Mysteries of the Compact Disc Revealed

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HISTORY

The compact disc (CD) has an interesting history that may be surprising. Although the format was not widely popular until the early 1990's, the data storage medium has been in existence for over thirty years.

James T. Russell of Bremerton, Washington is who conceived the idea of storing music and data in a digital format in the late 1960's. His inspiration was to invent a new medium for music that would not require any mechanical parts to touch the source as it is played, thus preserving the quality of the music. What James discovered was that the only way to do so would be with a laser light.

It was Battelle Memorial Institute that funded the project while Russell worked in their Pacific Northwest Laboratory in Richland, Washington. By 1970, Russell had patented the first compact disc (web.mit.edu).

Russell continued to improve the design, adapting it to a multitude of formats, although no investors were onboard for mass production. It wasn't until the early 1980s that Sony and Philips realized the potential of the medium, purchased the license and released the first musical CDs to the public in late 1982 (web.mit.edu).

THE BASICS

A music CD stores sounds in a digital format, in contrast to a vinyl record or cassette tape, which store the music in analog form. An analog source such as a vinyl record is played by reading across a series of waves and bumps that essentially imitate the wavelengths of the audio track. A CD uses a digital code that composes "snapshots" of the sound wavelengths at frequent intervals. When this code is read by a CD player, it translates the code of "snapshots" back to the original sound wavelengths. This can be imagined just like an animated flipbook—the "snapshots" of the sound wavelengths will perform like a series of individual images, which, when streamed together, create an animation.

Each of the "snapshots" that compose a song is read as a byte, which is a series of ones and zeros (known as bits), in groups of eight. This binary code would read like nonsense to a human, but to a computer, it is a language that can communicate music or any number of other types of data. In order for this language to be read by the CD player's laser, the information is stored with a series of extremely tiny bumps that represent the binary code. The CD is read by a laser and photo–electrical cell that can identify the binary code and then translate the binary language into a signal that can be played through your speakers (www.howstuffworks.com).

THE CD CONSTRUCTION

A CD is composed of just a few different layers of material. Beginning at the top, you will find a label (mostly layers of ink), a thin acrylic coat, the aluminum, and then a polycarbonate plastic (Figure 1). The plastic on the bottom of the disc protects the data layer and also helps the laser focus its light—much like a glass or plastic lens can help your eye focus (www.howstuffworks.com).

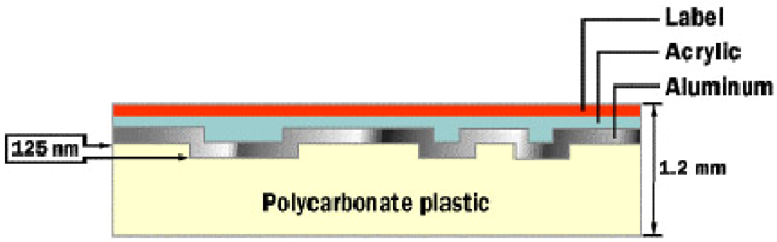

Figure 1: Sectional Side–View of a CD
Image Courtesy of Howstuffworks.com

The production of a CD begins with the bottom layer of polycarbonate plastic. The top of the plastic is stamped out to form the tiny bumps that will eventually be read as binary code. The reflective aluminum layer is then pressed on top of the plastic, conforming to the plastic's new bumps. Next, the acrylic is laid for additional protection and then the label on top of it all (www.howstuffworks.com).

THE LANDS AND PITS

The tiny bumps that are pressed into the polycarbonate plastic are known as lands. They are pressed onto the plastic at an extremely microscopic scale—a mere 125 nanometers. A human hair, at about 50,000 nanometers in width, is huge compared to the height of these lands. These lands are slightly wider than they are tall, at about 500 nanometers, or half a micron. Each row of lands is also separated by 1.6 microns from the next (www.howstuffworks.com).

What are left when the lands are put on the disc are the pits in between (Figure 2). These lands and pits represent the binary code, which is a language of just two characters, a 1 and a 0, each known as a bit. Variations of the land and pit lengths will represent a different sequence of bits that create a byte. In the case of a music CD, these variations represent different wavelengths of sound (ee.washington.edu).

