Volume 5 The Computer Music and Digital Audio Series

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The Compact Disc

A HANDBOOK OF THEORY AND USE

A-R Editions, Inc.
Madison, Wisconsin

Contents

1 Introduction to the Compact Disc

2 Fundamentals of Digital Audio

3 The Compact Disc System

4 CD Player Design

5 Practical Concerns

6 Diverse Disc Formats

7 Disc Manufacturing

Chapter One

Introduction to the Compact Disc

INTRODUCTION

Let's try a conceptual experiment. From your conceptual seat in your conceptual concert hall, you lean forward in anticipation as the conceptual orchestra begins its conceptual performance of Beethoven's Tenth Symphony. (No, I'm not conceptualizing; he really did start a Tenth.) Your job is to write down all the information you hear. Ready? Begin!

Whew! After only a few bars, you give up. Even writing down the score in musical notation is overwhelming, much less recording all the timbres, aesthetic considerations, hall acoustics, and so forth.

We have to conclude that music is a surprisingly complex phenomenon; it is filled with information. To store it, we require a system which can deal with incredible amounts of information. It is not surprising that historically the latest and highest technology has always been utilized to make recordings, because only the best technology satisfies our current expectations of what a good recording should sound like. As higher technology was devised and pressed into service, our expectations were redefined. All of which brings us to the topic at hand: digital audio and the compact disc.

ANALOG VERSUS DIGITAL

To understand the nature of analog and digital systems, along with their differences, let's try another conceptual experiment. Suppose that you are stationed in the Arctic Circle. (Since I'm writing this book in Miami in July, this concept has particular appeal to me.) The Audubon Society has charged you with the important mission of noting the effect, if any, of barometric pressure on the mating habits of penguins.

A barometer measures changes in atmospheric pressure. Attached to the barometer is a recording device, a cylinder with graph paper attached to it, and a pen with ink (and anti-freeze). As the atmospheric pressure changes, the pen traces a line on the slowly rotating cylinder. At the end of every day, the cylinder has completed one rotation, and you change paper. You are thus left with a graph of barometric pressure over time.

What you have is an analog recording. It is analog because it is a continuous representation, an analogy, or a model of the actual phenomenon. It's very nice, but its accuracy is limited by numerous factors, including the precision of the cylinder's rotation and the flow of ink. Its usefulness is also limited by the fact that its representation is graphical. For example, to communicate your findings to the Audubon Society headquarters, you would have to send the actual graph paper or a copy which might not be as accurate as the original.

You figure there might be an alternative, and there is. Instead of relying on the graph paper, you decide to document individual readings themselves. You design a device that reads the pressure from the barometer every minute and prints out the number. At the end of a day, there are 1,440 numbers, representing the changing pressure.

What you have is a digital recording. It is digital because the signal is subjected to measurement at discrete points in time, and the information is stored as discrete numbers. It's very nice because the numbers are inherently more robust than the analog graph, and if your digital device is well designed, the numbers are probably more precise. In addition, it is far easier to communicate your findings; simply reading the numbers over the radio would do the job. Moreover, when the scientists at headquarters write down the numbers, they will have an exact copy of your results.

Suppose, however, that the scientists back at headquarters squawk that the numbers are not as good as a graph and complain that there is no record of pressure between each measurement. You could point out that you aren't as stupid as you look. Atmospheric pressure can change only so fast. For example, suppose the barometric pressure was 30.034 inches at 11:01:00 P.M., and 30.036 inches at 11:02:00 P.M. Although you didn't take a reading at 11:01:30 P.M., you can calculate that the pressure was 30.035, and not, say, 29.022. The atmosphere would not work like that. Thus by knowing how fast things change, you can sample often enough to obtain complete information about what's happening.

On the other hand, an event outside the interest of our barometric experiment, such as the overpressure created by a nearby penguin exploding at precisely 11:01:30 P.M., would not be documented. But that doesn't affect our study. By defining how fast things of interest change, we can ignore those events which happen faster.

