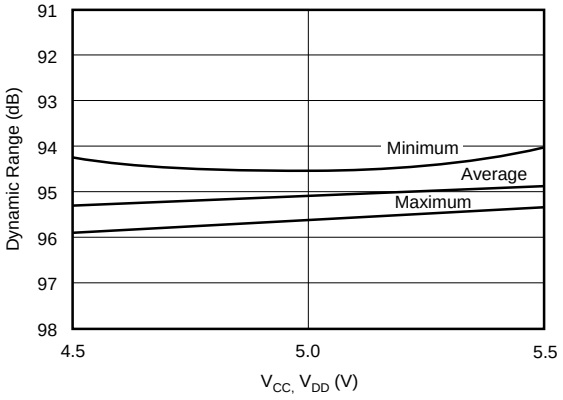
256fs
THD+N vs $V_{CC}$, $V_{DD}$
FULL-SCALE INPUT



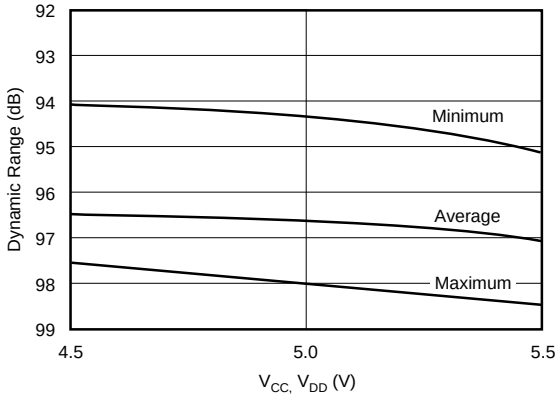

384fs
THD+N vs $V_{CC}$, $V_{DD}$
FULL SCALE INPUT



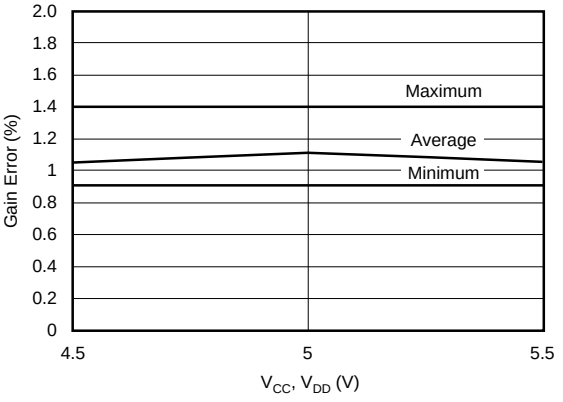

256fs
DYNAMIC RANGE vs $V_{CC}$, $V_{DD}$



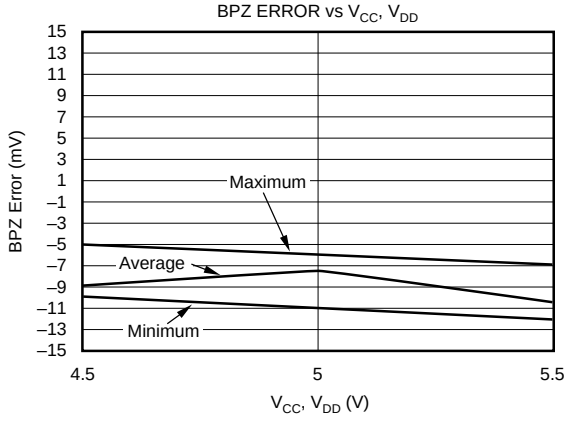

384fs
DYNAMIC RANGE vs $V_{CC}$, $V_{DD}$




384fs
GAIN ERROR vs $V_{CC}$, $V_{DD}$




384fs
BPZ ERROR vs $V_{CC}$, $V_{DD}$

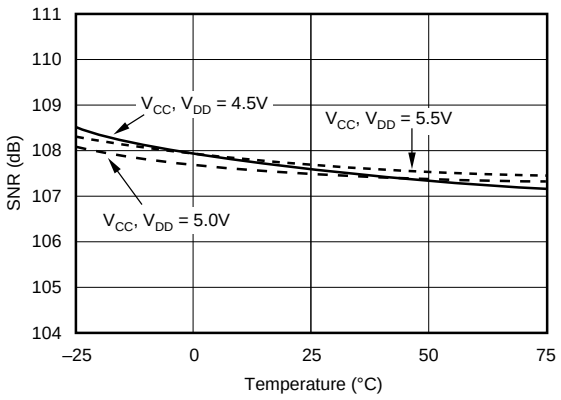


# TYPICAL PERFORMANCE CURVES (CONT)

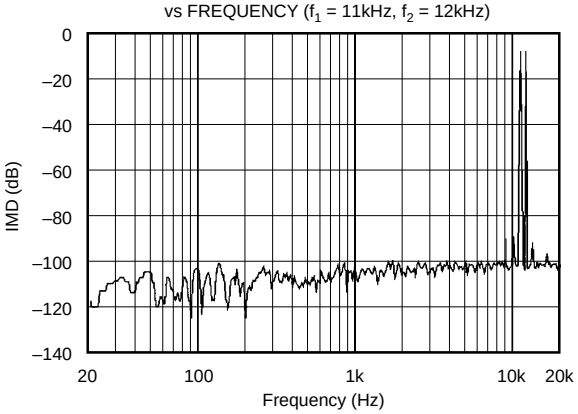
At $T_A$ = +25°C, $V_S$ = ±5V, $R_L$ = 100Ω, $C_L$ = 2pF, and $R_{FB}$ = 402Ω, unless otherwise noted. Based on 200 piece sample from 3 diffusion runs.

## DYNAMIC PERFORMANCE

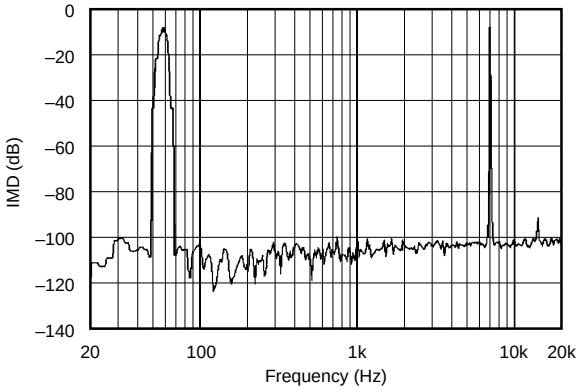
384fs
SNR vs TEMPERATURE and POWER SUPPLY




INTERMODULATION DISTORTION
vs FREQUENCY ($f_1$ = 11kHz, $f_2$ = 12kHz)




INTERMODULATION DISTORTION
vs FREQUENCY ($f_1$ = 60Hz, $f_2$ = 7kHz)




**CAUTION:** Minimum and maximum values on typical performance curves are not meant to imply a guarantee. Curves should be used for reference only. Refer to specification for guaranteed performances.