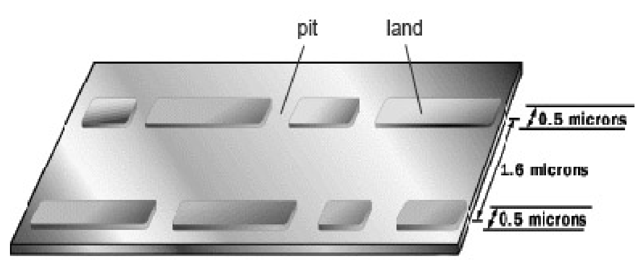

Figure 2: Lands and Pits from the Underside of a CD
Image Courtesy of Howstuffworks.com

THE LASER MECHANISM

The laser used for reading a CD has the width of about 780 nanometers and projects light in a straight line onto the base of the disc. The laser is generated by a small gallium–arsenate semiconductor and is projected through a couple of lenses that focus the beam to the proper diameter. As the disc spins past the laser, the pits reflect the light, each time representing a binary "1." The light that hits a land is at a precisely closer distance to the laser; thus, the wavelength reflected off the land is 180 degrees out of phase (Figure 3), effectively canceling the opposing light wave and reflecting no light (by deconstruction between the source light and reflected light) (ee.washington.edu).

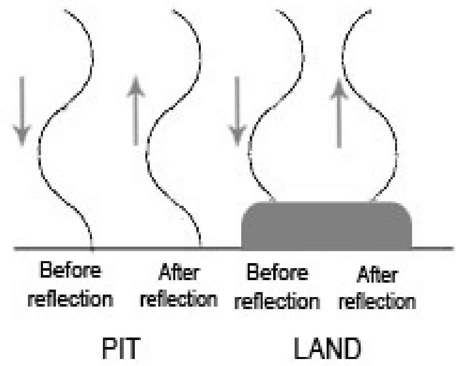

Figure 3: Light Reflected off Pits and Lands

The reflected light from the pit is intercepted by a prism, which directs it to a photo–electrical cell (Figure 4). The photo–electrical cell is sensitive to the light and translates the signals into electrical impulses. These impulses are interpreted as the binary code. In the case of a music CD player, the hardware's Digital–to–Analog Converter (DAC) then translates the code back to the original analog audio (www.howstuffworks.com).

READING THE CODE

When you start up your CD player, the laser begins on the inner edge of the CD and slowly moves outward while the disc spins, unraveling the line of code upon the disc. This long spiral of code is packed very tightly onto the 4.8 inch diameter disc. If unwound, end–to–end, this line of code would stretch about three and a half miles (www.howstuffworks.com).

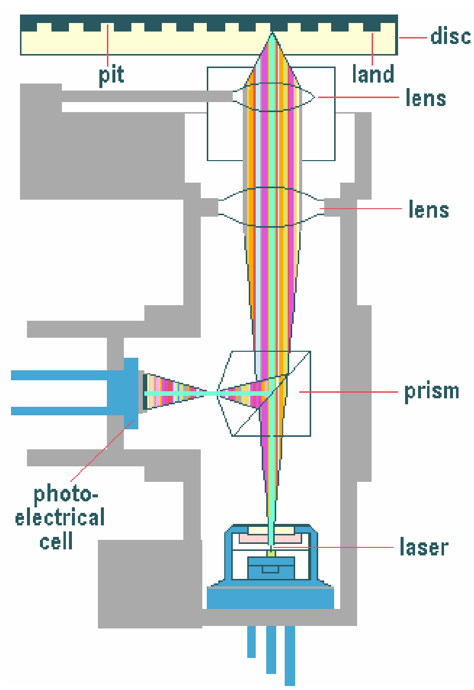

Figure 4: Laser Mechanism
Image Courtesy of whitleytech.com

Embedded into the line of code that creates the music are smaller pieces of information that the player recognizes as track information. This tells the player where it is currently located on the disc and where other tracks of information are in relation to it (ee.washington.edu). This is a feature of CDs that makes them much more convenient—no need to scan, searching for the song you want—you can skip to any place you like.

In order to properly read these very tiny lines of code, the laser must move at an extremely delicate and precise rate. While the disc drive spins the CD at a rate between 200 and 500 revolutions per minute (RPM), a tracking drive must slowly draw the laser out from the center (Figure 5). When a CD is played, the tracking drive moves outward at a constant rate of less than one thousandth of a millimeter per second. This extremely precise rate of motion makes it rather susceptible to failure and track skipping if the device is jostled, as you may have experienced with a Walkman. This skipping can be prevented through the use of small memory packages stored in the CD player's hardware. This extra memory allows the CD player to read several steps ahead of what is being played, store the information in a memory package, and then play the music from there. So if the laser gets off track, your ear never knows and the laser is able to get back on track and continue storing the data into the memory packages (www.whitleytech.com).