At any rate, satisfied that the barometric pressure will be accurately documented, you can get down to the primary scientific task of watching the penguins.

Our conceptual experiment illustrates fairly well the relevant differences between analog and digital representations. In fact, barometric pressure is a close analogy to audio signals, since both are simply pressure changes in air. Of course, changes in barometric pressure would produce a very low frequency (about 0.00001 Hz), but if you speeded it up about 100 million times, it might sound musical, or at least like punk rock.

Back to reality. Let's nail down our comparison between analog and digital systems. The principal distinction lies in the way they represent information. Digital information can exist only in pieces, as discrete values, as numbers. This is vastly different from analog information, where one continuous, infinitely indivisible value is recorded.

Analog and digital systems thus differ considerably. There is no doubt about that. Nevertheless, the basic question has still eluded us: Why digital? At first glance, the use of digital technology for audio purposes seems very cumbersome. After all, we must convert sound into a series of numbers, each of which must accurately describe the sound at that instant in time. We must first store these billions of numbers and then convert them back into sound to hear what's going on. That's a lot of work. Moreover, since analog audio technology seemed perfectly adequate for a hundred years, is it really necessary to replace analog with digital?

One answer is this: Sure, digital audio is a lot of hassle, but it's worth it. One justification for digital audio lies in the very nature of its signal. Sound is an analog phenomenon, and so is noise. An analog audio device cannot distinguish between them; hence, the noise of an analog signal is the sum total of all the noise introduced in its path. For example, every time an analog tape is copied, its noise increases. The numbers comprising a digital signal will carry an error, introduced when they are first selected, but they are impervious to noise; for example, rerecording does not add noise. A digital number cannot become noisy; it is right or wrong.

Analog reproduction is more frail than digital. An analog system introduces distortion as it attempts to convey the exact analog nature of its information. In contrast, a digital system, at least philosophically, has an easy job. It must be able to distinguish only between 1s and 0s to reproduce the signal. The only theoretical limitations are those dictated by the quantity and accuracy of the numbers. In other words, with digital we can more precisely manipulate and process information, and thus achieve a more accurate result.

Along similar lines, digital audio is advantageous because its signal is robust. It is a cruel world out there, and under adverse conditions, a digital signal suffers less degradation than an analog signal. Moreover, a digital signal suffers no degradation at all until conditions have deteriorated beyond a known level. The design performance of a digital system is designed into its circuits. Performance is thus always a known, defined quantity.

Another justification for digital audio is its consistency of performance. Analog devices can work quite well when they are new, but frequent adjustment and maintenance are necessary to ensure consistent performance. Because digital systems often permit a higher degree of circuit integration, they exhibit greater long-term accuracy, with less performance variation or failure. In fact, when a digital system fails, the problem is often an analog part inside.

Digital circuits are also very efficient because logical functions and operational features can be easily designed and implemented. Moreover, such functions and features can be quickly altered or updated; often the hardware circuit remains unchanged, and a change in programming achieves the new result.

Finally, digital audio's sonic performance is excellent. First-generation digital audio products rivalled the result of a century of analog evolution, and digital's evolution guarantees the gap will widen.

Of course, digital audio isn't perfect—far from it. Its complexity breeds considerable challenges that are not found in analog systems. To use and appreciate such equipment properly, a fair amount of technical understanding is required, as demonstrated in the following pages.

LP VERSUS CD

Many methods of audio storage have evolved since Edison made the first audio recording in 1877 on a cylinder covered with tin foil. Early acoustical recordings were made on wax cylinder and shellac disc, and many electrical recordings used 78 rpm and long-playing records. Subsequently, numerous magnetic tape formats were developed. However, all of these audio systems shared identical foundations; they recorded and reproduced an analog signal by using a mechanical pickup in contact with the medium. Overall, this technology is now a mature one and has virtually exhausted the possibilities available within the limitations of analog master tape, phono cartridges, analog circuitry, motors, and mechanical systems.

The difference between analog and digital audio technologies can be illustrated by a close look at a long playing record, and a compact disc, illustrated in figure 1.1.