# FUNCTIONAL DESCRIPTION

PCM1710 has several built-in functions including digital attenuation, digital de-emphasis and soft mute. These functions are software controlled. PCM1710 can be operated in two different modes, **Serial** or **Parallel**. Serial Mode is a three-wire interface using pin 26 (MD), pin 27 (MC), and pin 28 (ML). Data on these pins are used to control de-emphasis mode, mute, double-speed dubbing, input resolution and input format. PCM1710 can also be operated in parallel mode, where static control signals are used on pin 26 (DM1), pin 27 (DM2), and pin 28 (DSD). Operation of both of these modes are covered in detail in the next sections.

**CAUTION**: Mode control signals operate on level triggered logic. The minimum timing conditions detailed in Figures 5 and 6 MUST be observed.

### MODE CONTROL: SERIAL/PARALLEL SELECTION

| | |
|---|---|
| MODE = H | Serial Mode |
| MODE = L | Parallel Mode |

TABLE III. Serial and Parallel Mode are Selectable by MODE Pin (Pin 24).

### MODE CONTROL: SELECTABLE FUNCTIONS

| FUNCTION | SERIAL MODE (MODE = H) | PARALLEL MODE (MODE = L) |
|---|---|---|
| Input Data Format Selection | 0 | X(Normal Mode Fixed) |
| Input Data Bit Selection | 0 | X(16-bit Fixed) |
| Input LRCI Polarity Selection | 0 | X |
| De-emphasis Control | 0 | 0 |
| Mute | 0 | 0 |
| Attenuation | 0 | X |
| Double Speed Dubbing | 0 | 0 |
| NOTE: 0: Selectable, X: Not Selectable. | | |

TABLE IV. Selectable Functions in Serial Mode and Parallel Mode.

Table IV indicates which functions are selectable within the user's chosen mode. All of the functions shown are selectable within the serial mode, but only de-emphasis control, mute and double-speed dubbing may be selected when using PCM1710 in the parallel mode.

### PARALLEL-MODE: DE-EMPHASIS CONTROL (PIN 24 [MODE] = L)

| DM1 (Pin 26) | DM2 (Pin 27) | De-emphasis |
|---|---|---|
| L | L | OFF |
| H | L | 32kHz |
| L | H | 48kHz |
| H | H | 44.1kHz |

TABLE V. De-emphasis (Pins 26 and 27).

In the parallel mode, de-emphasis conditions are controlled by the logic levels on pin 26 (DM1) and pin 27 (DM2). For PCM1710, de-emphasis can operate at 32kHz, 44.1kHz, 48kHz, or disabled.

### PARALLEL-MODE: DOUBLE-SPEED DUBBING CONTROL (PIN 24 [MODE] = L)

| | |
|---|---|
| DSD = H | Normal Mode |
| DSD = L | Double-Speed Dubbing Mode |
| NOTE: When the Double-Speed Dubbing Mode is selected, the System Clock must be 384fs (CKSL: Pin 23 = H). | |

TABLE VI. DSD (Pin 28).

In the parallel mode, double-speed dubbing can be enabled by holding pin 28 (DSD) at a logic "low".

**CAUTION:** Double-speed dubbing cannot operate if the system clock is set at 256fs.

### SERIAL MODE CONTROL

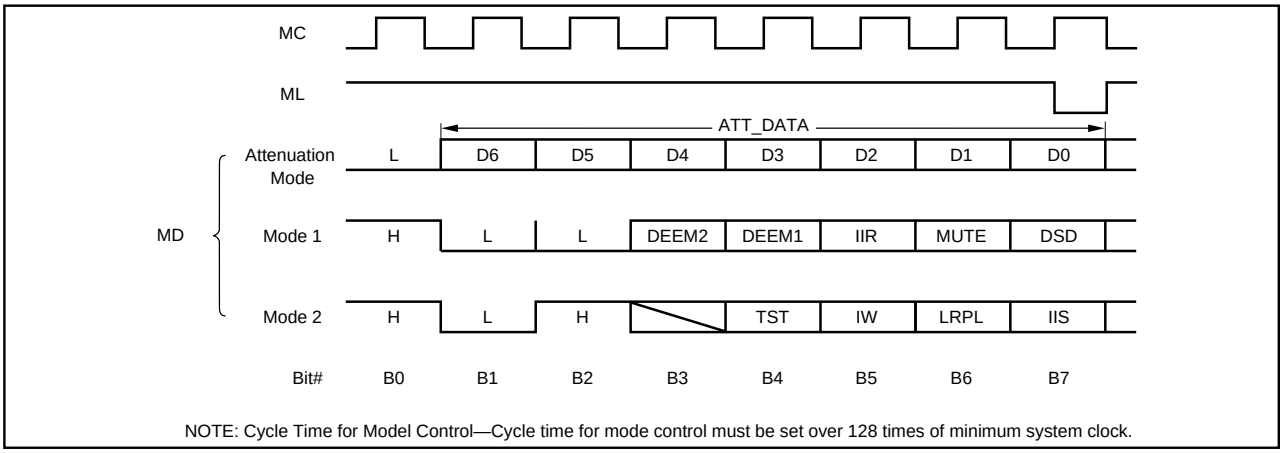
In order to use all of PCM1710's functionality, the **serial mode control** should be used. PCM1710 must be addressed three separate times to set all of the various registers and flags that control these functions.

Table VII together with Figure 6 details the control of the PCM1710 in the serial mode. Internal latches are used to hold this serial data until the PCM1710 is enabled to use the data. The serial mode is used by applying clocked data to the following pins:

| NAME | PIN | FUNCTION |
|---|---|---|
| MC | 27 | Clock for Strobing in Data |
| ML | 28 | Latches Data into the Registers |
| MD | 26 | 8-bit Data Word Defining Operation |

