

# Audibility of a CD-Standard A/D/A Loop Inserted into High-Resolution Audio Playback\*

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Claims both published and anecdotal are regularly made for audibly superior sound quality for two-channel audio encoded with longer word lengths and/or at higher sampling rates than the 16-bit/44.1-kHz CD standard. The authors report on a series of double-blind tests comparing the analog output of high-resolution players playing high-resolution recordings with the same signal passed through a 16-bit/44.1-kHz “bottleneck.” The tests were conducted for over a year using different systems and a variety of subjects. The systems included expensive professional monitors and one high-end system with electrostatic loudspeakers and expensive components and cables. The subjects included professional recording engineers, students in a university recording program, and dedicated audiophiles. The test results show that the CD-quality A/D/A loop was undetectable at normal-to-loud listening levels, by any of the subjects, on any of the playback systems. The noise of the CD-quality loop was audible only at very elevated levels.

## 0 BACKGROUND

Since the standardization of the 16-bit/44.1-kHz CD pulse-code modulation format, over 25 years ago, its quality as a recording medium has been the target of regular criticism, both in the subjective audio press and among audio professionals. The complaints typically focus on a perceived harshness, lack of depth, and/or a cold, sterile sound. However, blind comparisons of CDs against their source tapes have revealed these perceptions to be unfounded. To that extent, the CD standard was transparent, whether the original source was digital or analog.

Meanwhile digital technologies evolved, and in the past several years two new high-resolution audio technologies, Super Audio CD (SACD) and DVD-Audio, have emerged as alternatives.

The usefulness of the increased dynamic range afforded by longer word lengths for mixdown has never been in question. Both new systems moreover carry multiple channels, clearly a potential advantage for home playback. But these acknowledged capabilities aside, each of the high-resolution audio technologies has also been claimed to

offer superior-sounding playback. As a licenser asserted in these pages [1],

A long-term audiophile criticism of the CD has been that it lacks the resolution to reproduce all the detail in a musical performance. . . . High-quality audio practice now recognizes the CD channel as a “bottleneck”. . . . Higher resolution audio promises better sound than the CD, and the potential for this has already been demonstrated in carriers that permit a wider frequency response . . . and greater dynamic range. . . . [E]xperience shows and anecdotal evidence suggests that higher sample rates “sound better.” Typical observation are that with higher sampling rates the sound is clearer, smoother, has improved low-frequency definition, and is more “natural.” In the author’s experience higher sample rates can lead to better foreground/background discrimination. “Objects” are better separated from the acoustic and therefore sound clearer and more “complete.”

The subjective and recording-engineer magazines have also declared repeatedly that both formats offer entirely obvious sonic improvements over the CD standard.

Such assertions show no awareness of previous relevant investigative work [2]–[4], though all of those papers address one parameter: the possibility that high-resolution recording offers sonic improvement because of its greater potential high-frequency extension. Regardless, all conclude that CD quality is adequate, and indeed the Plenge et

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al. [2], at the dawn of the CD era, implied that even its bandwidth might be more than is needed.

## 1 THE TESTS

Despite the claims made for them, neither SACD nor DVD-A, so far as the authors know, has been subject to properly controlled blind testing of its superiority to CD audio; at least no such results have been published. With the printing of the characterizations in Stuart's lead paper [1] in this *Journal*, it became clear that it was well past time to settle the matter scientifically. This engineering report, then, describes double-blind comparisons of high-resolution stereo playback with the same two-channel analog signal looped through a 16/44.1 A/D/A chain (see Fig. 1). Unlike the previous investigations, our tests were designed to reveal any and all possible audible differences between high-resolution and CD audio, many of which, according to published claims, occur within the commonly accepted audio bandwidth. The theoretical sonic advantages of the high-resolution signal should not survive the degrading 16/44.1 "bottleneck," and differences would be audible.

