DIGITAL VERSATILE DISC (DVD)

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Abstract – *The Digital Versatile Disc (DVD) is a new optical recording medium with a storage capacity seven times higher than the conventional Compact Disc. The major part of the capacity increase is achieved by the use of optics, shorter laser wavelength and larger numerical aperture, that reduces the spot diameter by a factor 1.65. The track formed by the recorded pits and lands as well as the track pitch can be reduced by the same factor. The storage capacity is further increased by a complete redesign of the logical format of the disc including a more powerful error correction and recording code. We will outline the system requirements of the Digital Versatile Disc and the related channel coding.*

1 Introduction

The Compact Disc (CD), introduced more than a decade ago, is a very successful medium for the distribution and storage of digital audio and other digital information. It is anticipated that its storage capacity, 680 MByte, will be insufficient for future graphics-intensive computer applications and high-quality digital video programs. An extension of the Compact Disc family, the *Digital Versatile Disc (DVD)*, is a new optical recording medium with a storage capacity seven times higher than the conventional Compact Disc. From a consumer vantage point, the DVDs will be capable of storing high-definition video/audio for feature-length movies and are expected to gradually replace video cassette tape and CD-ROM computer data discs once DVD becomes accepted as a commercial product. The DVD format will support a variety of uses. There will be at least two types of products introduced in 1996: the DVD movie player and the DVD-ROM. An audio-only version of the DVD is still under development.

The single-layer disc can hold 4.7 GByte which amounts to seven times more data than an audio CD. Typically, this is room for 135 minutes of wide-screen (16:9 aspect ratio) video at MPEG-2 quality accompanied by multiple audio and subtitle channels. Applying multi-layer technology, a storage capacity of up to 17 GBytes was obtained. The major part of the capacity increase is achieved by the use of optics, shorter laser wavelength and larger numerical aperture, that reduces the spot diameter by a factor 1.65. The

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track formed by the recorded pits and lands as well as the track pitch can be reduced by the same factor. The storage capacity of the DVD is also increased by a complete redesign of the logical format of the disc including a more powerful Reed-Solomon product code (RS-PC) and recording code (EFMPlus). In the next sections, we will discuss the various design issues and choices that had to be made.

2 Physical aspects

The main physical parameters of the single-layer DVD are listed in Table 1. The parameters of the dual-layer disc are more conservative. Mechanical specifications such as outer diameter and center hole diameter of the DVD are equal to those of CD, allowing full backward compatibility. The disc thickness was halved to 0.6 mm which resulted in a higher storage capacity than possible with a disc of thickness 1.2 mm. Specifications of the obsolete 1.2 mm-thick MultiMedia CD disc can be found in [1]. Mechanical instabilities, such as disc warp, of the 0.6 mm thick disc have been solved by back-to-back bonding of two 0.6 mm discs. Clearly, overall thickness of the sandwich is the same 1.2 mm of the CD, and the sandwich has the same mechanical stability. By employing a red laser at 635 nm wavelength and a numerical aperture (NA) of 0.6, the read-out resolution is increased by a factor 1.65. The subsequent scaling of the track pitch and the pit length per bit, increase the actual physical data density by a factor of 3.5. The nominal read-out reference speed goes up from 1.2 to 4 meters per second. An overview of the various factors that underlaid the capacity increase is shown in Figure 1.

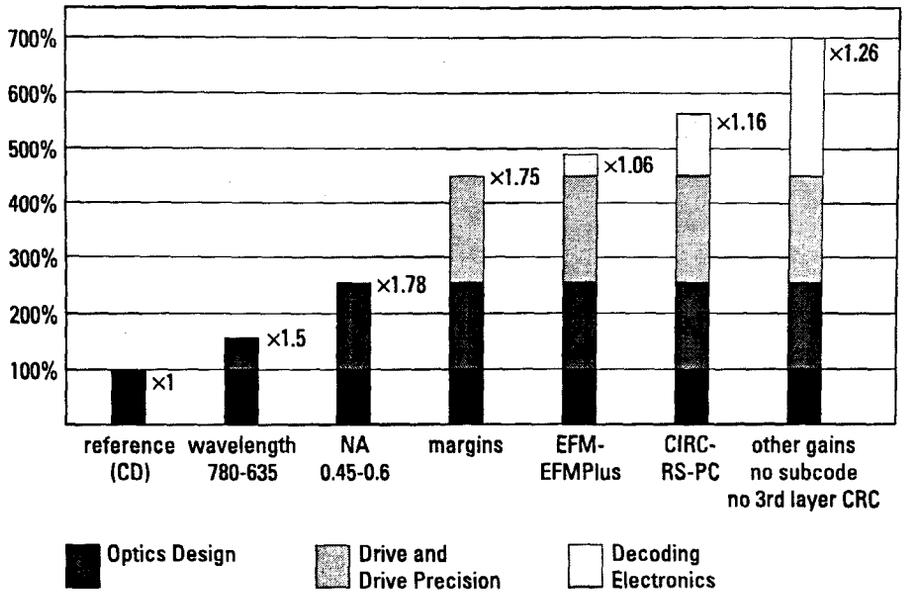

Figure 1: Overview of the factors determining the capacity increase.

We have partitioned the various sources that contributed to the capacity increase into optics, drive precision, and electronics. It can be seen that the margins of drive and disc have become more stringent by a factor 1.75. It is anticipated that the manufacturing of players and discs can be done with greater precision than 15 years ago when the CD was conceived.

A second method to increase the capacity by a factor of two is by using a dual-layer disc, where the layers are on one side of the disc The principle of operation of the dual-layer disc is shown in Figure 2.

Table 1: Main physical parameters of single-layer DVD vs CD-ROM.