| | B0 | B1 | B2 | BIT NO. | MODE FLAG | FUNCTION MODE SELECTION | | | MODE BY DEFAULT |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | MODE | BIT VALUE | SELECTED FUNCTION | |
| Mode 1 | H | L | L | B3 | DEEM2 | Sampling Frequency for De-emphasis | | DEEM2: 0 / 1; DEEM1: 0 → 48kHz; 1 → 32kHz / 44.1kHz | |
| | | | | B4 | DEEM1 | | | | |
| | | | | B5 | IIR | De-emphasis | 0 | De-emphasis OFF | OFF |
| | | | | | | | 1 | De-emphasis ON | |
| | | | | B6 | MUTE | Mute | 0 | Mute OFF | OFF |
| | | | | | | | 1 | Mute ON | |
| | | | | B7 | DSD | Double-Speed | 0 | Double-speed OFF | OFF |
| | | | | | | | 1 | Double-speed ON | |
| Mode 2 | H | L | H | B3 | | Not Assigned | | | |
| | | | | B4 | TST | Test Mode | 0 | Infinite Zero Detection OFF | ON |
| | | | | | | | 1 | Infinite Zero Detection ON | |
| | | | | B5 | IW | Input Resolution | 0 | 16-Bit | 16-Bit |
| | | | | | | | 1 | 20-Bit | |
| | | | | B6 | LRPL | Polarity for LRCI | 0 | Lch:high/Rch:low | Lch:high Rch:low |
| | | | | | | | 1 | Lch:low/Rch:high | |
| | | | | B7 | IIS | Input Format | 0 | Normal | Normal |
| | | | | | | | 1 | IIS | |

TABLE VII. Serial-Mode Control Input Format (Pin 24 [MODE] = H)—Refer to Figure 6 for Timing Diagram.




NOTE: Cycle Time for Model Control—Cycle time for mode control must be set over 128 times of minimum system clock.

FIGURE 6. Mode Control Input Format, Serial Mode.

### DIGITAL ATTENUATION

One of the functions which can be implemented through use of the serial mode control is attenuation. This function allows the user to control the level of the output, independent of the of the input level set by the actual input data supplied to the DAC.

Referring to Figure 6, when the first data bit (B0) on MD (pin 26) is low, the attenuation function is enabled. The next seven bits (B1 - B6) define a binary value, ATT_DATA, that indicates the desired level of attenuation. The attenuation level is given by:

$$\text{Level} = 20\log_{10}(1 - \text{ATT_DATA}/127)\ \text{dB}$$

When all 7 bits of the ATT_DATA word are high (ATT_DATA = 127), attenuation is infinite and the output of PCM1710 will be zero.

## MODE 1 CONTROLS

This mode can be enabled with the sequence of 1, 0, 0 as the first three bits on MD (pin 26). This mode allows for the following functions:

| | |
|---|---|
| De-emphasis | On/Off |
| De-emphasis Frequency | 32kHz, 44.1kHz, 48kHz |
| Soft Mute | On/Off |
| Double-Speed Dubbing | On/Off |

### DIGITAL DE-EMPHASIS

PCM1710 allows three different sampling rates for digital de-emphasis. B3 and B4 are used for binary control of the de-emphasis frequency:

| B3 | B4 | Frequency |
|---|---|---|
| 0 | 0 | OFF |
| 0 | 1 | 48kHz |
| 1 | 0 | 32kHz |
| 1 | 1 | 44.1kHz |

Once the reset has been established on pin 27 (MC), the de-emphasis frequency defaults to 44.1kHz. B5 is a master control for de-emphasis. A high level on B5 enables de-emphasis (frequency controlled by B3 and B4), and a low level on B5 disables de-emphasis.

### SOFT MUTE

Soft mute is enabled when B6 is high. The soft mute occurs gradually, unlike the forced infinite zero detection. When the mute data bit is high, complete muting will occur in 127/fs seconds. For $f_S$ = 44.1kHz, complete mute will occur in 2.88ms.

### DOUBLE-SPEED DUBBING

Double-speed dubbing is used when the application allows for the CD to be copied at twice the normal playback rate. Double-speed dubbing is enabled when B7 is high. This mode can only operate when the system clock is set at 384fs. Double-speed dubbing can only occur when the sample rate is 44.1kHz. Since $f_S$ is set at 44.1kHz, the system clock in double-speed mode is at 192fs.

## MODE 2 CONTROLS

Mode 2 is enabled when B0 is high, B1 is low, and B2 is high. This mode controls infinite zero detection, input resolution, LRCI polarity and input format.

### INFINITE ZERO DETECTION

B4 is used to enable or disable infinite zero detection. PCM1710 monitors both data input (DIN) and bit clock (BCKIN). When the data input is continuously zero or one for 65,536 cycles of the bit clock, infinite zero detection occurs, which forces the output of the PCM1710 to one-half of $V_{CC}$ (typically 2.5V). Once this happens, only the output amplifier is connected. This is done to avoid having the noise shaped output spectrum of the DAC appear at the output of the PCM1710. This function is especially useful for CD applications when the player is between tracks. An inherent attribute of all delta-sigma architectures is the presence of quantization noise when the input is constant (all 1s or 0s). When the zero detect circuit disconnects the DAC from the output amplifier, a very low level "click" noise may be audible. The click noise occurs at approximately –76dB, and in many cases is inaudible.

### INPUT RESOLUTION

PCM1710 is capable of accepting either 16-bit or 20-bit input data. Specifications for PCM1710 are tested and guaranteed using 16-bit data. When 20 bits are used, dynamic performance is improved by approximately 2dB. Refer to "Typical Performance Curves" for a comparison of 16-bit and 20-bit data. A low on B5 places PCM1710 in 16-bit mode, and a high on B5 sets PCM1710 to 20-bit mode.

### SAMPLE RATE CLOCK POLARITY

B6 controls the polarity of the sample rate clock (LRCIN) polarity. When B6 is low, data will be accepted on the left channel when LRCIN is high, and on the right channel when LRCIN is low. When B6 is high, data will be accepted on the right channel when LRCIN is high, and on the left channel when LRCIN is low.

### INPUT FORMAT

Normal input mode for PCM1710 is MSB first, right justified. PCM1710 may also be operated with IIS (32 continuous clock cycles per word) input format. When B7 is low, the input format is "normal". When B7 is high, the input format is "IIS". However, PCM1710 can only accept IIS input format when it is in 16-bit mode. 20-bit data must be entered in normal mode.

### DEFAULT MODE

At initial power-on, default settings for PCM1710 are 44.1kHz $f_S$, de-emphasis off, mute off, double-speed off, infinite zero detect on, 16-bit input LRCIN left channel high, and normal input mode.

### SYSTEM CLOCK

| SAMPLING FREQUENCY | SYSTEM CLOCK FREQUENCY |
|---|---|
| 32kHz | 256fs 8.1920MHz |
| 32kHz | 384fs 12.2880MHz |
| 44.1kHz | 256fs 11.2896MHz |
| 44.1kHz | 384fs 16.9344MHz |
| 48kHz | 256fs 12.2880MHz |
| 48kHz | 384fs 18.4320MHz |

TABLE VIII. Relationship of fs and System Clock.