With the help of about 60 members of the Boston Audio Society and many other interested parties, a series of double-blind (A/B/X) listening tests were held over a period of about a year. Many types of music and voice signals were included in the sources, from classical (choral, chamber, piano, orchestral) to jazz, pop, and rock music. The subjects included men and women of widely varying ages, acuities, and levels of musical and audio experience; many were audio professionals or serious students of the art.

Most of the tests were done using a pair of highly regarded, smooth-measuring full-range loudspeakers in a rural listening room with an ambient noise floor of about 19 dBA SPL, all electronics on (see Fig. 2). We also took the test setup to several other locations: a Boston-area mastering facility with very large four-way studio monitors; a local university audio facility, again with large high-powered monitors in a custom-designed listening space (the subjects for this test were students in the recording program); and a private high-end listening room equipped with well-reviewed electrostatic loudspeakers and very expensive electronics and cables. In all venues we performed informal tests of the subjects' upper hearing limits to see whether there was a correlation between this parameter and the audibility of differences.

For the CD loop we used a well-regarded professional CD recorder with real-time monitoring. Levels in both channels were matched to within 0.1 dB using a very high-performance adjustable analog gain stage, which was always in the 16/44.1 signal path. Audio switching was handled by an ABX CS-5 double-blind comparator (see Fig. 3).

High-resolution audio offers a lower digital noise floor, so playback levels are a significant factor. Does the lower noise have any practical consequence, given modern compression techniques and existing noise floors in microphones, preamplifiers, and mixing consoles? We found that most of the SACD and DVD-A recordings produced what might be termed realistic playback (that is, the subjects heard the sources loudly and clearly, with natural timbres and appropriate scale but without discomfort) at a system gain such that a 1-kHz octave band of noise re-

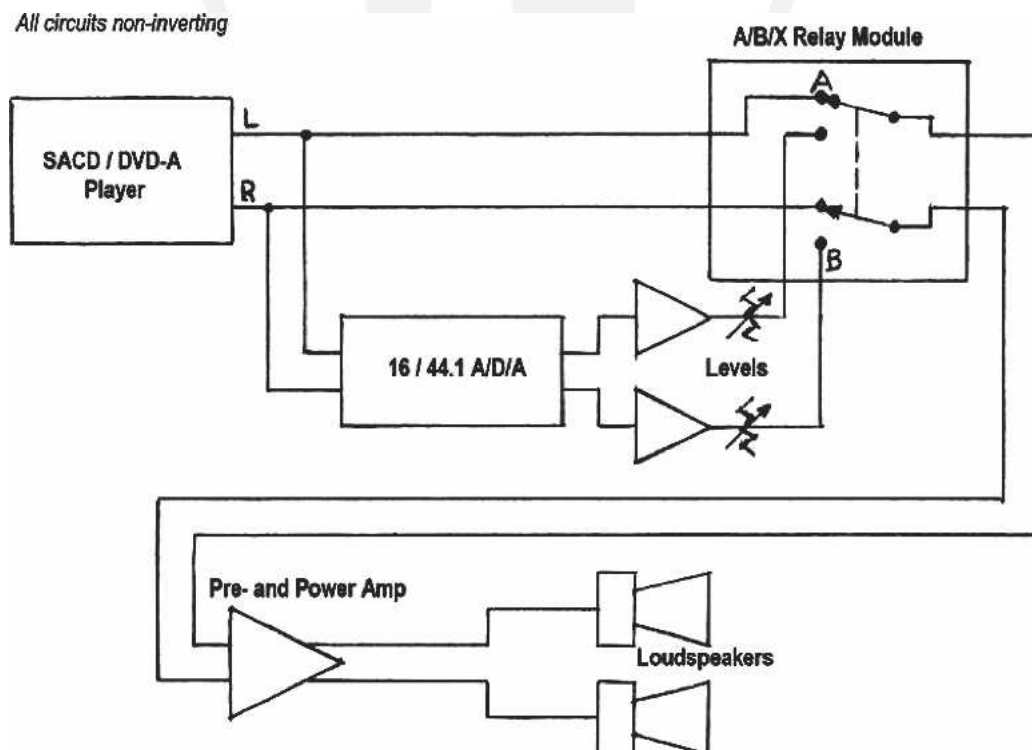


Fig. 1. Block diagram of test setup for double-blind comparison of high-resolution stereo playback with same two-channel analog signal looped through a 16/44.1 A/D/A chain. (Drawing by Roy Allison.)

