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AN IN-DEPTH LOOK AT THE MINIDISC

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ABSTRACT

The purpose of this paper is to provide the reader with an in-depth look at the MiniDisc as a storage device. This paper will cover the history of the MiniDisc as well as the technical specifications for how MiniDiscs operate. The paper will include details surrounding the benefits of this form of data storage as well as some of the limitations and weaknesses of MiniDiscs.

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INTRODUCTION

Modern society thrives on the utilization of technology and computational devices in order to function at a relatively normal level. There are literally thousands of embedded systems, ubiquitous computing devices, and technological wonders that surround daily living. Ranging from a modern wristwatch to the Blue Gene/L, one of the world's fastest supercomputers (pictured below), a person can hardly walk ten feet without encountering, to some extent, a device that utilizes computational technology.

Figure 1 – The Blue Gene/L (Courtesy of IBM Corp.)

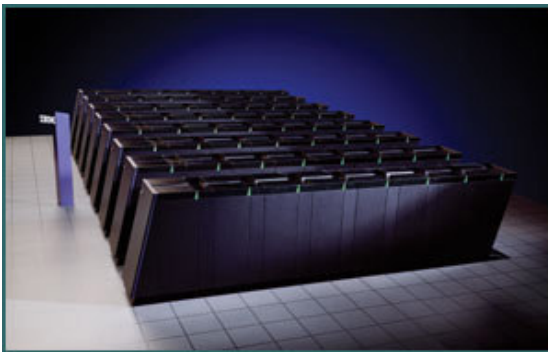


Figure 2 – Modern Wristwatch



While many of these devices function usefully without needing permanent (non-volatile) storage, the ability to store data has become crucial to many of today's daily tasks. As the applications for non-volatile storage have increased, so have the types of devices used to store data. This paper focuses on a single type of non-volatile storage, the MiniDisc. This paper will outline the history of the MiniDisc, how the technology behind it works, as well as the inherent benefits and limitations of this unique type of storage device.

HISTORY OF THE MINIDISC

Important Note: The MiniDisc is a proprietary product produced by Sony Corp. Because of the nature of the research and development of this technology, much of the material used for this paper came from various Sony Corp sources, including the Sony website, Sony whitepapers, and Sony technical manuals.

Like many of today's optical storage devices, the MiniDisc was first conceived as a device for the recording and playback of music. When the first recordable Compact Disc (CD) was announced in the 1980s, Sony set out to create a device that would function much like both a CD and magnetic tape. The ability to read and write multiple times (similar to magnetic tape), with the random-access and quick seek time of the CD became the primary goal of this new type of technology (Sony, 2005).

As a result of this research, Sony produced two types of storage devices: the Write-Once (WO) optical disk in 1986, and the Magneto-Optical (MO) disk in 1988. As the discussions about these new devices progressed, it was decided that a completely new type of device needed to be built that would function similar to a CD but utilize magnetic storage technology. The new technology was designed to use a 64 mm disc, which is approximately one-quarter the area of a CD. The new technology was also speculated to hold approximately the same length (in minutes) of music that a CD could hold (approximately 74 minutes at that point in history).

As the research progressed, a new compression technology was developed by Sony in order to ensure that the music would fit on the smaller disc size. This compression technology is still currently known as Adaptive Transform Acoustic Coding (ATRAC) (Hoult, 2002; Tsusui, 1992). Along side the development of the compression algorithm was also innovative research in shock-proofing the device in order to ensure continuous playback even amidst jostling.

The research and development of this new technology was finally announced and publicly released in May of 1991 (Sony, 2005) and was known as the MiniDisc (MD). Although the disc itself was deemed to be rather rugged, in order to add further protection for portability, it was encased in a plastic shell. An image of a MiniDisc (front view) is provided below.

Figure 3 – MiniDisc (front view)



Sony began a massive campaign (particularly in Japan) to expedite the acceptance of this new technology. In 1994 Sony released an encoding type known as MD Pictures for storing digital images on the device (Sony, 2005). Eventually, a computer interface was created for the MiniDisc, allowing it to be used for data storage.

