

The Compact Disc Digital Audio System

An example of the development of High Tech Consumer Electronics.

Translation of important excerpts from this book¹ on the history of the CD, originally written in the German language.

High Technology for consumers

The Compact Disc System is an excellent example for the aggregation of numerous research and development activities towards one product. From the first idea to the marketing, this product aspect was of central importance and formed a red line that also guided the basic research to materialize the ambitious product goal.

The most important goal was the creation of a new medium for audio recordings that could establish itself on the traditional record market. The application of high technology was needed to get real benefits compared to the fully developed record player technique in 100 years. These new features, welcomed by the consumer, did not lead to more difficult control of the player.

The realization of simple control of the CD player, by effective concealing of the inner workings, caused a supple introduction in the record player market and ousted the old record in a couple of years.

Scientific Research within Philips

*“.....in the construction of optical discs
.....teamwork of optical, electronic, mechanical
and chemical scientists and engineers has been vital.”*
(Gijs Bouwhuis, 1985)²

An important condition concerning the product development of the Compact Disc Digital Audio System by the Philips Gloeilampenfabrieken was the support of the own scientific research laboratories.

The technology of most of the planned components for the CD-System was not mature enough, therefore the application in cheap consumer equipment was not possible without further elaborate research.

Introduction of high tech in these products was only possible by the ability of Philips, within their own company, to transfer recent research results into a format suitable for mass production.

Video Long Play, start of the technique

The roots of the Compact Disc System are to be found in the start of the research and development activity of an optical video medium in 1969. This resulted, already in 1972, in a proposal for a video disc system, named “VLP” (“Video Long Play”). Analog to the Long Play audio record, it should give the possibility to use the television set, besides to receive the transient TV programs, to reproduce recorded video on an optical disc.

Problematic was how to accommodate the sound and video information, which differed orders of magnitude compared to the LP. The solution was found in using dense optical

¹ Lang, Jürgen K.: Das Compact Disk Digital Audio System: ein Beispiel für die Entwicklung hochtechnologischer Konsumelektronik. ISBN 3-00-001052-1. Dissertation for the Technische Hochschule Aachen.

² Bouwhuis, Gijs. “Introduction” in: Bouwhuis, G., J. Braat, A. Huijser, J. Pasman, G. van Rosmalen and K. Schouhamer Immink. Principles of Optical Disc Systems. Bristol/Boston: Adam Hilger 1985, pg. 4.

recording on a disc with reproducible mechanical dimensions, this forms the kernel of the technical matter, for VLP and Compact Disc alike. The video signals were pressed as microscopic elevations on a metalized plastic carrier, to be read out with a gas laser, contact less. These video discs could contain at each side a 30 minute color program. In comparison with the LP record two advantages were yielded: no wear of the disc and the possibility by using a laser to miniaturize the imprint of information. If the large frequency range of the VLP should be used to record only analog audio signals of narrow frequency band, a playing time of 48 hour was possible with reasonable sound quality. However the marketing prospects of such a consumer product did not look bright.

Birth of the Compact Disc

The initial idea to transfer simply the Video Long Play (VLP) concept into the audio domain was not successful for reason that the highbrow technology had priority over the requirement to design a marketable product.

The real breakthrough, marking the birth of the CD, needed a further step in Ottens³ mind. This step was in 1972 not so obvious as it is now in retrospect⁴. A paradigm needed to be conquered that in almost hundred years was formed: the always unsurpassed position of the gramophone record as a medium for sound recording. Notwithstanding minor improvements, the basic functional parameters were, for compatibility reasons, not changed since Emil Berliner's Gramophone of 1887.

In Ottens' imagination he dared to question the supreme position of the LP on the international markets, replacing it by a completely incompatible high-tech product that had to be developed in-house to become a major player in the audio recording field. This idea became the foundation for the development of the Compact Disc.