### NORMAL/DOUBLE-SPEED DUBBING

For most CD playback applications operating at 384fs, the system clock frequency must be 16.9344MHz, in both the normal mode and double-speed dubbing mode. Table VIII illustrates the relationship between fs and output clock frequency in both modes.

| PARAMETER | ML/DSD (PIN 28) | |
|---|---|---|
| | H (Normal) | L (Double Speed) |
| XTI Input Clock Frequency | 384fs | 192fs |
| XTI Frequency | 16.9344MHz ($f_S$ = 44.1kHz) | 16.9344MHz ($f_S$ = 88.2kHz) |
| CLKO Output Clock Frequency | 384fs | 192fs |

TABLE IX. Relationship Between Normal/Double Speed and fs.

### EXTERNAL SYSTEM CLOCK

Figure 7 is a diagram showing the internal clock in conjunction with an external crystal oscillator.

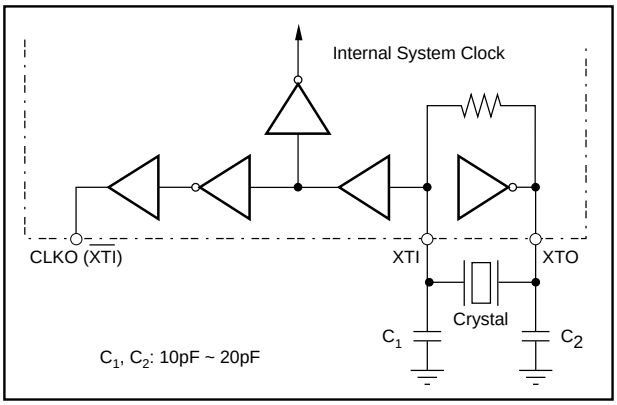



FIGURE 7. External Crystal Oscillator.

Figure 8 is a diagram showing the internal clock with an external clock source, instead of an oscillator. An external system clock (input to XTI) must meet the following conditions:

| | | |
|---|---|---|
| **HIGH LEVEL** | $V_{IH} > 0.64V_{DD}$ | $T_H > 10ns$ |
| **LOW LEVEL** | $V_{IH} > 0.28V_{DD}$ | $T_L > 10ns$ |

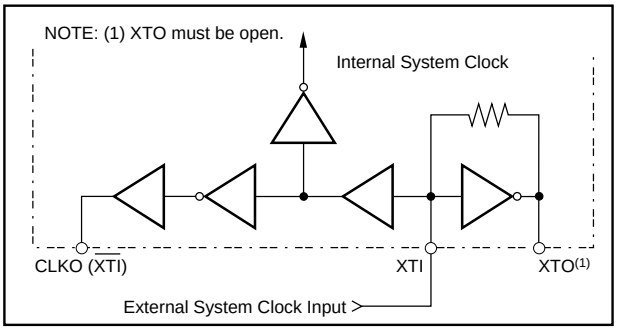



FIGURE 8. External System Clock.

## POWER SUPPLY CONNECTIONS

PCM1710 has two power supply connections: digital ($V_{DD}$) and analog ($V_{CC}$). Each connection also has a separate ground. If the power supplies turn on at different times, there is a possibility of a latch-up condition. To avoid this condition, it is recommended to have a common connection between the digital and analog power supplies. If separate supplies are used without a common connection, the delta between the two supplies during ramp-up time must be less than 0.6V.

An application circuit to avoid a latch-up condition is shown in Figure 9.

### BYPASSING POWER SUPPLIES

The power supplies should be bypassed as close as possible to the unit. Refer to Figure 19 for optimal values of bypass capacitors. For applications which require very high performance at low levels (such as keyboards, synthesizers, etc.) it may be beneficial to provide additional bypassing on pin 15 ($V_{CC1}$) with a low ESR 100µF capacitor. This will eliminate stray tones which may be above the noise floor.

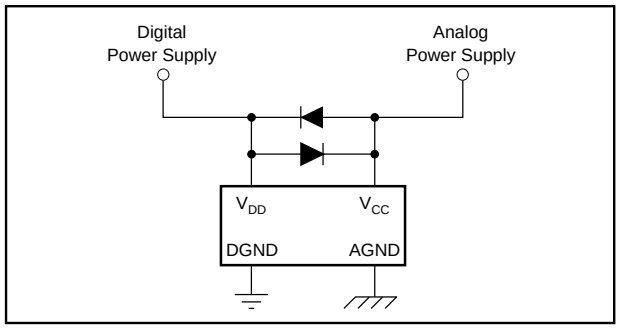



FIGURE 9. Latch-up Prevention Circuit.

## THEORY OF OPERATION

PCM1710 is an oversampling delta-sigma D/A converter, consisting of an input interface/attenuator, a 4th-order multi-level delta-sigma modulator, a low pass filter and an output amplifier (see Figure 10).

Multi Level Delta Sigma

### MODULATOR

The delta-sigma section of the PCM1710 is based on a 5-level amplitude quantizer and a 4th-order filter. This converts oversampled 16-or 20-bit input data to 5-level delta-sigma format. A block diagram of the 5-level modulator is shown in Figure 11.

This 5-level delta-sigma modulator has the advantage of improved stability and jitter sensitivity over the typical one bit (2-level) delta-sigma modulator.

The combined oversampling rate of the delta-sigma modulator and the internal 8X oversampling digital filter is 48fs at a system clock of 384fs and 32fs at a system clock of 256fs.

A block diagram of the 4th-order filter section Hf (z) in the delta-sigma modulator is shown in Figure 12.

In general, high order one-bit delta-sigma modulators have disadvantages due to loop instability (multiple integration stages). The five level delta-sigma modulator of the PCM1710 uses phase compensation techniques to obtain stable operation. In Figure 12, the coefficients B1 to B4 give the basic form of the filter, and A2 to A4 are used for phase compensation of the feedback loop.

The theoretical quantization noise performance of five level delta-sigma modulator is shown in Figure 13 and 14. In the audio band, the quantization noise floor level of the PCM1710 is less than 130dB (at a system clock of 384fs).