Although the MD became quite popular in Japan and several other countries, the MD never reached widespread acceptance as a portable device in the United States. Just as the MD was beginning to receive notice in the US, the development of MP3 technology rapidly overtook the sale of MD devices. Despite the relatively low popularity of this device in the United States, it still represents a unique type of storage widely used in several areas of the world.

HOW THE MINIDISC WORKS

In order to understand how the MiniDisc works, it is first necessary to realize that there are two basic types of MDs: prerecorded, and user recordable. The prerecorded MDs are those that come with music or data already recorded onto the device. The prerecorded MDs function very similarly to a prerecorded Compact Disc, and thus will not be discussed in the scope of this paper. It is sufficient to note that the technology for creating prerecorded MDs and prerecorded CDs is quite similar, except for the compression technology that MDs use in order to fit more music onto a smaller disc size (compared with a CD).

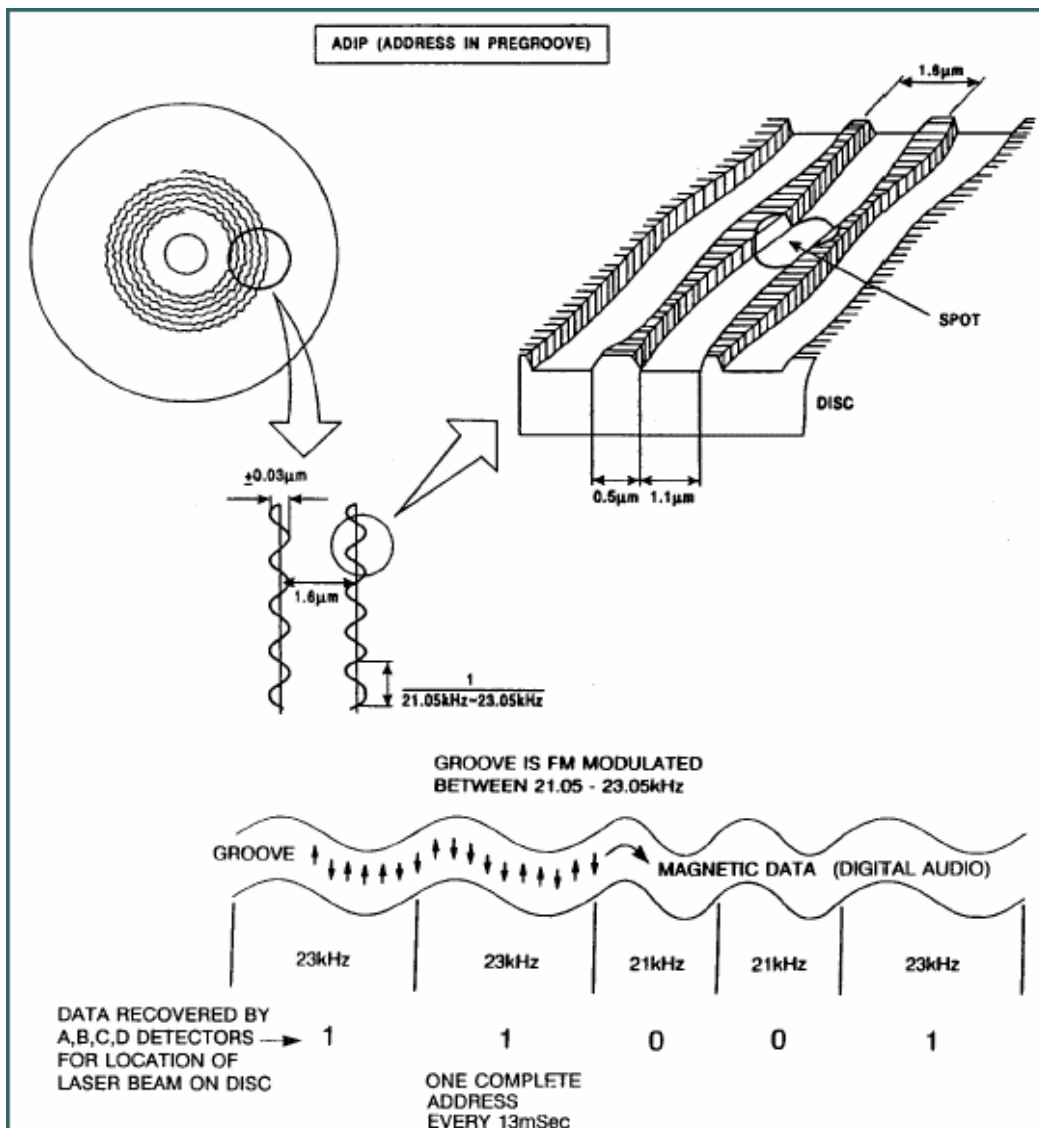
The second type of disc, the user recordable disc, is the primary device of interest. The idea of having a CD-like device that is rewriteable and takes up less room than a CD led to the development of several unique and proprietary technologies.