To be successful on the established audio record market, it was advantageous that the new medium should cover the whole range of available music recordings. That limited the playing time to less than an hour, contrary to earlier proposals.

Conclusion: Instead to record very long music programs on a large disc, the restricted playing time brought the possibility to reduce drastically the disc diameter, giving a real "compact disk".

The idea of a compact audio version of the VLP concept fascinated Ottens in such a way that he already in 1972 established a development group consisting of 2 persons to study the technical realization of optical read out.

Nobody could imagine that this small project, in the shadow of the Video Long Play activities, in the long run would surpass the VLP.⁵

Research involvement, ALP

The first public VLP demonstrations took place in 1972. To get the benefit of scientific research for his audio optical disc project, Ottens could use the ambition aroused by the activities for the VLP at Philips Research Labs (Nat. Lab.).

On the one hand to enhance synergy between science and technique and on the other to prevent drifting away of the Nat. Lab. research from his product idea, he placed Toon van Alem, a staff member of his Audio Division, by the side of the Nat. Lab. researcher Loek

³ Lou F. Ottens, Technical Director of the Audio Product Division initiated the study for broader use of the analog Video Long Play system.

⁴ Nayak, P.R. and J.M. Ketteringham. *Breakthroughs!* San Diego 1994. page 369

⁵ Market acceptance of the VLP system (named Laser-Vision) was not sufficient. The new video cassette recorder was preferred by the public.

Boonstra. Ottens gave no concrete instructions to the small research team: “Just try to figure out what looks possible”. The connection with the prestigious VLP project was indicated by naming the forerunner of the future CD: ALP, Audio Long Play.

This start of the cooperation of researchers of the Nat. Lab. with engineers of the Main Industry Group Audio developed later into a characteristic feature which left his mark upon the total concept.

In the beginning Boonstra and van Alem restricted themselves to study methods of recording audio signals on a modified VLP player. Obvious, but not necessary, was the use of the VLP modulation system. Different source signals with small bandwidth were frequency modulated on different carriers, resulting in separated frequency bands for each source signal.

The possibility to read out at the same moment different FM modulated audio signals made multi channel audio recording easy, very usable for stereo and the upcoming quadrophony⁶. End 1974 the first experimental ALP disc was played.

However severe problems had to be solved: For a one hour stereo or quadro playing time the disc diameter became 20 cm or 7 inch. This did not fulfill Ottens compactness requirement. Also the sound quality appeared not perfect, microscopic faults in the test disc gave a crackle like that heard by the common record players!.

Innovation phase (1976-1978)

The ALP project came more before the wind when in January 1976 Johann J.G.Ch.van Tilburg became general and commercial manager of the Main Industry Group Audio.

In a short time Ottens got friendly with his boss and disclosed him his ALP activity, which proceeded up to now silently.

Van Tilburg was surprised and enthusiast for this new system and promised to promote official development, but some “details” should be changed: The sound quality, indeed, was better than the old shellac records but not sufficient for the introduction of a new product. The diameter of the disc should be reduced to 11.5 cm, the diagonal of a compact cassette. And lastly the name ALP should be changed to a more expressive one.

Step towards digital technique

Considering the audio quality problems of the ALP, it was clear that the original strategy to take over as much as possible of the VLP technique could not be followed anymore. Based on the use of frequency modulation, the modulated audio signals laid more or less in their original form on the disc. As is the case with the traditional records, every fault in the reading, even very small ones, necessitates a distorted audio output signal. This “analogy” between the quality of the reading process and the quality of the reproduction caused an insurmountable problem. Faults on the surface of the recording medium and faults from the tracking mechanism can never be totally avoided. It follows that with an analog modulation process, like FM, the enhancement of sound quality is a very difficult and costly issue.

A fundamental step in the development of the ALP was the decision, taken by the development team in cooperation with the research group of Dr. J.B. Hans Peek, to switch to quite another modulation system. Lorend Vries, staff member of Peek’s research department “Distribution Systems and Fundamental Aspects”, had already tried earlier to develop an analog method to suppress burst faults on the surface of the ALP disc. This led him in the first quarter of 1976 to the first study regarding a digital version of the ALP.

