

Microsoft®



A Windows Media™ Technology

HDCD® Process Decoder Gain Scale Application Note

INTRODUCTION

A key feature of the HDCD process is Peak Extend. Peak Extend increases the dynamic range of Redbook CDs by 6dB. The Peak Extend feature is selectable on the Model 1 (or Model 2) HDCD encoder - the recording or mastering engineer has the ability to set Peak Extend ON or OFF on the Model 1 HDCD encoder. So it is possible to have HDCD recordings with, or without Peak Extend. Because Peak Extend adds 6dB of dynamic range to the top end, the "average" decoded signal level will be 6dB lower than an HDCD recording without Peak Extend, or a non-HDCD recording. Unless the decoded level of Peak Extended and non-Peak Extended recordings are matched using Gain Scaling, Peak Extended Recordings will be 6dB quieter than non-Peak Extended recordings and this is not acceptable. All HDCD decoders must either 1) lower the gain of non-HDCD recordings and HDCD recordings without Peak Extend by 6dB, or 2) raise the gain of the Peak Extended recording 6dB. This is a requirement of the HDCD license agreement. This gain matching can be done in either the digital domain or the analog domain, as explained later in this application note.

Peak Extend and Gain Scale Basics

It's very important to remember that by definition, non-Peak Extended recordings are either:

- 1) an HDCD encoded non-Peak Extended recording

- OR -

- 2) non-HDCD encoded recording (in other words, standard PCM 16 bit recordings)

When any HDCD Process Decoder recognizes an HDCD Peak Extended recording, it reduces the decoded average signal level of this recording only, to allow for the increased head room of the "extra" 6dB of dynamic range. For the other cases - HDCD recordings without Peak Extend, or non-HDCD recordings - the average decoded levels need to be matched to the decoded HDCD Peak Extended recording. This 6dB gain matching could have been built into the HDCD decoder, and done digitally, automatically, however we have given the user the option of doing the gain matching in the analog domain, which may offer some sonic benefits. Table 1 summarizes these average and peak level differences using an example of a -20dB average and 0dBfs peak level in the original material.

HDCD® and High Definition Compatible Digital® are registered trademarks of Pacific Microsonics, Inc.

Microsoft Corporation

One Microsoft Way, Redmond WA 98052 • hdclops@microsoft.com • www.hdcd.com
HDCD Gain Scale, Rev 0.1



RECORDED LEVEL	HDCD DECODED	Non-HDCD DECODED
Model 1 with Peak Extension ON	Ave. Level = -26dB Pk. Level = 0dBfs	Ave. Level = -20dB Pk. Level = 0dBfs
Model 1 with Peak Extension OFF	Ave. Level = -20dB Pk. Level = 0dBfs	Ave. Level = -20dB Pk. Level = 0dBfs
Standard 16 Bit PCM	Ave. Level = -20dB Pk. Level = 0dBfs	Ave. Level = -20dB Pk. Level = 0dBfs

Table 1
HDCD versus Non-HDCD Decode
Level Summary

As you can see, the average level is at -26dB in the HDCD decoded case and is at -20dB in the non-HDCD decoded case. In addition, one can also see that when the Model 1 is used to encode the recording and Peak Extension is OFF, regardless of the type of playback technology employed (i.e., whether the player or DAC has HDCD decoding or not), the average and peak decode levels remain at -20dB and 0dBfs, respectively. **We decrease the average signal level of HDCD encoded Peak Extended recordings by 6dB in order to fit the increased dynamic range of the recording below the 0dBfs digital limit (and hence into the rest of the circuitry following the HDCD process decoder).** Since human perception of “loudness” is determined by average levels and not peak levels, decoded Peak Extend recordings will thus sound 6dB quieter than non-Peak Extend recordings unless the difference in average levels is compensated for after the decoding has been performed. This 6dB average volume level difference originates from the HDCD mastering process when the Model 1 is used to convert and process the source material with the Peak Extend option turned on. The patented complementary HDCD process consists of the Model 1 HDCD encoder with decimation filtering and the HDCD process decoder interpolation filter.