The disc is made using a special layer of Ferrite-Terbium-Cobalt that is used for storing the data (MiniDiscs, NA), as opposed to using a pit signal (stamped) which is used by the prerecorded disc. The MO (Magneto-optical) layer is set between two dielectric layers, along with a low reflectivity layer ('low' being relative to the reflective layer on a CD). On top of that layer is a protective layer and a silicone grease lubricant to make contact between the magnetic head and disc less resistive.

Before analyzing the magnetic material and the recording process, it is important to note some of the special features of the actual physical methodology used for formatting and organizing the data on the disc. The recordable MD employs a disc shape similar to a CD and also uses a single track spiral technology similar to a CD. Thus the music (or data) stored on an MD is stored on a single track that spirals around the disc. This allows easier access for continuous playback or continuous reading. Something unique to the MD that is not found on a CD is what is known as a "pregroove" (MiniDiscs, NA). The pregroove is a "wobble" in the form of a sine wave that coincides with the data track as it spirals around the disc. The pregroove is a 22.05 kHz signal that is FM modulated in order to provide address information for the track. The addressing schema and information is exactly the same for each disc, which is

what allows the motor to know the exact location of the laser unit used for reading/writing (to be explained later). This Address In Pregroove (ADIP) information is put onto the disc during the time of manufacturing, and is never altered through the recording process. It must remain constant in order to provide addressing for the laser head. A diagram that demonstrates the use of the ADIP signal is provided below.

Figure 4 – MD ADIP Diagram



The special recording layer is a type of material that is magnetic and can have its magnetic properties (magnetic direction) altered by an external influence or field. However, one of the special properties of Ferrite-Terbium-Cobalt that makes the MiniDisc so unique is the fact that the magnetic direction of the material can only be easily altered when at a special temperature, known as the Curie point. Once the material reaches the Curie temperature, (approximately 185 degrees Centigrade) then the magnetic field of the material can be more readily altered by an external field.

In order to write data, a laser is utilized to bring the material to its Curie temperature (as described previously). Once the material has reached that temperature, a magnetic head on the opposite side of the disc can produce a field that will alter the state of the current bit, forcing it one way or the other. The coercivity of this material is low enough that a strong magnetic field is not necessary in order to alter the state of the bit, but is high enough that the magnetic state of the adjacent bits does not interfere with the current bit. The coercivity is approximately 80 Oersted (MiniDiscs, NA). It should also be noted that the Ferrite-Terbium-Cobalt material does not require an extremely high temperature, thus reducing the power consumption of the laser used to heat the material. The Curie temperature for this material is approximately 185 degrees centigrade (MiniDiscs, NA). The layers that surround the magnetic layer are specially adapted to withstand the high temperature necessary to bring the material to its Curie point.