⁶ Woodward, J.G. “Quadrophony – A Review” *JAES* 25 (10/11), Oct./Nov. 1977, p. 843-854

With the acceptance of the concept of Vries, the step from an analog medium towards a digital medium was set. This meant that the sound signals in coded form were recorded on the optical disc. Such a coding, whereby the sound wave is analyzed and represented in digital symbols, has the basic advantage that still under difficult transmission situations a fault free transfer can be realized⁷. Mathematical methods are there to detect faulty readings.

By the introduction of digital techniques the ALP developers could use the expertise of the Nat. Lab. researchers in Eindhoven who worked on professional communication and data storage systems.

In the first place Delta Modulation⁸ was studied, mainly for the relative low data rate it produced, but delta modulation could not fulfill the high fidelity requirements. Pulse Code Modulation (PCM) became the next choice. With PCM the amplitude of the sound signal is repeatedly measured with a precision of 14 to 16 bits, giving a large data stream but a very good description of the original signal. In the digital realm it is also possible to apply error correction. This is needed to counter the effects of the unavoidable surface defects of the disc.

Market considerations

During the year 1977 it became clear that the ALP project could no longer remain in the shadow of the VLP. The introduction of the digital processing broke the technical relationship between ALP and VLP. But also the planned changes with reference to the VLP led to a growing independence of the ALP project. Heavy weighted, besides the smaller dimensions of the disc, the earlier decision to replace the gas laser by a much smaller semiconductor laser. This would allow a reduced dimension of the player.

To realize these high technical goals the current research and development capacity was not sufficient. For a consequent continuation it was needed to lift the ALP out of the phase of advanced development into a broadly supported product development by the Philips Company.

Questionable was whether the later market possibilities of the ALP could justify this costly endeavor. Ottens was afraid that the not foreseeable ALP development costs could influence negatively the decision of the responsible Program Committee in case of doubt.

Instead of balancing development expenditure against possible market turnover, Ottens put the possible costs of an ALP player in the center of the deliberations. Namely, if the player was produced in large quantities, the development costs per apparatus should become lesser and lesser. Only the cost of the used material will remain.

Of importance here was to take into account the micro-miniaturization going on in the semiconductor field⁹, the advancement of the solid state laser technology¹⁰ and that of the a-spherical lenses¹¹.

After totaling (with some optimism) the cost of all needed components, it appeared that a price of 150 Dutch Guilders should be possible. This, of course, under the assumption of a

⁷ Compare: Blesser, Barry A. "Digitization of Audio: A Comprehensive Examination of Theory, Implementation, and Current Practice" *JAES* 26(10), October 1978, p. 740

⁸ Schouten, J.F., F. de Jager and J.A. Greefkes. "Delta Modulation, a new modulation system for Telecommunications" *Philips Technical Review* 13, 1951, p 249-258

⁹ The trend towards more complex IC's with lower prices per IC was already in 1972 recognizable. Compare: Bucy, J. Fred. "For semiconductors: growth not maturity" *IEEE Spectrum*, April 1972, p. 55-58, fig. 1

¹⁰ Acket, G.A., J.J. Daniele, W. Nijman, R.P. Tijburg and P.J. de Waard (Eindhoven / Briarcliff Manor) "Semiconductor Laser for Optical Communication" *Philips Technical Review* 36(7), 1976/77, p.204-215

¹¹ Braat, J.J.M. "Aspheric surfaces: design and optical advantages" *Philips Technical Review* 41(10) 1983/84, p. 289-295

sufficient large production quantity. The Philips Program Committee shared this vision of an attractive and payable product, and so the CD development started in November 1977.

Coordination and cooperation (1978-1980)

CD-Lab and marketing

The start of the official development offered J. J. G. Ch. van Tilburg¹² the rare chance to synchronize market introduction and technical development.