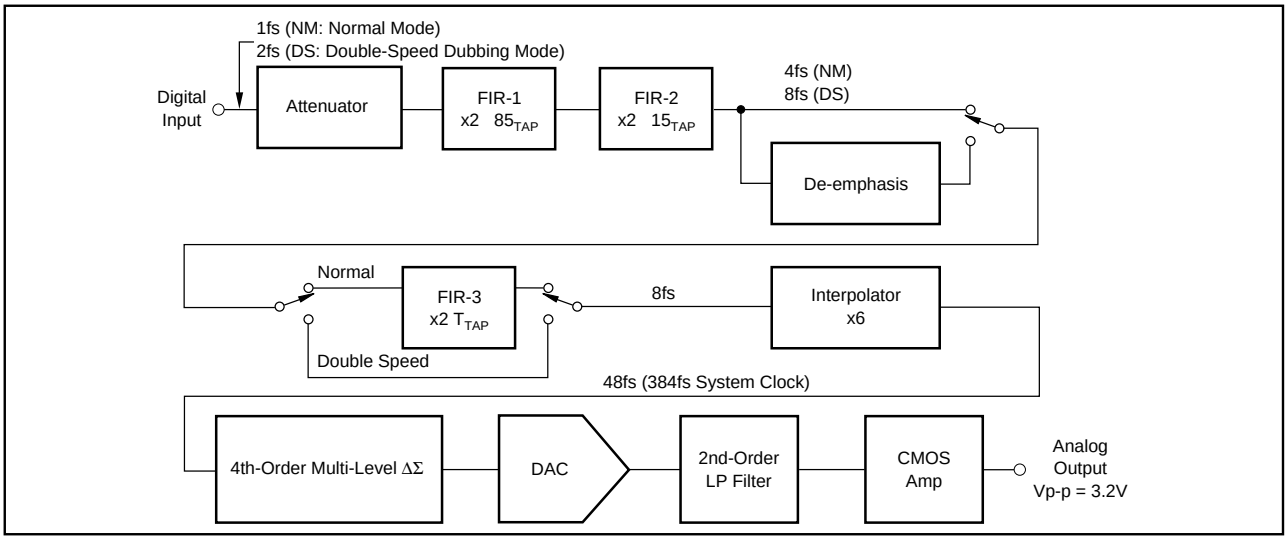



FIGURE 10. PCM1710 Block Diagram.

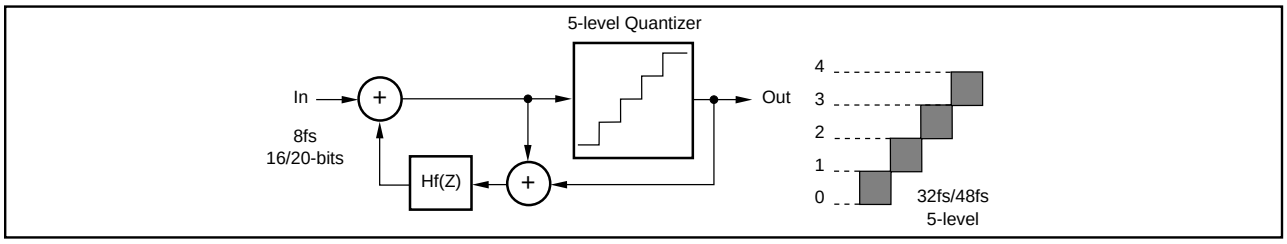



FIGURE 11. Block Diagram of Multi-level ΔΣ Modulator.

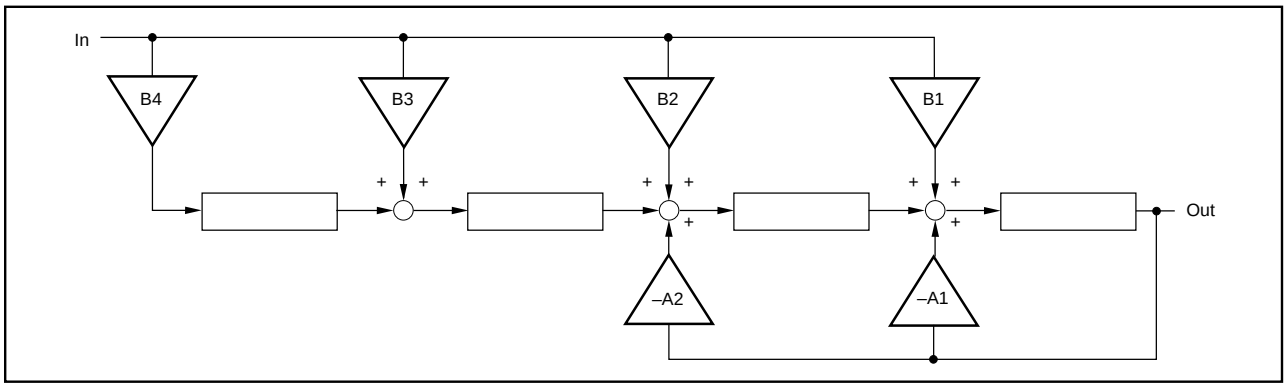



FIGURE 12. Block Diagram of 4th-order Filter Section ($H_f$ (z)).

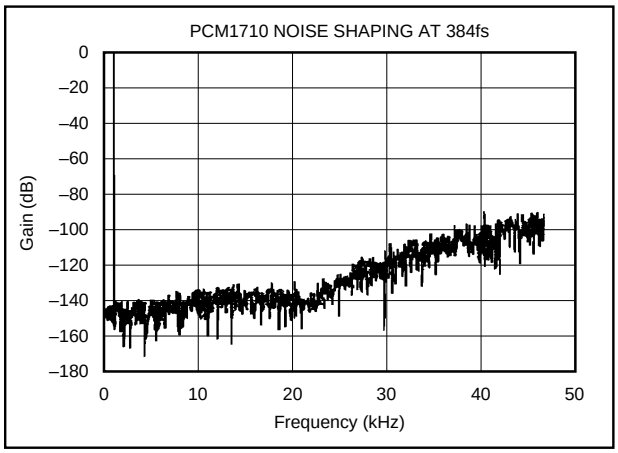



FIGURE 13. Theoretical Modulator Performance at 384fs.

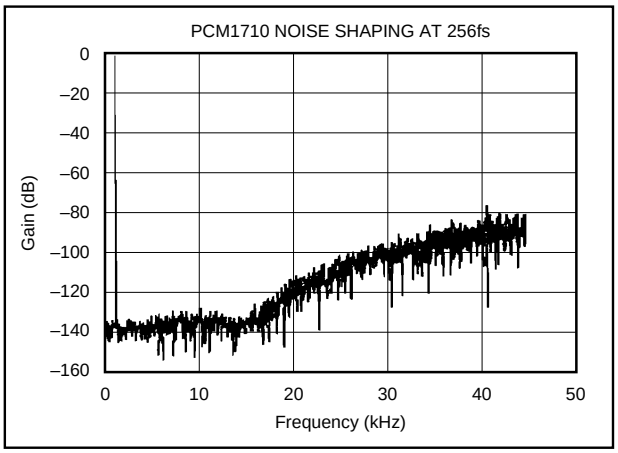



FIGURE 14. Theoretical Modulator Performance at 256fs.