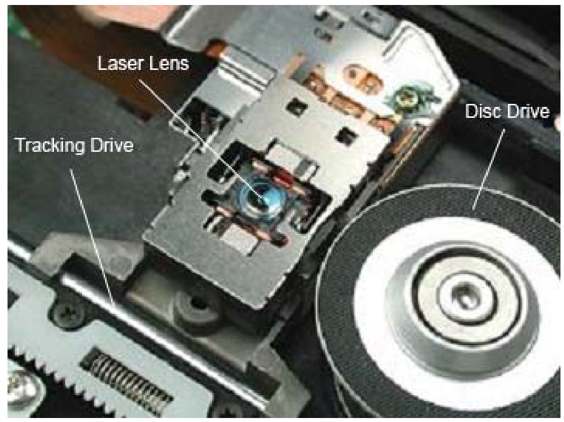

Figure 5: Disc Reader Mechanism
Image Courtesy of Mediatechnics.com

In order for the laser to successfully read the CD as the tracking drive moves it outward at a constant speed, the disc drive must adjust the rotational speed of the CD. If the CD were to rotate at a constant speed, the rate at which the lines of code would pass the laser lens would become much faster as it reaches the outer rim. This is due to the difference in linear speed of any rotating object—just like on a merry–go–round you may notice that it feels like you are moving at a much slower rate when standing in the center compared to when you lean off the edge. So as the laser moves toward the outside on the tracking drive, the disc drive's speed must slow accordingly. Thus, the speed of the CD slows at a linear rate from about 500 RPM to 200 RPM as the CD is played from start to finish (www.whitleytech.com).

Your computer drive may rotate at much faster rates. As the drive in your computer reads information from a data CD, it doesn't need to go at any specific rate, like the speed of a song does. Current CD–ROM drives can read data at tens–of–thousands of RPM.

THE FUTURE OF THE FORMAT

The CD was one of many great achievements during the twentieth century. It is a portable format that allows crisp music to be heard repeatedly without any wear on the format by the hardware. With the introduction of CD–Rs (CD–Recordable) and CD–RWs (CD–Re–Writable), the format has allowed us to back–up and transfer our music and computer files. The technology that makes it all possible continues to evolve, taking slightly different forms and providing us with new capabilities for our information storage and multimedia capabilities.

We have already witnessed a stage of the format's evolution with the introduction of the DVD (Digital Versatile Disc or Digital Video Disc) in 1997. While maintaining the same dimensions of a CD, a DVD holds nearly seven times as much data, with a capacity of about 4.7 Gigabytes (GB) versus a maximum of 700 Megabytes (MB) on a CD. More lines of code are packed on the disc by shrinking everything from the size of the lands and pits on the disc to the wavelength of the laser (780 nm to 660 nm) (blu–ray.com).

Another leap in digital media is about to take place. A new format not far from release in the United States is expected to supersede current DVDs. While there is a battle between two consortiums, each developing similar formats; the most impressive is that by Sony, Phillips and a host of other contributors. The new format, currently called Blu–ray Disc DVD (BD–DVD) allows for about 27 GB on a single layer and 54 GB on a double layer. There is even a four–layer disc in development that will allow over 100 GB on a single disc, while maintaining the same dimensions of a CD (blu–ray.com).

While the new developments in the digital disc format have come very far since the introduction of the CD in 1982, don't expect to see the original format squashed by new competition overnight. There is a huge investment in the current hardware and software libraries that will prolong the life span of the format. The newer technologies must provide significant improvements in quality and convenience in order for them to be accepted by consumers. While the new formats may creep in and take over, you can be certain that any digital disc of the future will be based upon the fundamental principles described here. It is only little variations in the technology that changes, but you now know the technology that makes it work and how they work together.

Glossary of Terms

Binary Code
A string of eight binary digits to represent characters.

Bit
A binary digit. Either a “1” (one) or a “0” (zero).

Byte
A package of eight bits.

Gallium Arsenate Semiconductor
An integrated circuit with an electrical conductivity greater than insulators but less than good conductors. Composed of a rare metal and salt of arsenic acid.

Gigabyte
A unit of computer memory space holding exactly 1,024 Megabytes.

Laser
Acronym for Light Amplification by Stimulated Emission of Radiation. A device that creates and amplifies a narrow beam of light (bell–labs.com).

Megabyte
A unit of computer memory space holding exactly 1,048,576 bytes.

Micron
Unit of measurement. One millionth of a meter (10-^{6})

Nanometer
Unit of measurement. One billionth of a meter (10-^{9})

Photo–Electrical Cell
A small electric unit used to convert light images into other forms of energy such as electricity.

Wavelength
The distance between one peak on a wave of light and the next peak

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