Model 1 HDCD Encoder

First, the Model 1 is used to convert and process the audio data. The Model 1 is an extremely accurate, dual channel 24 bit A/D converter, Digital Processor, and decimation filter that performs the conversion of the source material to HDCD encoded 16 bit digital data. The Model 1 has several options available to the recording engineer to increase dynamic range during decoded playback, Peak Extend among them. It is very important to remember that the use of Peak Extend is optional at the time of recording.

Microsoft®



A Windows Media™ Technology

HDCD Process Decoder

Secondly, the HDCD process decoder and interpolation filter are used in a playback unit (such as a CD Player, DAC, Signal Processor, or DVD Player) to decode the HDCD recording. The HDCD interpolation filter also functions as a state of the art Digital Filter when fed data from non-HDCD recordings. When the HDCD decoder identifies an HDCD 16 bit recording, it decodes the HDCD process data and can tell if Peak Extend was used in the mastering process. Peak Extend is a restorable, instantaneous soft peak limiter which has a direct one - to -one mapping so that it can be easily and quickly restored in the HDCD decoder. Because this operation is performed digitally, it has a precise and stable curve (see Figure 1).

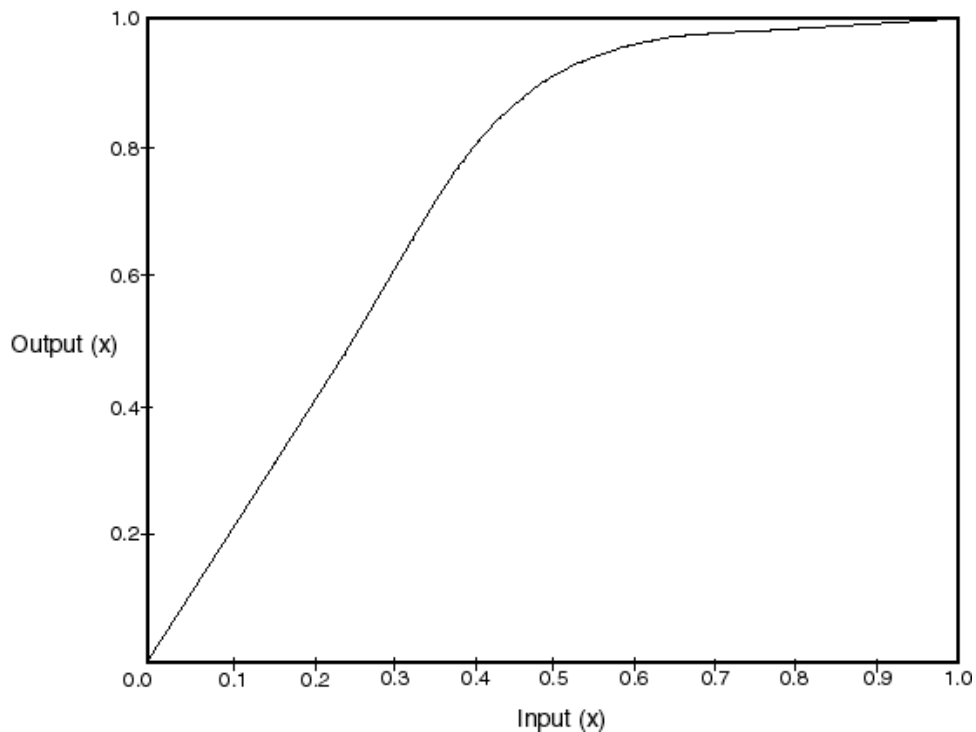


Figure 1
Peak Extension Limit Curve

Its intended use is for wide dynamic range source material. For all signal levels below the beginning of the limit, there is no effect on the signal other than a constant gain factor. The current HDCD process gain factor is two, allowing the average signal level to be increased by as much as 6dB or 1 bit for material with very high but infrequent peaks. During the mastering process using the Model 1, if the recording engineer wants to increase the dynamic range of the recording, then Peak Extend can be enabled.