# APPLICATION CONSIDERATIONS

## 16-BIT vs 20-BIT OPERATION

In the serial mode, PCM1710 can be configured to accept either 16-bit or 20-bit data. The specifications listed in this data sheet are the 16-bit data. Some improvements in dynamic performance can be realized by using 20-bit data.

Internally, the PCM1710's digital filter uses only 20-bit data. If the input data is 16-bit, the filter adds four zeros to complete the 20-bit input word. Typical performance differences between 16-bit and 20-bit data are shown in Tables X and XI.

| DATA | 256fs | 384fs |
|---|---|---|
| 16-bit | –91dB | –93dB |
| 20-bit | –94dB | –96dB |

TABLE X. THD+N Performance at Full Scale.

| DATA | 256fs | 384fs |
|---|---|---|
| 16-bit | 94dB | 96dB |
| 20-bit | 96dB | 98dB |

TABLE XI. Dynamic Range.

## DELAY TIME

There is a finite delay time in delta-sigma converters. In A/D converters, this is commonly referred to as latency. For a delta-sigma D/A converter, delay time is determined by the order number of the FIR filter stage, and the chosen sampling rate. The following equation expresses the delay time of PCM1710:

$$T_D = 22.625 \times 1/fs$$

For $f_S$ = 44.1kHz, $T_D$ = 22.625/44.1kHz = 513.04µs

Applications using data from a disc or tape source, such as CD audio, CD-Interactive, Video CD, DAT, Minidisc, etc., generally are not affected by delay time. For some professional applications such as broadcast audio for studios, it is important for total delay time to be less than 2ms.

## INTERNAL RESET

If the sample rate clock (LRCIN) is stopped during operation, the infinite zero detect circuit will cause the output to go to $V_{CC}/2$ after 65,536 cycles of the bit clock (BCKIN). Once a new system clock has been applied, there will be a delay until output data is correlated to the input. This is due to the digital delay of the filter.

When power is first applied to PCM1710, an automatic reset function occurs after 64 cycles of LRCIN.

## CHANGING SAMPLING RATE

For normal operation, LRCIN and XTI should be synchronized at either 256fs or 384fs. When the sampling rate is changed during operation, output data is invalid during the delay period ($T_D$) and for two subsequent cycles of LRCIN. After two cycles of LRCIN, the output is a valid representation of the input data.

## OUTPUT FILTERING

For testing purposes all dynamic tests are done on the PCM1710 using a 20kHz low pass filter. This filter limits the measured bandwidth for THD+N, etc. to 20kHz. Failure to use such a filter will result in higher THD+N and lower SNR and Dynamic Range readings than are found in the specifications. The low pass filter removes out of band noise. Although it is not audible, it may affect dynamic specification numbers.

The performance of the internal low pass filter from DC to 24kHz is shown in Figure 15. The higher frequency rolloff of the filter is shown in Figure 16. If the user's application has the PCM1710 driving a wideband amplifier, it is recommended to use an external low pass filter. A simple 3rd-order filter is shown in Figure 17. For some applications, a passive RC filter or 2nd-order filter may be adequate.

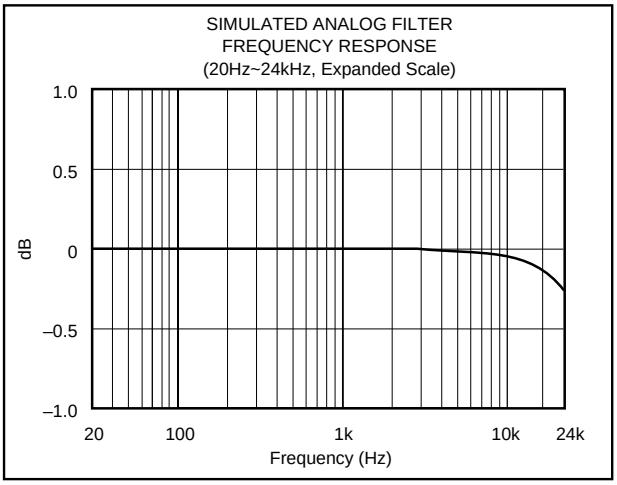



FIGURE 15. Low Pass Filter Frequency Response.

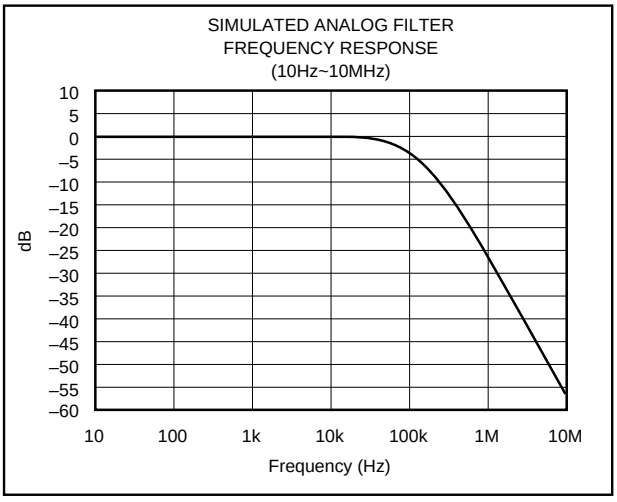



FIGURE 16. Low Pass Filter Frequency Response.

## TEST CONDITIONS

Figure 18 illustrates the actual test conditions applied to PCM1710 in production. The 11th-order filter is necessary in the production environment for the removal of noise, resulting from the relatively long physical distance between the unit and the test analyzer. In most actual applications, the third-order filter shown in Figure 17 is adequate. Under normal conditions, THD+N typical performance is –70dB with a 30kHz low pass filter (shown here on the THD meter), improving to –92dB when the external 20kHz second-order filter is used.

## EVALUATION FIXTURES

Two different evaluation fixtures are available for PCM1710.

### DEM-PCM1710

This evaluation fixture is primarily intended for quick evaluation of the PCM1710's performance. DEM-PCM1710 can accept either an external clock or a user-installed crystal oscillator. All of the functions can be controlled by on-board switches. DEM-PCM1710 does not contain a receiver chip or an external low pass filter. DEM-PCM1710 requires a single +5V power supply.

### DEM-DAI1710

This fixture is more complete than DEM-PCM1710; it includes a Digital Audio Interface (DAI) receiver chip for easy use and to provide a low-jitter 256fs system clock to the PCM1710. Also included are dual second-order low pass filters using Burr-Brown's OPA2604 dual FET-input op amp. The output of the DEM-DAI1710 is 2Vrms, using standard BNC-type connectors.