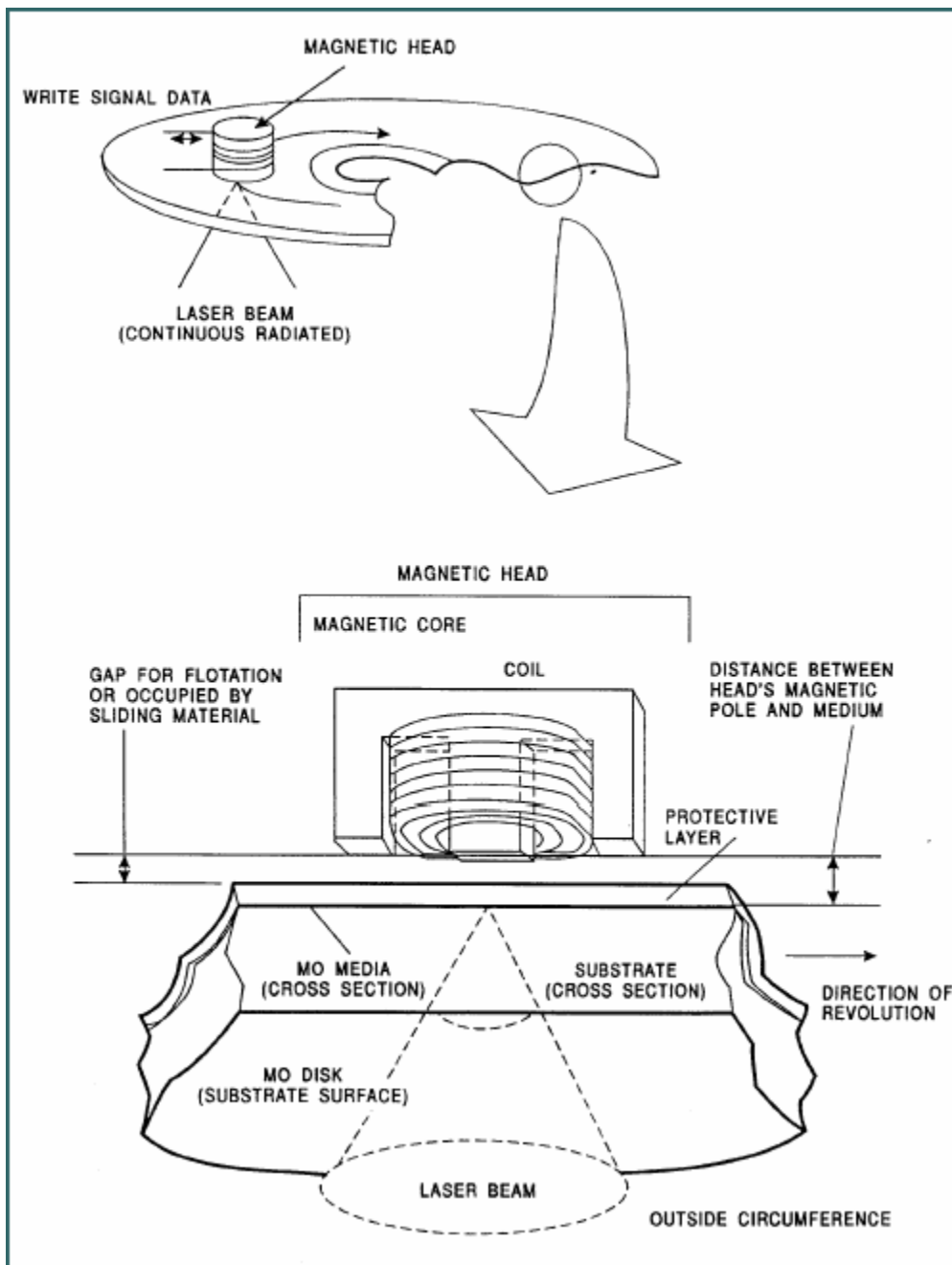
The properties of the material allow an extremely high number of state changes to take place before corruption or significant deterioration of a bit. This allows rewriting by simply reheating the bit to be altered, and forcing the state of the bit to be that of the desired state. This also speeds the rewriting process by not requiring erasure of existing data before a rewrite.

The recording format is known as Magnetic Field Modulation because it is the magnetic field of the head that modulates the magnetic layer on the disc. Although a laser is used in the process of recording, it is important to note that the laser is not used to record the state of the bit. The laser is only used to heat the material to the Curie temperature, allowing the material to become “writeable.” The image below shows an MD with the protective sliding door pulled back, exposing the disc. A drawing (courtesy of Sony Corp) is shown on the next page that demonstrates the layout and basic functionality of both the magnetic head and the laser.