Microsoft Corporation

One Microsoft Way, Redmond WA 98052 • hdclops@microsoft.com • www.hdc.com
HDCD Gain Scale, Rev 0.1

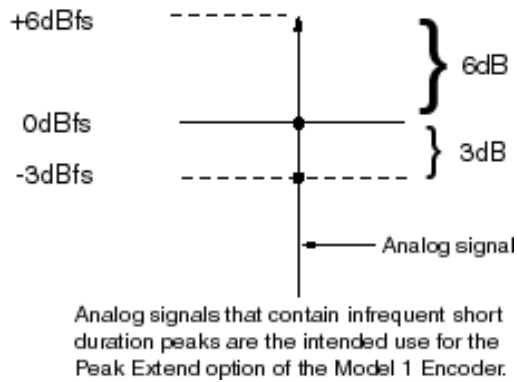


Figure 2
Before HDCD Encode

Please refer to Figures 2 and 3 for an example of this option - as one can see, the top 3dB (i.e., -3dBfs to 0dBfs) of the HDCD recording actually contains 9dB of compressed signal that is uncompressed when decoded by the HDCD decoder. Peak signal levels are increased up to 6dB above 0dBfs (again, after decoding), which effectively increases the signal's dynamic range by 6dB. The use of Peak Extend also raises the level of the rest of the program, which is a real sonic benefit even when using standard players or DACs (that are not equipped with an HDCD decoder).

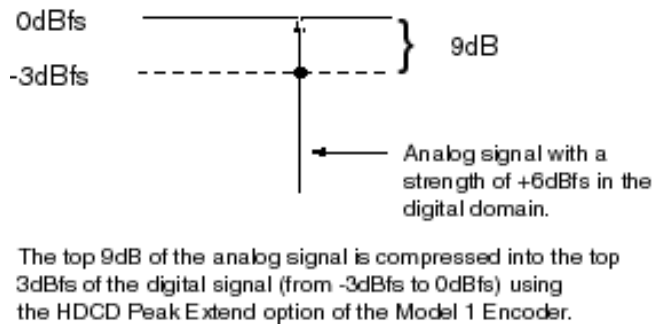


Figure 3
After HDCD Encode

Here's how ... Because the Model 1 compresses the top 9dB of the signal (when Peak Extend has been enabled), the rest of the signal is "in effect" pushed up. This effect increases low level signals, improving low level resolution by approximately 1 bit on standard players or DACs.

To produce this increased dynamic range and because the peak digital signal level prior to decoding is 0dBfs (which cannot increase beyond 0dBfs in the digital domain by definition), **the average signal level of decoded HDCD Peak Extend recordings must be decreased by 6dB** (to allow for the increased head room of the "extra" 6dB). As stated earlier in this application note and worth mentioning again, we perceive loudness by average levels and not peak levels.

Microsoft®



A Windows Media™ Technology

Decoded Peak Extension encoded recordings will thus sound 6dB quieter than non-Peak Extension recordings, unless the difference in average levels is compensated for after the decoding has been performed. Key to this discussion is that the 6dB average level difference originates from the HDCD process used to encode the material when the recording was produced using the Model 1 with the Peak Extend option enabled.

Analog or Digital Gain Scaling?

For instance, when using one of the many the HDCD Process Decoders, using the Digital Gain Scaling Mode and gain scaling is performed INTERNAL to the HDCD Process Decoder. Of course, the gain of the analog stages following the DAC must be adjusted for correct output levels when the HDCD decoder is used compared to other digital filters. If neither Gain Scaling scheme was performed, whenever playback changed between non-Peak Extended and Peak Extended recordings the listener would have to manually adjust the playback level to maintain the same subjective loudness.

Digital Gain Scaling Mode

When implementing Digital Gain Scaling, the circuit designers task is straightforward. For all HDCD Process Decoder implementations, simply configure the SCAL function to select Digital Gain Scaling – all playback level adjustments are performed INTERNAL to the HDCD Process Decoder. Of course, the gain of the analog stages following the DAC must be adjusted for correct output levels when the HDCD decoder is used compared to other digital filters. Also, the analog circuits must be capable of handling the full level of the +6dB peaks.