All of the functions of PCM1710 can be evaluated by using the DEM-DAI1710 jumper selections. DEM-DAI1710 requires +5V and ±5V to ±15V power supplies. The schematic diagram for DEM-DAI1710 is shown in Figure 19. For more detailed information on the evaluation fixtures, contact your local Burr-Brown representative.

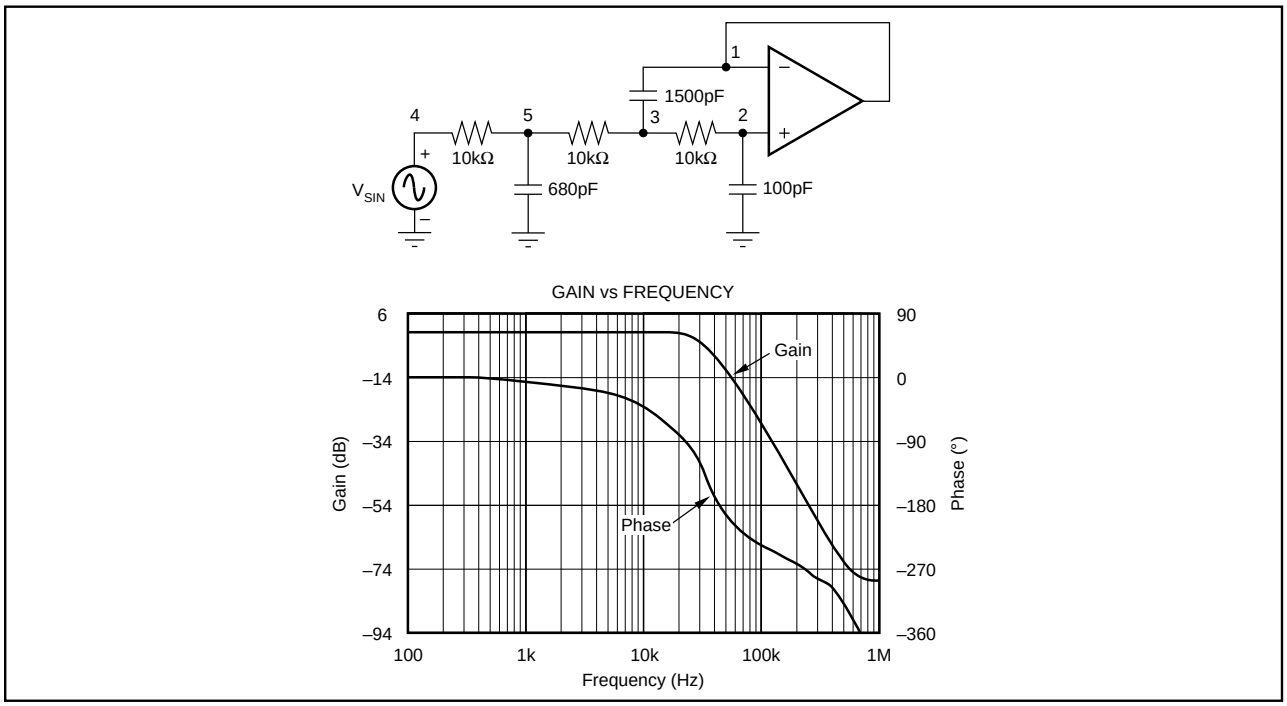



FIGURE 17. 3rd-Order LPF.

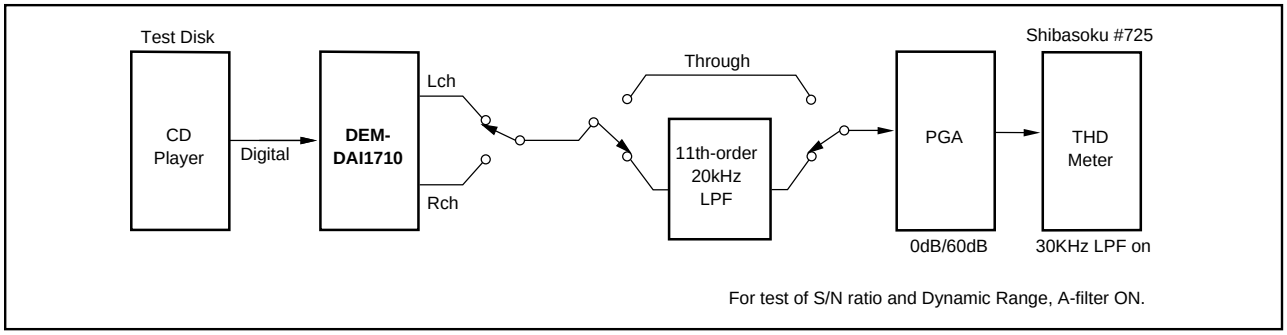



FIGURE 18. Test Block Diagram.