Figure 5 – MD Exposed Disc



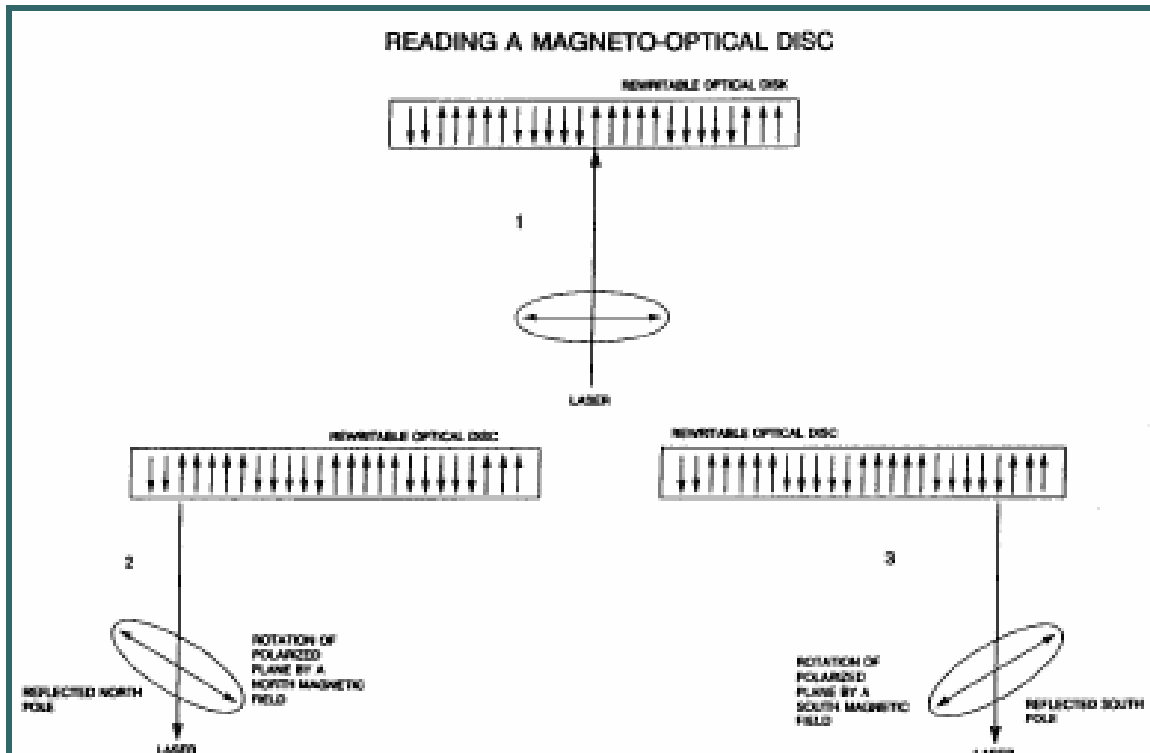
Figure 6 – Magnetic Head and Laser on MD System (courtesy of Sony Corp)



To read from a MiniDisc requires different technology for both the prerecorded disc and the user recordable disc. Because the process of reading from the prerecorded disc is so similar to that of a prerecorded CD, the reading process will not be discussed at length in this paper.

