

FEATURE - PART 4

(R)evolution of Portable Audio: The world goes digital

Not even the Sony Walkman could shield analog audio from the future, but the key technology that launched the Compact Disc first appeared in a telephone during World War II. Darren Yates explains.

COMPACT disc DIGITAL AUDIO

Above: Compact Disc Digital Audio was the right product at the right time (Public Domain).

Right: The first commercial digital audio recorder was an adapted Betamax VCR (Image credit: Franny Wentzel, CC BY-SA 3.0).

Alec Reeves had sadly passed away by the time global tech giants Sony and Philips jointly launched the Compact Disc in 1982. The optical disc that brought the world digital audio for the first time may well seem to be an invention of its time, but digital audio more broadly, and the Compact Disc in particular, owe much of their success to technology that was first used during World War II to secure secret phone calls between British Prime Minister Winston Churchill and U.S. President Franklin D. Roosevelt. Today, digital audio seemingly permeates almost every technology device, but like a good many inventions, it owes its existence to engineers whose names deserve greater recognition.

Pulse Coded Modulation

The son of a surveyor, Reeves was born in Surrey, U.K. in 1902 and graduated as an electrical engineer from Imperial College, London at just 19. He moved to Paris four years later to work in the laboratories of the fast-growing International Telephone and Telegraph (ITT). Reeves amassed an impressive 82 patents during his lifetime, yet it's debatable that any were more influential to the future of digital audio than one awarded in 1938, the rather plainly titled 'Electric Signalling System'.

Improving audio quality, in particular reducing the



background hiss in audio (improving the Signal-to-Noise Ratio or SNR), was a key battleground during the 1960s and 70s, leading to new noise-reduction technologies such as Dolby NR and dbx. But it was a battle first fought way back in the 1930s around the world as telecommunications rapidly expanded.

Long-distance phone calls during that era were typically sent through a series of repeater stations. The voice audio was

converted into an analog electrical signal and transmitted, whether travelling hundreds or thousands of kilometres over cable. However, over such distances, that signal would drop in strength and require repeater stations at regular intervals to amplify that signal back up before heading off onto the next leg of the journey. The problem was each amplification step also increased the background noise (reduced the SNR) and reduced the quality.

It was for this problem that Reeves figured out a radical solution that involved converting the audio into a series of digital binary pulses that could be easily transmitted and boosted as necessary. Then, once at its destination, the digital signal could be converted back to the original audio without the usual loss of audio quality. The solution was dubbed 'pulse coded modulation' (PCM), for which, Reeves received a patent in 1938.



Right: The world's first CD player, the Sony CDP101 (Image credit: Atreyu, CC BY 3.0).

Unfortunately, his idea was ahead of its time – certainly ahead of the electronics and thermionic valves or ‘tubes’ then available. In the end, the U.S. Bell Laboratories incorporated the first practical PCM audio system in 1943 into the encrypted speech system called ‘SIGSALY’ used for secret communications between Churchill and Roosevelt during WWII.

Transparent discs

It wasn’t until 1958, however, that the other half of the ‘compact disc’ equation – the physical disc media itself – began taking shape. David Gregg, an electrical engineer working for U.S. electronics company Western Electric, developed a transparent optical disc that used light transmission through a disc to store electrical signal data. He patented his optical disc design in 1962 and formed his own company – Gauss Electrophysics – to further the technology. What’s interesting is that the disc was designed to store analog VHS-style video – the first commercial digital video disc format was still 25 years away. The industry giant MCA (Music Corporation of America) eventually bought the patents to the disc technology in 1968 with a view to further improving and commercialising it.

Digital audio recording

Back in the audio world, transmitting secure phone calls as digital audio was one thing, but it was an entirely different matter to record digital audio onto some form of storage media. Reel-to-reel audio tape during the 1960s managed to reach 20kHz of bandwidth at reasonable tape speeds, but it would need a bandwidth 100 times that to accurately capture a PCM signal good enough to replay as music. It’s a bigger story for another time, but the solution already existed in the form of the video tape recorder. These professional devices, often still the size of a fridge in the mid-1960s, were recording TV’s signals with a bandwidth of up to 5MHz – all that was needed was for someone to come up with the right idea. That ‘someone’ was Heitaro Nakajima, an electrical engineer working for the Japanese Broadcasting Corporation known as ‘NHK’. In 1967, he developed the first PCM digital audio converter to attach to



a video tape recorder. The system converted audio into a 12-bit binary data stream with a sample rate of 30kHz. Thanks to a theorem developed by another engineer, Harry Nyquist, that 30kHz sample rate enabled the recorder to capture analog signals up to 15kHz. The 12-bit binary stream was potentially sufficient to deliver a dynamic range (loudest sound to smallest) of 72dB (about 4,000:1), an improvement on analog tape at the time.

That original system created by Nakajima was a mono (one-channel) system only, but by 1969, a stereo system had been built. Three years later, Japanese electronics firm Denon produced the first commercial digital audio recording using the recording system Nakajima had developed for NHK.

Nakajima quits

Nakajima had joined NHK not long after completing his engineering degree in the 1940s, but he continued his studies, receiving a Doctor of Engineering

degree in 1958. His success in developing the digital audio recording system in 1968 soon had him on the radar of one Masaru Ibuka, better known as co-founder of Sony. After some gentle encouragement from Ibuka, Nakajima quit his job at NHK in 1971 and walked through the front door of Sony as the new boss of the Audio Technology Centre. Another piece of the Compact Disc puzzle had just fallen into place.