Firstly the name of the player was fixed. Among other proposals it was chosen “Compact Disc”, resembling the very successful “Compact Cassette” and stressing the compact dimension of the audio player.

Secondly in 1978 a new development laboratory was established, called Compact Disk Laboratory, in short C.D. Lab.

Joop P. Sinjou became manager of the C.D. Lab. Earlier he managed a group of the VLP project. The task of the C.D. Lab was the construction of a first prototype of a C.D. player. Not only should this prototype be used as a base for the product development, but it should also get an attractive appearance to function at the demonstrations as a design model.

Compact Disc and “Pinkeltje”

To accomplish both requirements, the possibility of technical improvements and still a good looking prototype, Sinjou split the reproduction system in two parts. The bulkiest part, containing all the discrete electronic components, was built in a frame with the dimension of a table. On this “table“ was placed a small, metal playback unit, that contained besides all needed control knobs the mechanical turntable with the optical reader. During demonstrations a table-cloth would cover the so called “cubic meter electronics” frame, giving the impression that the mechanical player alone was the whole reproduction apparatus¹³.

This advantageous split allowed the audio player to resemble the later production models, but necessitated an early fix of all exterior specifications.

The most important external specification of the CD player is the dimension of the audio disc. In connection with the now replicable plastic VLPs, the first Compact Discs were double sided, two discs arranged back to back. With those discs, regarding a total playing time of one hour, it was theoretically possible to reduce the disc diameter to 10 cm. However after 30 minutes the disc had to be turned over.

Finally a diameter of 11.5 cm was chosen, that gives a stereo playing time of 60 minutes on only one side. The possibilities remained open to press, later on, cheap one sided discs and also a later introduction of a CD player in a car radio remained possible.

The double sided silvery shining Compact Disc influenced the outside appearance of the player. To demonstrate the new and unknown technique of optical reading of a CD to the general public, the disc should be visible while playing. This literal “transparency” helped to acquaint them with the new phenomenon. Therefore the mechanical works were designed for a top loader. A transparent lid on top had to be opened to exchange the CD disc. Aware of later demonstrations, the apparatus was designed with relative small dimensions. As was custom at the lab, each new research and demonstration apparatus got a nickname for internal

¹² At that moment the one and only General Director of the Main Industry Group Audio

¹³ During demonstrations the table was always covered, but it remained no secret for the audience that a lot of electronics was placed under the table.

use. This demo optical player was baptized “Pinkeltje”, a name of a dwarf from a Dutch fairy-tale¹⁴.

Listening tests

Given the fact that in the mean time other companies had started to develop audio versions of different videodisc systems, van Tilburg, Ottens and Sinjou understood that the creation of a world standard was of paramount importance for further development of the Compact Disc. Philips could not introduce such a new audio system without the support of the phonographic industry. Without the willingness of music publishers and audio media producers, to distribute their own repertoire on a newly invented audio disc, the CD technology could never reach the market.

With video tape recorders you could create your own recordings. This alleviated, for some time, somewhat, the interchange problem caused by different systems on the market. However, the full dependence of audio reproduction from prerecorded music software made it improbable that several systems could survive.

For reason of Philips’ development lead in CD technology, demonstrations could be arranged shortly after reaching full functionality of the “Pinkeltje” prototype in autumn 1978. Time was needed till March 1979 to perfect the fault correction and cover up systems by the Nat. Lab. researchers, Lodewijk “Lorend” Vries and his assistant Theo Diepeveen¹⁵. Even before this “tictictic” noise became inaudible by their efforts, internal demonstrations raised great enthusiasm and expectations.

Demonstrations

Besides the choice of appropriate technical product specifications was it needed, for reason of successful introduction of the CD, to conquer three hurdles of a market technical sort. Firstly, the desire of the competition to establish their own systems in development, giving raise to a multitude of incompatible systems, what works against the needs of the consumer, who likes a during, stable standard for his music collection. Secondly the Philips interest to promote the successful Compact Disc Audio System as the only world standard and lastly to license the system to many competitors.