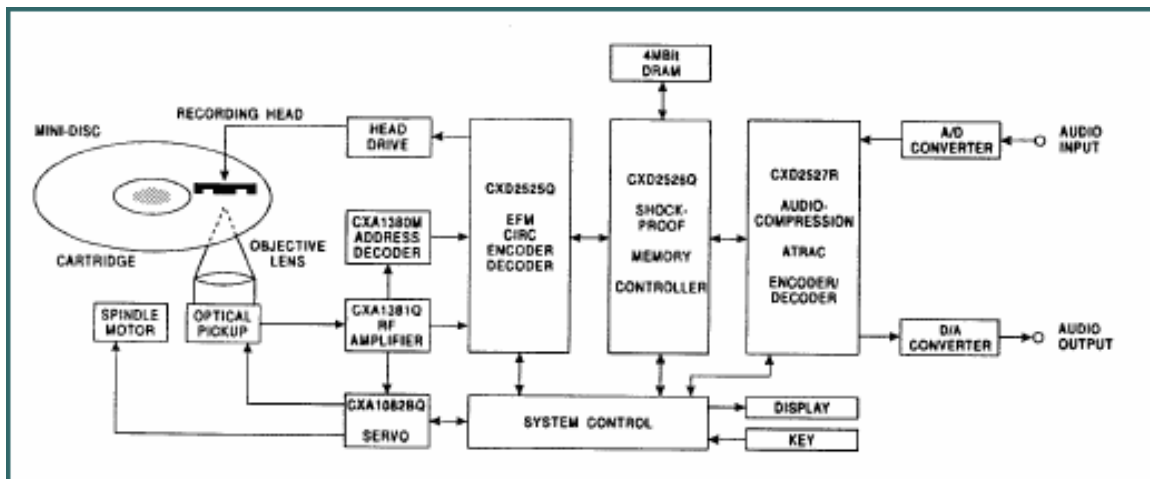
In order to read from a recordable MD, there is a laser light emitted to the disc (similar to the process of reading from a CD), but in this case there are no “pits” (the name given to the grooves or valleys used in prerecorded media). In the case of recordable MDs, the laser light passes through the magnetic layer and is reflected off of the underlying reflective layer. As the light passes through the magnetic layer, it is polarized. The polarization of the light by the magnetic material is known as the Kerr effect (MiniDiscs, NA). Based on the direction of the bit being read, the light will be polarized one of two directions. Thus the polarization can be used to determine the current state of the bit, providing information as to what the bit should be translated to digitally. A diagram of the reading process is shown on the following page.

Figure 7 – MD Reading Diagram (courtesy of Sony Corp.)



In order to better understand the MD as a storage device, it is important to point out several features of the MD system that distinguish it from other similar storage devices. For example, the shock-proof memory buffer that is put in place was unique to the MD. After the MD was released, many CD players also came with some sort of buffer memory to assist in continuous playback. The MD uses the buffer for both reading and writing of data. Additionally, similar technologies do not utilize built-in compression algorithms as does the MD. The use of the ATRAC compression system is what enables the storage of so much data on such a small disc (Hoult, 2002; Tsutsui, 1992). To clarify the process of how the MD system functions, a block diagram is provided on the following page.

Figure 8 – MD System Block Diagram (courtesy of Sony Corp.)



There are many aspects and details of a MiniDisc that have not been specifically addressed in this paper. The intent of this paper is to give a brief, but technical background to the MiniDisc storage system. Although several technical details have been intentionally left out of this paper, an interested reader may desire to further study the topics not covered (or only briefly covered) in this document. Some of these topics include (but are not limited to): Shock proofing system, system control, physical disc format (caddy), track layout and data format, address structure, data structure, TOC (table of contents), ADIP structure, ATRAC encoding, power and noise handling, and psychoacoustics.

BENEFITS AND LIMITATIONS

As with any type of storage technology, the MiniDisc inherently has several benefits as well as several disadvantages. To better grasp some of the highlights and problems with this technology it is useful to view these concepts in

terms of actual applications of the MiniDisc. The following sections will outline some of the common applications of MDs.

Audio Storage

The MiniDisc was originally produced as a competitor to the Compact Disc. As such, the primary application of the MD was originally for music storage. The MD was designed similarly to a CD in the way that information is stored and processed. One of the primary differences of the MD is the size. Although it may appear as though the data density is much greater with MD technology, it actually is not. The reason that the MD is smaller than a CD is because of the compression technology that is built right into the MiniDisc system. CD audio tracks are not stored in compressed format, but MD audio tracks are compressed. To give a good understanding of some of the differences between the MiniDisc and the Compact Disc, the following table was created.

