A DIGITAL AUDIO DISC USING ADAPTIVE DELTA MODULATION

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Abstract

A digital audio disc system has been developed, suitable for professional background music equipment. It utilizes Continuously Variable Slope Delta Modulation (CVSDM), one of the Adaptive Delta Modulation (ADM) schemes. The system employs the same recording format (error correction and modulation) as that of the Compact Disc (CD) which permits use of disc mastering facilities and signal processing circuitry developed for the CD system.
Eight audio channels can be recorded on one disc, which corresponds to one hour per channel, totaling eight hours of recording time with an audio bandwidth of 15 kHz.

1. INTRODUCTION

Magnetic record/playback systems using open-reel tapes have been widely used in business as background music (BGM) equipment. These systems utilize special long-playing music tapes, supplied by companies which usually rent the reproduction systems. Also, many compact cassette decks are used similarly.
The use of such systems involves problems regarding mass-reproduction of music sources, deterioration of sound quality, maintenance of the playback systems (especially the heads), etc.
The CD, which has recently attracted special interest as a bulk read-only memory (CD-ROM), presents no such problems. The manufacturing technology of the CD, the mass-production technology of the playback equipment (including the optical pick-up, signal processing circuitry and servo circuitry) has already been established.
The current audio CD standards provide for a playback time of up to 75 minutes in two-channel stereo, which is too short for BGM equipment. Furthermore, the present high sound quality of CD may exceed the quality required in such systems.
Playback time can be extended by utilizing a speech compression technique[1].
There are several methods of speech compression. One type, waveform coding, can be applied to signals other than speech and permits comparatively natural sound reproduction.
An Adaptive Delta Modulation (ADM) disc system has been developed by applying Continuously Variable Slope Delta Modulation (CVSDM), one of the ADM schemes which enables coding with a relatively simple circuit among other schemes, to the CD system. The system can replay eight monaural channels on one disc, or provide a total of eight hours of playback. This paper outlines the system and then describes the manufacture of the ADM disc and its playback equipment.

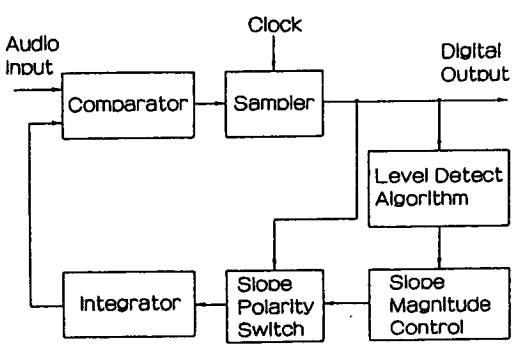

Fig. 1 Block diagram of Continuously Variable Slope Delta (CVSD) modulator

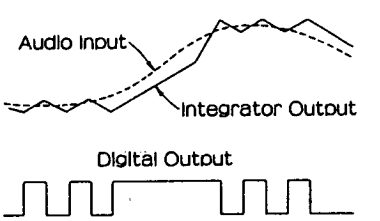

Fig. 2 Waveforms of CVSD modulator

2. OUTLINE OF THE SYSTEM

2.1 ADM Coding Scheme

Figure 1 shows a block diagram of the ADM-CVSD modulator. To reduce such distortions as slope overload and quantization noise, the slopes of integrator output waveforms are controlled by monitoring, whether or not the last four bits of the code strings appearing in the digital output are the same. That is, if the same code continues to appear, the slope of the input waveform is large and therefore that of the integrator output waveform is increased, while it is decreased if different codes appear. In the case of CVSDM, slope variations have continuous values. To reduce distortion, the slope is changed exponentially rather than linearly.
Figure 2 schematically shows the waveforms of the audio input, the integrator output and the digital output signals of Figure 1.
This figure shows that a code string of one bit can be obtained for an audio input to one channel.
The demodulator consists basically of the same circuitry as that of the modulator, i.e., in Figure 1, the digital code string is fed to the sampler instead of to the comparator. In this case the output signal from the integrator becomes the demodulated audio signal.
The sampling clock frequency is usually chosen at least ten times the bandwidth of the input signal. In this experimental ADM Disc system, the bandwidth of the input signal is 20 Hz to 15 kHz and the sampling clock frequency is 176.4 kHz which is derived from the CD System.

2.2 Application to the CD System

In the manufacturing process of the CD, audio signals are converted to PCM data by a professional digital audio processor and recorded generally on a 3/4-inch VTR tape. In the mastering factory, the PCM data are recovered from the VTR tape through a PCM processor and encoded into the CD format using a CD code processor. The CD encoded data are then sent to the laser cutting machine. In reproduction, data recorded on the disc is passed through an EFM demodulator and CIRC decoder in the CD player for conversion back to the original PCM data. This data is then converted into audio signals by a D-A converter. A schematic diagram of the CD system is shown in Figure 3.

If attention is paid to the data input specifications of the CD code processor, any digital data can be recorded on the CD.
Because the sampling frequency used for the CD is 44.1 kHz and the number of quantization bits is 16 per channel, the data transmission rate is 176.4 kBytes/second.
ADM data is expressed by code strings of the bit per channel. Therefore, if the sampling frequency is 176.4 kHz and the number of the channels is eight, the data rate is identical to that of a standard CD, 176.4 kBytes/second.