The Compact Disc demonstrations were based on these three goals. Company internal shows were held for the Philips Management in Eindhoven, the International Philips Top Management in Ouchy near Lausanne and company daughter Polygram in Baarn, the Netherlands.

Promotion of the new audio system for potential consumers took place **March 8, 1979** when the International Press was invited to the Philips Works in Eindhoven and a CD demonstration annex press conference was presented¹⁶.

¹⁴ Pinkeltje is a very small figure from a Netherlands fairy-tale series by Dik Haan. Pinkeltje is a *kabouter*, a friendly and always helping being. The Dutch word “pink” means little finger.

¹⁵ Peek, J.B.H. “Communications Aspects of the Compact Disc Digital Audio system”, *IEEE Communications Magazine* 23(2), Feb. 1985, p. 7-15

Vries, L.B. “The Error Control System of Philips Compact Disc” Paper delivered at the 64th Convention of the Audio Engineering Society, November 2-5, 1979, N.Y., Preprint 1548 (G-8)

Pohlman, Ken C. *The Compact Disc Handbook*. Oxford University Press 1992

¹⁶ Philips Koerier Vol. 35, no. 21, March 15, 1979. The “Philips Koerier” was the weekly company paper for the personnel.

Finally, only a few days later, a Philips crew with all the CD equipment departed for a week's journey to Japan to show the entertainment industries the results and status of the Philips CD development .

Special measures were taken to guarantee perfect functioning during demonstrations.

Identical copies from the "cubic meter electronics", the "Pinkeltje" player and the test CD's were constructed. The prototypes were carefully measured and adjusted before the show started, this to detect transport or climate induced changes.

Competition and Cooperation: Journey to Japan

In the mean time the competition had started different digital audio derivatives of their video disc systems, such as the "Mini-Disk" of AEG-Telefunken or the AHD System of JVC and other proposals of the companies Hitachi, Matsushita, Mitsubishi, Pioneer, Sannyo, Sharp, Sony, TEAC and Toshiba.

To hold upright the position of the Compact Disc, a strategic step was taken by the Philips management, namely to try to cooperate with a Japanese competitor. Considering the fact that the development of the CD system was already far advanced, this would mean to yield up all research and development results. But with an influential Japanese partner the international position would be strong for reaching a world standard and also the expertise of the partner in marketing and technology could be very worthwhile.

Therefore the Japan journey, from 14 up to 13 March 1979, was a diplomatic top act of the CD creation.

Knowing that important decisions with large scoop needed time to reflect, van Tilburg did not expect to get a reaction during this Japan journey. However, literally in the last minute, while he was packing his belongings to travel back, he got a phone call by **Akio Morita**, founder and President of **Sony**. Morita had decided, in accordance with his Board of Directors, to start cooperation with Philips on the CD project. His Vice President Norio Ohga would come to Eindhoven to formalize the agreement. Starting August 1979, Sony and Philips worked together.

Sony was an ideal partner for Philips, of utmost importance for the later achievements of the Compact Disc system.

Summary

The creation of the *Compact Disc Audio System* resulted, for the first time, in the introduction of complex micro electronic systems in large quantities into the life and works of the people of the world. The low price, the robust sound disc and the simple intuitive control of this friendly product made it open to all levels of society and brought high fidelity sound reproduction to the public. The combination of existing market potential, the successful concept as consumer product, the standardization and advanced technology, procured the Compact Disc a distribution all over the globe. The resulting impact on the community and technology formed one of the most important technologic impulse of the 20th century. The descent from the video domain, the radiation into the professional audio market and the CD-ROM (and its successors) in the multi media domain evolved the concept of the optical disc far above the level of only an audio carrier.

The Compact Disc System became a historic milestone in the information age.