

Analog 'Apples' and Digital 'Oranges'

The ear is the best judge of the quality of recorded music, but making a valid comparison of competing recording techniques is surprisingly difficult



How faithfully can a recording reproduce this orchestra's sound?

dbx, Inc.

By IVARS PETERSON

When concert pianist Jim Boyk records his music, he wants to reproduce the sound faithfully. "I want there to be as few barriers as possible between me and my listeners, even if the listener is listening to a record of me instead of to me in person," Boyk says. Although no recording can duplicate "live" sounds exactly, recording technology has improved considerably since the century-old, tinny, crackling sounds from Edison's original phonograph. In the last few years, digital recording has emerged amid claims that it offers hitherto unheard-of realism in sound reproduction.

Boyk is also the artist in residence and a lecturer in music at the California Institute of Technology in Pasadena. Last summer, he, along with two undergraduate students and two mathematics professors, designed a listening experiment to compare digital and analog recording to live sound.

Digital recording stores a sound's waveform as a sequence of numbers. The system samples the incoming sound wave,

typically about 44,000 times a second, and for each sample assigns a numerical value corresponding to the loudness or amplitude at that instant. In contrast, conventional analog recording stores a sound wave's shape as a continuous variation in the intensity of magnetization along a recording tape or the shape of a record's grooves. Digital recording seems to offer a wider dynamic range (the sound intensity difference between the loudest passages recorded without distortion and the quietest passages that don't get lost in the background noise) than conventional analog recording. Less noisy digital recordings, lacking background hiss and suffering less distortion, ought to sound more realistic.

Digital recording sounds very attractive, "but it's also obvious that there are all kinds of potential problems," says Boyk. "You're taking this subtle, incredibly detailed and complex curved line and substituting for it a chain of dots," he says. Theoretically, "if you sample frequently enough, you can do the job not merely well, but perfectly." However, commercial recording systems are built upon compromises and vary considerably. Meas-

urements and specifications say very little about how a recording actually sounds, although they are useful for checking a circuit's behavior or for consistency. "There's only one test, and that's to listen to it," says Boyk.

Boyk and his students spent months checking previous work, identifying technicalities that could affect the results and exploring the psychological subtleties involved in listening tests. For example, they realized it was important that people do the tests individually, rather than in groups, to avoid unconscious cuing.

Boyk's carefully designed listening test showed that although neither recording technique was a unanimous winner, the majority preferred the analog sound. The experiment did not support the claim that digital recording is flawless or even superior. But the result is controversial because the quality of digital recording machines varies considerably, and Boyk tested only two. Some critics say that people are simply more used to the distortions that analog recording introduces. Boyk argues that his test avoided the biases built into previous, more informal tests.

The most crucial element of Boyk's design was the use of live sound as a simultaneous reference for both the analog and digital recordings. While musicians performed in marathon sessions, a special microphone system picked up the sound and fed the signal to a laboratory where the feed was split in three. One line led directly to the speakers in the listening room. The other two lines went to any of three analog recorders and two digital recorders and then to the speakers.

Boyk and his group had to use the best available microphones, amplifiers and speakers so as not to mask differences among the recorders. The three feeds to the speakers were adjusted so that the sounds coming from the recorders and the direct feed were equally loud. (Previous research elsewhere had shown that if one of two identical sounds was slightly louder than the other, it sounded better rather than louder, an effect called "perceptual crossover.") Despite this care, neither the digital nor analog machines were used under "utterly realistic" condi-

tions. For instance, to get immediate playback, the digital signal was not actually recorded and stored on tape before being converted to a suitable form for driving the speakers. "It was the best we could do," Boyk says. "It's extraordinarily difficult to design a test that is valid, fair and realistic."

The listener used a switch to choose among positions labeled "apples," "oranges" and "reference" (the direct feed). The experiment was double-blind because neither the operator nor the listener knew whether, during any trial, apples were analog and oranges digital or vice versa (or when both feeds were one or the other). The apples and oranges were juggled randomly between trials.

A few factors could not be controlled. Neither the analog nor digital machines were absolutely silent. Boyk admits that some listeners may have been able to distinguish, consciously or unconsciously, the digital and analog feeds because of slight differences in the character of the background noise.

Seventeen subjects sat through 10 or 11 trials each, listening for up to two and a half hours. Listeners were asked: Are the apples and oranges identical? And, if not identical, which comes musically closer to the direct feed?

From the results, Boyk concludes that none of the tested machines reproduced sound perfectly, and that the majority of the listeners preferred the analog recording to the digital. However, he warns that the results apply only to the recorders tested. "There's nothing in our experiment that says there isn't some digital machine right now that is truly perfect," says Boyk. "I don't believe it, but we tested only two machines."