corded at an average level of  $-16$  dBFS produced an SPL at the listening position of 85 dB, unweighted. For some classical recordings of very wide dynamic range, listening levels 5–7 dB higher than this were used from time to time.

The test signal we used to produce 85 dB SPL at our standard gain is available on the Boston Audio Society Web site. The downward frequency sweep, used at the same playback level as a quick test of high-frequency hearing limits in our subjects, can be found on the same page, at [www.bostonaudiosociety.org/media](http://www.bostonaudiosociety.org/media).

## 2 THE RESULTS

The test results for the detectability of the 16/44.1 loop on SACD/DVD-A playback were the same as chance: 49.82%. There were 554 trials and 276 correct answers. The sole exceptions were for the condition of no signal and high system gain, when the difference in noise floors of the two technologies, old and new, was readily audible.

As the tests progressed, we repeatedly sorted the data for correlations with age, sex, upper frequency hearing limit, or experience. No such correlations have emerged. Specifically, on music at normal levels as defined here, audiophiles and/or working recording-studio engineers got

246 correct answers in 467 trials, for 52.7% correct. Females got 18 in 48, for 37.5% correct. Those subjects able to hear tones above 15 kHz got 116 in 256 trials, for 45.3% correct; listeners aged 14–25 years old (who were, as it turned out, the same group), also got 116 correct in 256 trials, 45.3%. The “best” listener score, achieved one single time, was 8 for 10, still short of the desired 95% confidence level. There were two 7/10 results. All other trial totals were worse than 70% correct.

Furthermore, none of the more elaborate and expensive playback systems (for which the subjects were all dedicated amateur audiophiles, active students in a professional recording program, and/or experienced working professionals) revealed detectable differences on music, again at levels as defined previously.

In one brief test with two subjects we added 14 dB of gain to the reference level quoted and tested the two sources with no input signal, to see whether the noise level of the CD audio channel would prove audible. Although one of the subjects was uncertain of his ability to hear the noise, both achieved results of 10/10 in detecting the CD loop. (We have not yet determined the threshold of this effect. With gain of more than 14 dB above reference, detection of the CD chain’s higher noise floor was easy, with no uncertainty. Tests with other subjects bore this out.)



Fig. 2. Critical listening position for majority of tests.

The high-resolution sources when played back at the +14-dB level were unpleasantly (often unbearably) loud, and modern, aggressively mastered CDs even more so. Room tone and/or preamplifier noise in almost all recordings masked the 16/44.1 noise floor, though we did find one or two productions in which there was a detectable difference in room tone at gain settings of +20 dB or more above the reference level. At these very high gains we could also hear subtle low-level decoding errors in all but the most expensive of the high-resolution players.

From the many different recordings we used it emerged that almost no music or voice program, recording venue, instrument, or performer exceeds the capabilities of a well-implemented CD-quality record/playback loop. The CD has adequate bandwidth and dynamic range for any home reproduction task, and it is a rare playback venue that is quiet enough to reveal the 16-bit noise floor of our A/D/A loop—which has no noise shaping and was therefore less than optimal in this regard—even at gains above our reference.

### 3 CONCLUSIONS

We have analyzed all of the test data by type of music and specific program; type of high-resolution technology; age of recording; and listener age, gender, experience, and hearing bandwidth. None of these variables have shown any correlation with the results, or any difference between the answers and coin-flip results.