Table 1 – MD vs. CD (based on spec sheets provided by Sony Corp)

Comparison Table - MiniDisc vs. Compact Disc		
	MiniDisc	Compact Disc
Frequency Response	5-20kHz	2-20kHz
Sample Frequency	44.1kHz	44.1kHz
Disc Size	2.5 inches	4.7 inches
PB/REC Time	60/74 Mins.	74 Mins.
Dynamic Range	105dB	96dB
Density/Coding	16 bit max/ATRAC	16 bit
Laser light Output Power	PB = .4 mW/.8mW for reading 6.8mW for recording	.2mW for reading

As can be seen from the previous table, the MD is highly qualified as an audio storage device. It can hold the same amount (in minutes) of audio information as a typical CD, has the same sampling rate, and is still within the ideal frequency response range. The primary benefits are that the MD is small, light, consumes very little power, and holds up under heavy jolting. The MD is also rewriteable, allowing for multiple edits or recordings on the same disc.

Data Storage

The MiniDisc was not originally intended for use as a data storage device, neither was the Compact Disc. However, the high density (relative to the time period) of the compact disc naturally led it into the realm of data storage. This is where the primary disadvantages of the MD become more obvious. For the Compact Disc, because the audio was not being compressed, nearly the same number of bits could be allotted for data storage (around 750 MB) as were allotted for audio. Thus the same technology that creates a 74 minute CD can also store approximately 750 MB of data. In contrast, although 74 minutes of music is stored on the MD, that music is stored in compressed format, which means that it takes up much less space in terms of bits or bytes. Just as the MD is roughly one-fourth the physical size of a CD, it also holds roughly one-fourth the amount of actual data. Thus when used for data storage, the MD only holds approximately 140 MB (MiniDisc, 2005). For this reason, although several computer drives for MD have been developed, the MD has not been widely accepted for use as a data storage device.

The applications where MDs are used for data storage tend to be in very rough or rugged environments. Because the MD is physically well suited for rough terrain, it makes it an ideal candidate for use in a variety of high-demand environments. The MD is able to withstand extreme temperatures relatively well, can withstand water damage, excessive wear and tear, and even magnetic disturbances, so long as the MD is not near the Curie temperature when a strong magnetic field interferes with it (Jones, 2005). Thus the MD is well suited for portable music applications and data applications where ruggedness is important, but storage size is not.

SUMMARY

The MiniDisc is a proprietary product of Sony Corporation that was developed with the intent of providing a more rugged and more portable music device than was available with the Compact Disc. The technology grew widely in several countries, but did not reach widespread acceptance within the US.

MDs utilize both magnetic and optical technology in order to function as a storage device. A magnetic substrate is used to store bits of information upon a spiral-track disc. This magnetic layer is only writeable when brought to the Curie temperature. Once cooled, the bit is no longer writeable. To read the data back, a laser light is transmitted through the magnetic layer to a reflective layer. Due to the Kerr effect, the light is polarized as it passes through the magnetic field and the orientation of polarization can then be used to determine the state of the bit.

Although MDs are similar to CDs in functionality, there are several technologies developed for MDs that do not exist for CDs. MDs utilize a proprietary compression algorithm (ATRAC) to compress audio before it is recorded to the disc. The audio is then uncompressed as it is retrieved from the disc. This allows for a much smaller disc size than a CD. MDs also have advanced shock control in order to allow both the reader and writer to function properly under jolting or vibration. For addressing within the track, the MDs also employ a unique sinusoidal “pregroove” that allows the laser head to keep track of the current location of the motor.

Despite the many unique and advanced features of the MiniDisc, its primary use as a storage device has been for audio. The built-in compression algorithm makes it ideal for music storage, but makes it difficult to work with as a data storage device. An MD can only hold approximately 140MB of data. However, an MD is also quite rugged and can withstand very harsh environments.

In summary, the MiniDisc is a very unique magneto-optical storage device that has a highly niche application, and an even more exclusive market. Among the many storage devices available on the market, the MD does not offer a highly competitive advantage over other forms of storage. Despite this, the MiniDisc did bring about several interesting technological advances and concepts that were not being utilized previous to its conception. Overall, the MiniDisc is an extremely fascinating device, with decent potential, but low acceptance in the market.

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