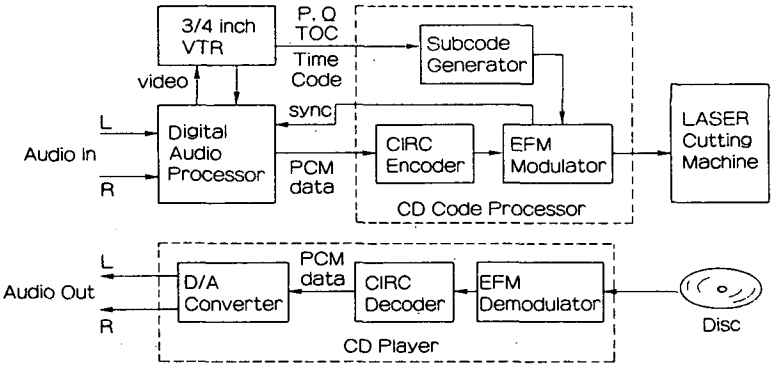

Fig. 3 Schematic diagram of Compact Disc (CD) system

The amount of data that can be recorded on one disc is the same as that of a CD, or 635.04 MBytes for one hour of recording. This is equal to the total number of samples of ADM data. The recording time per channel is 3600 seconds as calculated by 635040000/176400 = 3600. Since eight channels are used, the total recording time is eight hours.
Figure 4 shows a comparison of the data allocation between a CD and the ADM disc. In the ADM disc system, sampling is performed at a frequency four times higher than that of the CD system. Each sample consists of data from eight channels, or eight bits. These data are processed in the CD code processor and serially recorded on the disc. However, in this case, the eight-channel data may be considered to be recorded on eight tracks in parallel.

3. MANUFACTURE OF ADM DISC

3.1 Pre-Mastering

An ADM encoder has been developed which permits digital dubbing into the digital audio processor shown in Figure 3. Audio signals are first compiled into eight tracks by the analog tape recorder. Then they are input to eight CVSD modulators of the ADM encoder to be converted into ADM codes. The ADM data are output after they have been multiplexed according to the format of the digital audio processor.
The sampling frequency is generated from the synchronous signal supplied from the digital audio processor. Also, the ADM encoder has a CVSD demodulator which can be switched to monitor any one of the eight tracks ahead of the digital audio processor prior to final recording.

3.2 TABLE OF CONTENTS (TOC)

The 3/4-inch VTR tape on which the ADM data are recorded is reproduced by a conventional CD mastering system to make the discs. What requires attention here is the handling of address information called Table of Contents (TOC) which is recorded on the innermost area of the disc.
As shown in Figure 3, the TOC data, together with the data of subcode channels P and Q, are input to the CD code processor and then further processed separately from the PCM data before being recorded on the disc. In subcode channel Q, Absolute Time (ATIME) data indicating the lapse of time from the beginning of the disc and the time data indicating the lapse of time in each track being played are recorded.
The TOC data originally lists the starting time of each tune indicated by ATIME. However, when the starting times of the tunes differ in each track as in the ADM disc, the selection addresses in all tracks cannot be simply described.
In this newly developed system, therefore, arrangements were made so that the TOC data describe the ending times of each track. Continuous reproduction can be achieved by using this information.

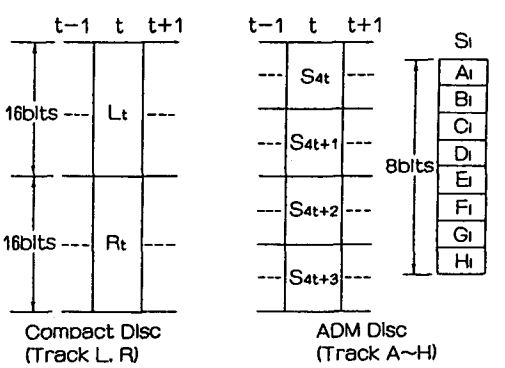

Fig. 4 ADM Disc data allocation compared with that of Compact Disc

4. PLAYER

An experimental ADM disc player with an internal ADM demodulator was developed. It incorporates a track select circuit and an ADM demodulator instead of the D/A converter.
The player permits the selection and reproduction of any one track by use of the front-panel keys. It also enables random access by inputting a track number and ATIME. It is normally programmed so that reproduction transfers smoothly from one track to the next in sequence, providing eight hours of continuous playback.

5. CONCLUSION

The new ADM disc system described above can utilize the mastering equipment and most of the player circuitry developed for the CD system, and permits eight hours of monaural reproduction. A one tip IC ADM-CVSD modulator/demodulator was used. Because the interface circuitry is simple and the major circuitry of the CD player can be used as it is, the ADM disc player can be produced at lower cost than that of the CD player.
The ADM disc system, which enables eight hours of playback from a single disc, makes use of the high reliability of the optical disc and is best suited for business use BGM equipment.

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REFERENCES

1) L.R. Rabiner and R.W. Schater, Digital Processing of Speech Signals, Prentice-Hall Inc., Englewood Cliffs, N.J., 1978.