The previous work cited, some of it at the very beginning of the CD era and some more recent, pointed toward our result. With the momentum of widespread “high-rez” anecdotes over the last decade, culminating in the Stuart assertions, we felt the need to go further and perform a

thorough, straightforward double-blind level-matched listening test to determine whether 16/44.1 technology would audibly degrade the sound of the best high-resolution discs we could find. We used a large and varied sample of serious listeners; we conducted our tests using several different types of high-quality playback systems and rooms; and we took as much time as we felt necessary to establish the transparency of the CD standard.

Now, it is very difficult to use negative results to prove the inaudibility of any given phenomenon or process. There is always the remote possibility that a different system or more finely attuned pair of ears would reveal a difference. But we have gathered enough data, using sufficiently varied and capable systems and listeners, to state that the burden of proof has now shifted. Further claims that careful 16/44.1 encoding audibly degrades high-resolution signals must be supported by properly controlled double-blind tests.

### 4 A NOTE ON HIGH-RESOLUTION RECORDINGS

Though our tests failed to substantiate the claimed advantages of high-resolution encoding for two-channel audio, one trend became obvious very quickly and held up throughout our testing: virtually all of the SACD and DVD-A recordings sounded better than most CDs—sometimes much better. Had we not “degraded” the sound to CD quality and blind-tested for audible differences, we would have been tempted to ascribe this sonic superiority to the recording processes used to make them.

Plausible reasons for the remarkable sound quality of these recordings emerged in discussions with some of the engineers currently working on such projects. This portion



Fig. 3. Test setup for block diagram in Fig. 1.

of the business is a niche market in which the end users are preselected, both for their aural acuity and for their willingness to buy expensive equipment, set it up correctly, and listen carefully in a low-noise environment.

Partly because these recordings have not captured a large portion of the consumer market for music, engineers and producers are being given the freedom to produce recordings that sound as good as they can make them, without having to compress or equalize the signal to suit lesser systems and casual listening conditions. These recordings seem to have been made with great care and manifest affection, by engineers trying to please themselves and their peers. They sound like it, label after label. High-resolution audio discs do not have the overwhelming majority of the program material crammed into the top 20 (or even 10) dB of the available dynamic range, as so many CDs today do.

Our test results indicate that all of these recordings could be released on conventional CDs with no audible difference. They would not, however, find such a reliable conduit to the homes of those with the systems and listening habits to appreciate them. The secret, for two-channel

recordings at least, seems to lie not in the high-bit recording but in the high-bit market.

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## THE AUTHORS



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Brad Meyer was born in Baltimore, MD, in 1942 and received a B.A. degree from Harvard College, Cambridge, MA.

He has been recording concerts since the late 1950s and worked making measurements, calibrating instruments, reducing data, writing reports, and learning acoustics at Bolt Beranek and Newman from 1966 to 1972. He started his own company, Point One Audio, in the late 1970s. He does location recording and digital editing of classical and some folk material.

Mr. Meyer has been on the executive committee of the AES Boston Section since the early 1980s and served two years as its chair. In addition to his past duties as writer and sometime editor of the Boston Audio Society *Speaker* newsletter and Society president, he has published audio articles for the *Boston Phoenix*, *High Fidelity*, *Stereo Review*, and *Stereophile*.

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He is a writer and editor, with particular interest in audio, music, and technology. He was audio editor (also managing editor) of the *Boston Phoenix* during the 1970s and worked for dbx engineering through the 1980s. He has been president of the Boston Audio Society and editor of its *BAS Speaker* newsletter, and has reviewed loudspeakers for *CD Review*, *Digital Audio*, *Speaker Builder*, *Car Stereo Review*, and currently for *Sensible Sound* magazine and the *BAS Speaker*. He also has annotated and produced CDs and written about music (classical and popular) for publications from the *Boston Globe*, *Phoenix*, and *Herald to Stereo Review*, has received two NEA fellowships for classical criticism, and recently helped edit the *NPR Listeners' Encyclopedia of Classical Music*. He currently works as a technical writer at BBN Technologies in Cambridge, MA.