	DVD	CD-ROM
read-out wavelength (nm)	650/635	780
reference NA	0.6	0.45
disc diameter (mm)	120	120
disc thickness (mm)	0.6	1.2
layers	single or dual layer	single layer
data capacity (GByte)	single-layer: 4.7	mode I: 0.68
	dual-layer: 8.5	mode II: 0.78
reference scanning speed (m/s)	4	1.2
reference channel bit rate (Mbit/s)	26.16	4.32
reference user bit rate (Mbit/s)	11.08	1.41
min. pit (or land) length (μm)	0.4	0.85
data bit length (μm)	0.267	0.6
channel bit length (μm)	0.133	0.3
track pitch (μm)	0.74	1.6

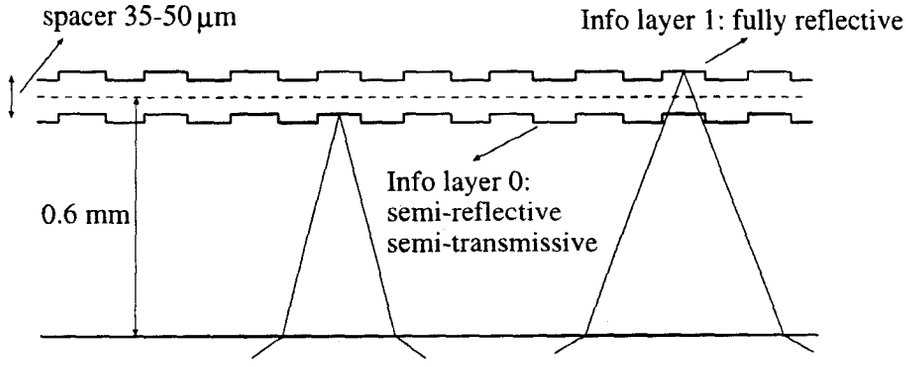

Figure 2: Dual-layer reading principle diagram.

The dual-layer CD is similar to the standard CD. It adopts the same molded substrate for the first data layer. The second layer is made by overlaying a fully-reflective aluminium layer on a partially reflective aluminium layer. The second layer is applied using the same principles as the 2P (Photo Polymerization) process. Focal plane servos are used to switch from one layer to the other. The two layers can be accessed without flipping the disc. Continuous play of video signals is obtained by reading outwards one layer, then inwards on the other. The sandwich dual-later disc has a capacity of 18 GByte.

Table 2: Main audio/video specifications of DVD .

recording code	EFMPlus
sector size (bytes)	2048
error correction	RS-PC
data transfer rate	variable speed date transfer at an average rate of 4.69 Mbit/sec for image and sound
image compression	MPEG-2 digital image compression
audio	Dolby[2] AC-3 (5.1 ch) LPCM for NTSC and MPEG audio, LPCM for PAL/SECAM
running time (movies)	133 min./side

3 Electronics aspects

The main audio/video specifications of the DVD are listed in Table 2. In the Compact Disc system, a concatenation of two codes, namely EFM (Eight-to-Fourteen Modulation) and CIRC (Cross Interleaved Reed Solomon Code) is used. CIRC is used for correction and detection of erroneously retrieved information, while EFM is used for transforming the digital audio bit stream into a sequence of binary symbols, called *channel bits,* which are suitable for storage on the disc [2]. As in CD-ROM, the user data is organized into sectors. Sixteen sectors make one ECC block. Under DVD format rules, sectors of 2048 user bytes are translated into 2418 bytes (2048 user + 52 sync + 16 header + 302 erco) which are in turn translated into 16×2418 channel bits. Thus, one user bit is translated into $4836/2048 = 2.36$ channel bits. In conventional CD, an audio bit is translated into $588/192 = 3.05$ channel bits [2], and we conclude that the 'format efficiency' of the DVD is improved by 32 %. The new format is even 47 % more efficient with respect to CD-ROM, which uses a 'third' error correction layer. Even though consuming a significantly lower data overhead, the error correction code, RS-PC, can cope with longer bursts and burst sequences, and more random errors. A comparison of the format efficiency of the DVD compared with conventional CD audio is provided in Table 3.

[2]Note: Dolby is a trademark of Dolby Laboratories Licensing Corporation.

Table 3: Comparison of format efficiency.

Parameter	*CD*	*DVD*	*Gain (%)*
synchronization (% per sector)	4	1	3
error corr. code (% per sector)	33	15	18
channel code (1/rate)	17/8	16/8	6
subcode (% per sector)	3	-	3
		Total	30

4 Conclusions

The Digital Versatile Disc (DVD) Disc is a new optical recording medium with a storage capacity seven times higher than the conventional Compact Disc. The user capacity of the single-disc is 4.7 GByte, and the dual-layer disc increases the data capacity to 8.5 GBytes. The major part of the capacity increase has been achieved by the use of optics, shorter laser wavelength and larger numerical aperture, that reduces the spot diameter by a factor 1.65. The track formed by the recorded pits and lands as well as the track pitch can be reduced by the same factor. We have outlined the system requirements of the DVD and the related channel coding. The conventional CIRC and EFM codes have been replaced by a more powerful error correction, RS-PC, and recording code, EFMPlus. As a result, the 'format efficiency' of the DVD relative to audio CD is improved by 32 % (49 % with respect to CD-ROM).

References

[1] K.A.S. Immink, 'EFMPlus: The Coding Format of the MultiMedia Compact Disc', *IEEE Trans. Consumer Electr.*, vol. CE-41, pp. 491-497, Aug. 1995.

[2] K.A.S. Immink, *Coding Techniques for Digital Recorders,* Prentice-Hall International (UK) Ltd., Englewood Cliffs, New Jersey, 1991.

[3] J. Watkinson, *The Art of Digital Audio,* Focal Press, London, 1988.