In Digital Gain Scaling mode, the HDCD Process Decoder automatically reduces the gain 6dB for both types of recordings in order to maintain the same average listening level volume (Peak Extended recordings and non-Peak Extended recordings). Don't forget that non-Peak Extended recordings can be either standard PCM 16 bit recordings or HDCD encoded non-Peak Extended recordings. Use of Digital Gain Scaling mode reduces the complexity of the subsequent analog circuits. It eliminates the need for switching relays or transistor stages to switch the analog gain in and out. These switching methods usually degrade sonics to the inverse of the care with which the design is accomplished, i.e., the more care taken here will reduce sonic degradation - it will not completely eliminate it.

The Digital Gain Scaling solution requires 1 bit of DAC resolution to properly decode Peak Extended recordings. This means that on non-HDCD recordings, the PMD-100 IC loses 1 bit of resolution. In practice, however this is rarely a problem. In fact, this configuration often times sounds better than Analog Gain Scaling, especially for sigma-delta type DACs. Once Analog or Digital Gain Scaling is implemented in a properly designed circuit, the net effect is that any loss of resolution in the DAC is essentially the same for both HDCD and non-HDCD recordings since the average levels are the same (again, in a correctly designed system). Normally an 18 to 20 bit DAC is used to play 16 bit recordings, so the top bit is not a great loss. With sigma-delta DACs, low level linearity is usually good while high level performance may not be.

Microsoft Corporation

One Microsoft Way, Redmond WA 98052 • hdcdops@microsoft.com • www.hdcd.com
HDCD Gain Scale, Rev 0.1

Microsoft®



A Windows Media™ Technology

Analog Gain Scaling Mode

When implementing Analog Gain Scaling, there is no loss of DAC resolution, but idle tones, crosstalk, and noise are brought up in level along with the signal, which frequently causes greater sonic degradation when compared to the loss of 1 bit of DAC resolution in the Digital Gain Scaling method. Using Analog Gain Scaling, the analog circuit designer's task becomes more difficult due to increased circuit complexity. The GAIN flag (or pin) from the HDCD Process Decoder will toggle depending on the Peak Extension status of the recording.

The circuit designer must decide to either increase the analog gain 6dB for Peak Extended recordings or reduce the analog gain 6dB for non-Peak Extended recordings. In either case, there must be a glitch-free 6dB gain stage inserted into the analog circuit for each channel that can be controlled by the Gain output pin of the HDCD decoder. And, as discussed above, the gain of the analog stages following the DAC must be adjusted for correct output levels when the HDCD process decoder is used compared to other digital filters. Also, the analog circuits must be capable of handling the full peak level of the 6dB peaks. We recommend that the gain change stage be capable of switching within 50mSec of the control signal level change to insure proper audio output levels.

SUMMARY

It is important to remember that either Analog or Digital Gain Scaling is required in the implementation of the HDCD Process Decoder because part of the complementary HDCD process includes the option to increase the recorded signal's dynamic range by up to 6dB. This recording option is called Peak Extend in the Model 1 (or Model 2) HDCD Encoder. The HDCD decoding term for restoring this extra dynamic range is called Gain Scaling.

To produce this increased dynamic range and because the peak digital signal level prior to decoding is 0dBfs (which cannot increase beyond 0dBfs in the digital domain by definition), the average signal level of decoded Peak Extended recordings must be decreased by 6dB to allow for the increased head room of the "extra" 6dB.

When Peak Extended and non-Peak Extended recordings are decoded using the HDCD Process Decoder, the Peak Extended recording will be 6dB lower in average volume level when compared to non-Peak Extended recordings. Non-Peak Extended recordings originate from either HDCD encoded non-Peak Extend recordings or from standard PCM 16 bit recordings.

Analog or Digital Gain Scaling implementations affect decoded volume levels differently. When using Digital Gain Scaling, the HDCD Process Decoder automatically matches both types of recordings. When using Analog Gain Scaling, the level adjustments are done by an external circuit. With Analog Gain Scaling, the circuit designer must decide to either reduce the non-Peak Extended recordings 6dB or increase Peak Extended recordings 6dB within 50mSec of the HDCD decoder control signal level change.

Microsoft Corporation

One Microsoft Way, Redmond WA 98052 • hdclops@microsoft.com • www.hdc.com
HDCD Gain Scale, Rev 0.1