The LP stores its information as an analog groove. Variations in its side-to-side amplitude and depth represent the original audio signal. If someone hit a big drum, the groove would take a big swing. The frequency of the drum sound determines the frequency of the groove's swing, and the amplitude of the drum sound determines the amplitude of the swing. In short, the groove is a physical analogy to the original sound wave. Left and right audio channels are stored on either side of the groove walls. To reproduce the information, a stylus runs through the groove and the phonograph cartridge converts the stylus's mechanical movements into an electrical signal which is later amplified. Analog tapes follow the same

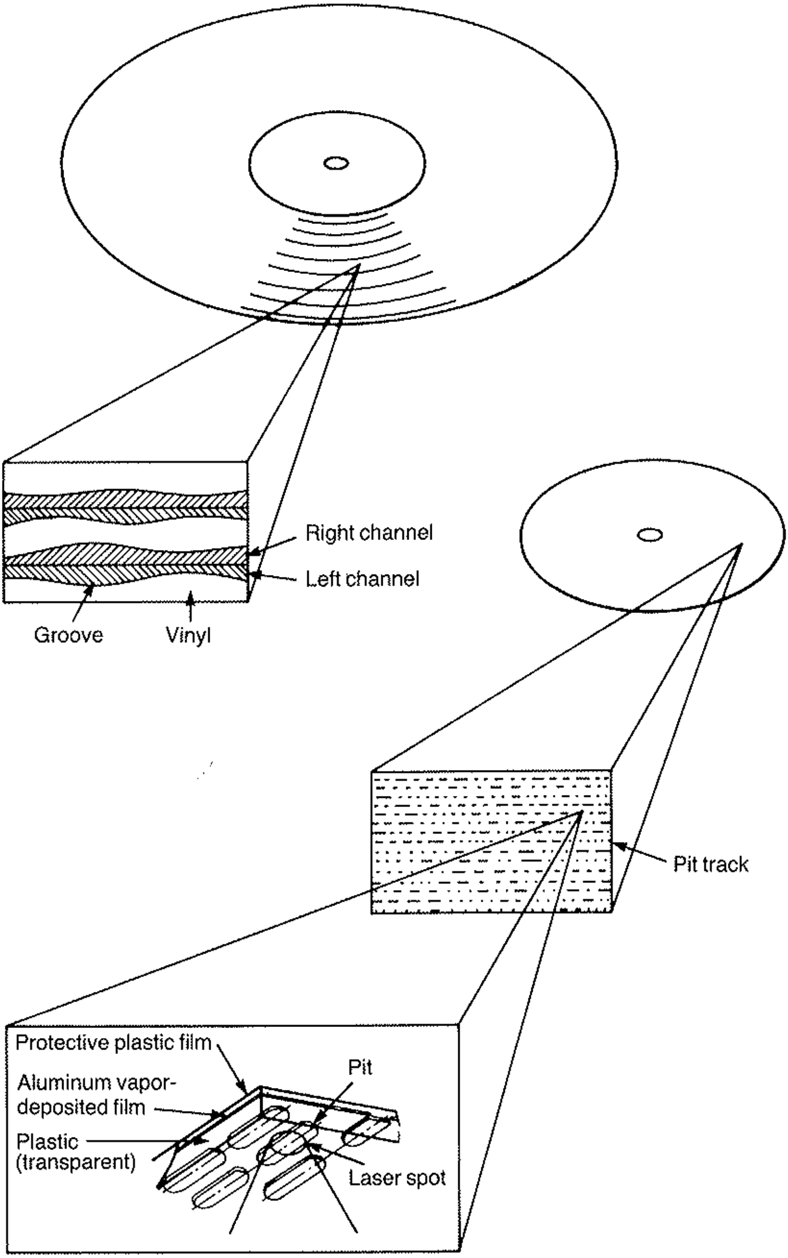

Figure 1.1 *LP grooves storing analog information contrasted to CD pits, storing digital information.*