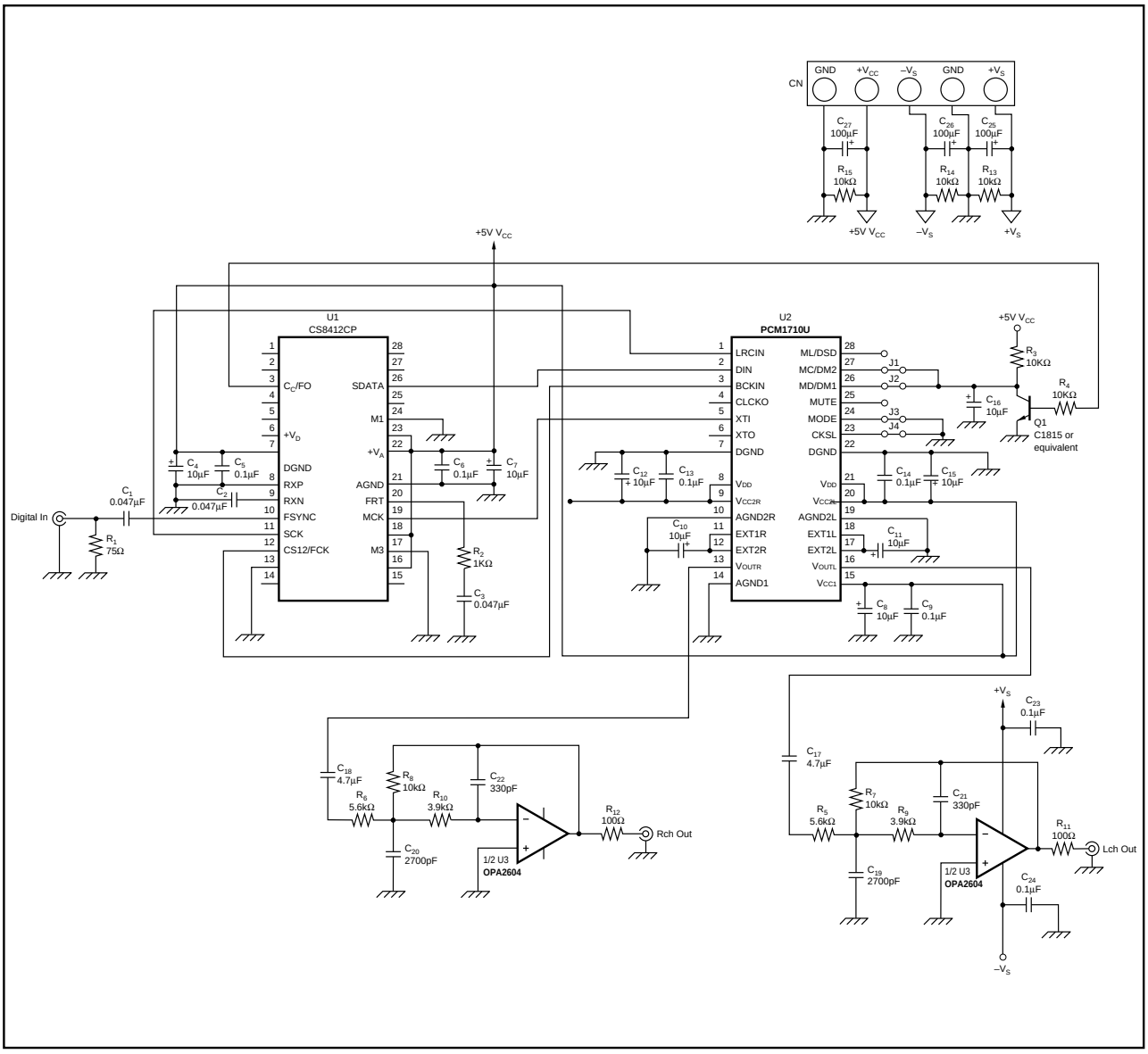



FIGURE 19. DEM-DAI1710 Schematic Circuit Diagram.

## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish | MSL Peak Temp (3) |
|---|---|---|---|---|---|---|---|---|
| PCM1710U | NRND | SOIC | DW | 28 | 28 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| PCM1710U/1K | NRND | SOIC | DW | 28 | 1000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| PCM1710U/1KG4 | NRND | SOIC | DW | 28 | 1000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| PCM1710UG4 | NRND | SOIC | DW | 28 | 28 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |

(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) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
**TBD:** The Pb-Free/Green conversion plan has not been defined.
**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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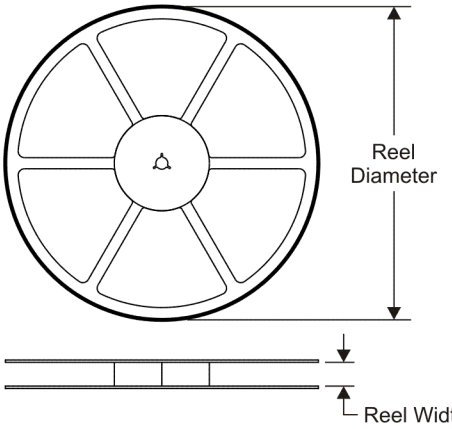
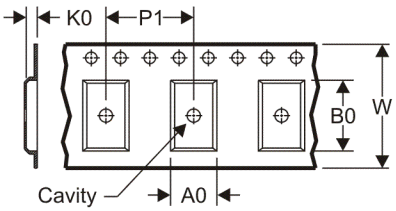
## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

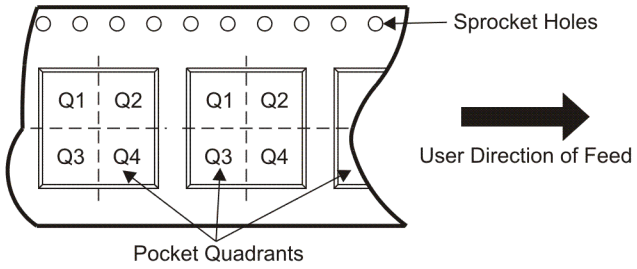



**TAPE DIMENSIONS**




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

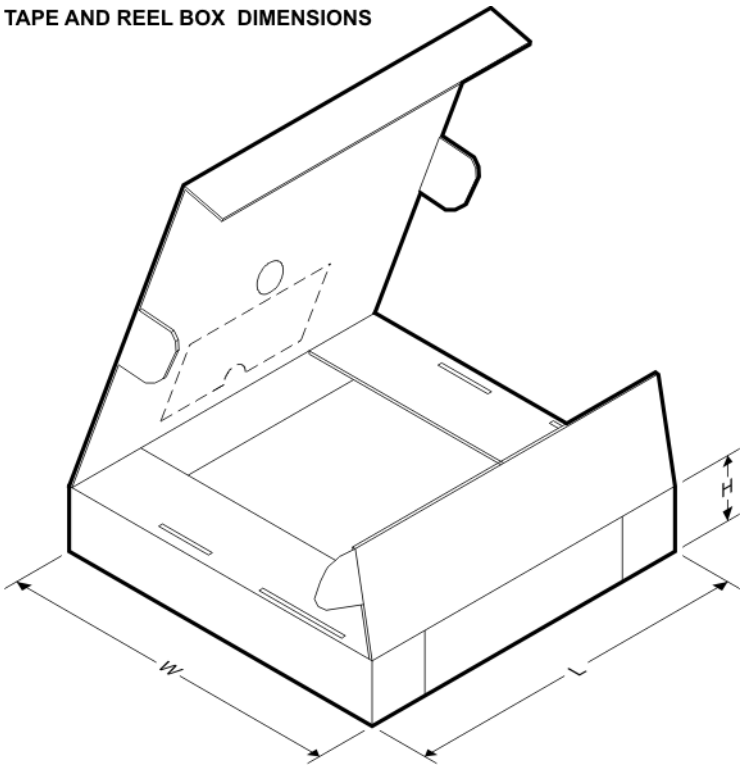
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PCM1710U/1K | SOIC | DW | 28 | 1000 | 330.0 | 25.4 | 10.9 | 18.2 | 2.9 | 16.0 | 24.0 | Q1 |

**TAPE AND REEL BOX DIMENSIONS**




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| PCM1710U/1K | SOIC | DW | 28 | 1000 | 333.2 | 345.9 | 31.8 |

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