Another important result was clarification of the conditions needed for a valid test. "I think we've got an excellent, conceptually straightforward and technically sound test," says Boyk. "We're not aware of anybody else who has done anything we think is valid. I'm aware of a lot of informal listening tests, which were so informal as to be totally worthless."

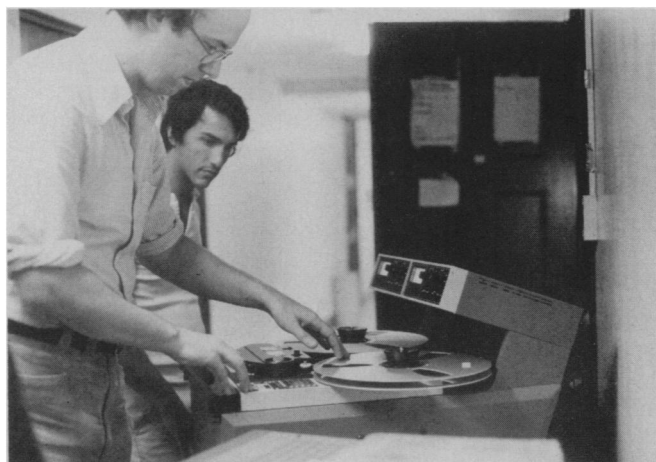
Bob Ingebretsen, president of Soundstream, a highly respected recording studio and maker of digital recording



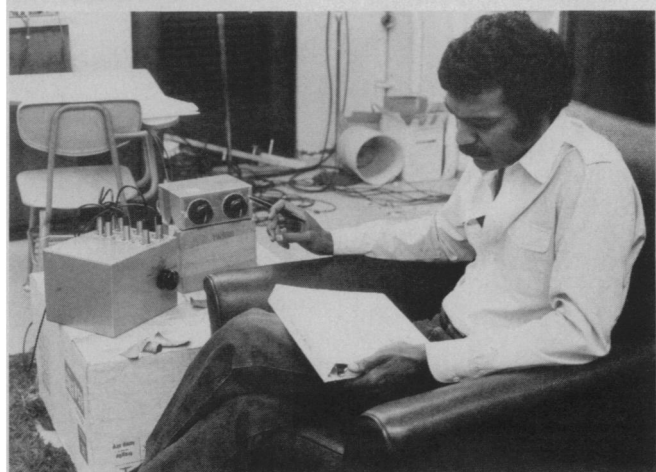
Listening tests can take many forms. Crescendo Recorders in Atlanta, for example, last year compared two different digital audio processors (left) and an analog tape machine. A variety of musicians, including a classical pianist and a rock drummer, provided the sound. After each performance, engineers, producers and musicians listened to the three recordings without knowing which was which. They preferred the digital recordings.



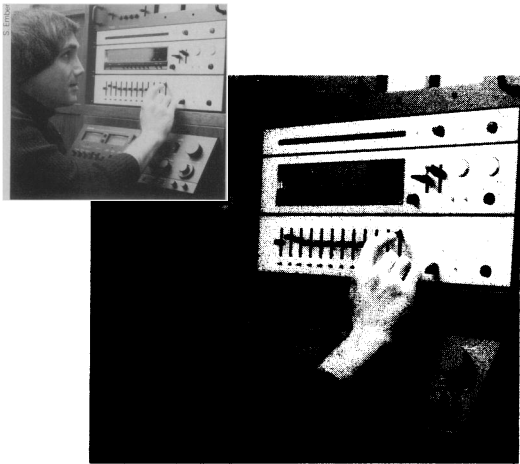
dbx, Inc.



Jim Boyk's test at the California Institute of Technology allowed listeners to compare the recorded sounds directly to a "live feed" from performing musicians, without a significant delay. These listeners generally preferred the analog sound. Here, Boyk (left) threads the tape on one of the analog recorders tested. Bottom, a subject listens, comparing the live feed to "apples" and "oranges."



Caltech



Steve Ember

In search of a 'golden' ear

Most people can't afford the luxury of a digital recording and playback system. Their experience is usually secondhand, limited to so-called "digital" phonograph records. Although the sound for these disks is originally recorded digitally on a master tape, the final form, as grooves on a disk, is analog. Comparing digitally mastered disks to conventionally recorded disks is even more difficult than comparing recording techniques because factors like the quality of the record manufacturing process intrude.

Steve Ember, an audio commentator and broadcaster on National Public Radio, has spent many years listening to high-quality recordings. He says technological advances have improved the quality of phonograph records whether analog or digital in origin. If records are produced with care from recording session to finished disk, "I would find it very difficult to choose between an analog recording and a digital recording," says Ember. "A very good digital recording can have startling realism." But there are enough strident, sharp and antiseptic-sounding digital recordings around to show that digital hasn't reached its full potential, he adds.

How easily can the differences be detected, particularly by someone who doesn't have the fabled "golden" ear that can pick up the minutest nuances in recorded sounds? That question brought me to Ember's home recording studio where he produces a daily, six-hour musical program for NPR. The setting for my prospective listening test was somewhat intimidating. A cryptic array of turntables, control consoles, tape decks, amplifiers, decoders and other pieces of audio equipment surrounded me. Two imposing speakers, each about as tall as I am (6 feet), stood at one end of the studio.

This listening test was much less "scientific" than Jim Boyk's elaborate experiment. There was no live music for comparison, and I was listening to the end product of the entire recording process, from musician and microphone to manufactured vinyl disk. The session began with a tape Ember had prepared to demonstrate differences among about 20 recordings. Initially, I wasn't sure what to listen for, but soon I began to notice how much clearer some selections sounded. In a few cases, with my eyes closed, I could imagine being in the same hall with the musicians. On these occasions, the only clues that I was listening to a recording were the infrequent clicks and pops typical of record noise and a continuous but very faint background tape hiss.

It didn't take a "golden" ear to pick out

the most satisfying and exciting sounds, I realized. Boyk had noted a similar response in his experiments. Several of his subjects had been surprised at how obvious the differences were. However, in comparing recorded disks in my listening test, both digital and analog recordings figured among my top choices. One was a spectacular digital recording of the opera *Carmina Burana*, done by the Soundstream studio. A number from the Broadway musical *Pippin* was an analog recording, as was a *Star Wars* selection. The examples reinforced Ember's contention that the best sounds came from producers who knew what they were doing in everything from the placement of microphones to the type of vinyl used for the record.

Phonograph records themselves have intrinsic limitations for reproducing the sound of live musical performances. Vinyl disks accommodate only two-thirds of the natural loudness of live music, which can range from the impact of a thunderous chorus to the delicate flavor of a quiet flute solo. In addition, record surface noise distracts the listener and hides quieter passages. Two audio systems have evolved to overcome these limitations. The newly introduced compact digital audio disks, which must be played on a special, laser-equipped player that directly reads the digits encoded on the disk's surface, promise to eliminate surface noise and to provide a dynamic range that reflects the diversity found in live music. Because the music is in the digits, the surface no longer matters.

The dbx encoding-decoding system arrives at a solution in a different way. The system electronically compresses the loudness of the music signal to a range that can be stored on a vinyl disk. During playback, a decoder expands the signal back to its original loudness, with the bonus of reducing surface noise to inaudible levels. Ember demonstrated some dbx Discs. Absent completely were the hissing and swishing sounds that used to signal that the listener was hearing a recording rather than live music. When the record started, there was complete silence, and then the crystal-clear music began.

After my listening test, I couldn't answer the question Boyk set out to answer: Does digital or analog recording come closer to reproducing sounds faithfully? I did learn that the differences were there to be heard, but when it came to judging phonograph records, many factors beyond the initial recording technique affected the sound quality. And in some cases, achieving concert hall realism was not nearly as important as the emotional impact that could be engineered by talented record producers. I had only to recall the *Star Wars* finale.

—I. Peterson

equipment in Salt Lake City, says digital systems can't all be lumped together. A wide variety of electronic factors, some barely measurable, can affect the sound. "We've had experience with taking the very same recorded digits and playing them through a digital playback of our own design versus playing them through another design and hearing dramatic differences," says Ingebretsen. On other occasions, with the best equipment available, people have been unable to distinguish between digital recordings and live feeds.

Jerry Ruzicka, vice president of dbx, Inc., says, "There is [analog] technology available today with which you can make original master recordings equal to or better than today's digital recordings. [Digital] technology, as it has evolved to this point for professional recording, is not perfect." Many current digital machines seem to introduce a stridency or harshness into recordings, especially for string ensembles and some solo instruments, he says, but improvements are possible. Ruzicka claims that a recently introduced dbx recorder, which samples 700,000 times a second, removes the unpleasant sound found in earlier digital recordings.

Ingebretsen notes, "Any kind of system, be it digital or otherwise, is going to introduce some kind of distortion into the process." People are used to hearing the familiar distortions inherent in analog recording. Digital recording has different kinds of distortion and also allows people to hear details they haven't heard before. "A lot of people who have expressed concern about digital react to that phenomenon," says Ingebretsen.

Boyk contends, "We just don't have the vocabulary for talking about the defects of a new thing [like digital recording], or the perceptual categories for perceiving the defects." Only a comparison with something like a reference direct feed can make a comparison vivid, he says.

The final judge is the human ear, which can detect subtleties no instrument can yet measure. But the difficulty and expense of arranging objective, valid listening tests remains an obstacle to resolving the analog-digital debate. □