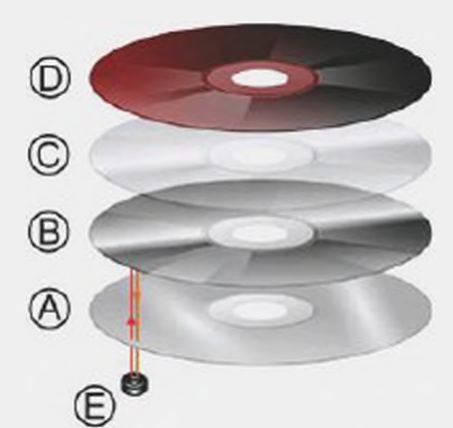
"These professional devices, often still the size of a fridge in the mid-1960s, were recording TV's signals with a bandwidth of up to 5MHz – all that was needed was for someone to come up with the right idea."

Philips improves the optical disc

Meanwhile, the late-1960s were proving to be a fertile period for Dutch giant Philips. In the race to create a video disc playback system, Philips engineer Klaas Compaan came up with a new reflective disc design that offered improvements to Gregg’s transmissive disc (including more compact design). In 1972, Philips joined forces with MCA to showcase a demonstration ‘video disc’ system, but it would take another six years before ‘LaserDisc’ would make its world introduction in 1978.

However, those six intervening

Above: Japanese audio brand Denon recorded the first commercial digital audio in 1972 (Image credit: Pittigrilli, CC BY-SA 4.0).



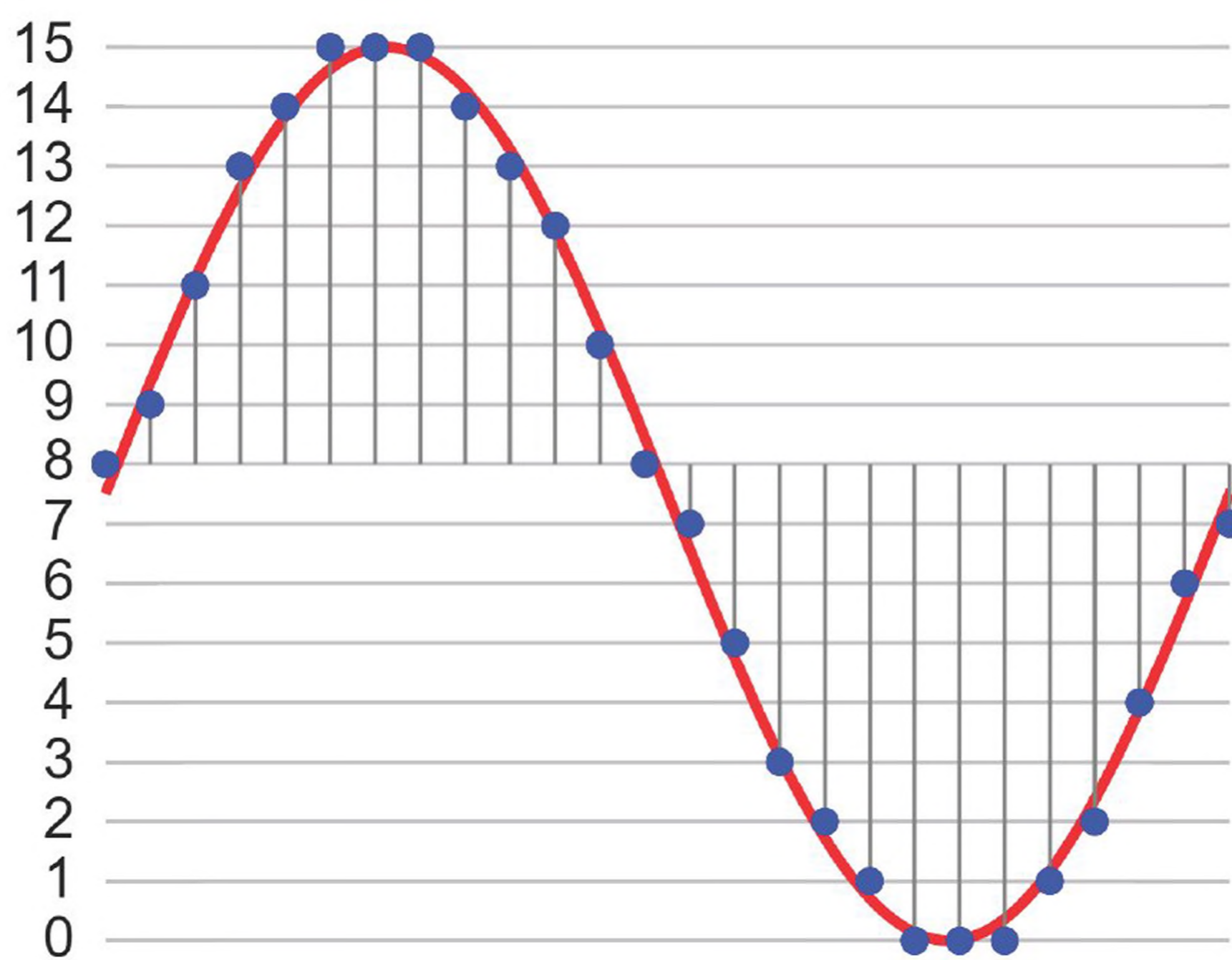
Above: CDs consist of four layers, with data read from the thin metal storage layer (B) (Image credit: Pbroks13, CC BY-SA 3.0).



Left: Philips went to market with its first CD player, the CD100, in 1983 (Public Domain).



Above: LaserDisc stored analog video on optical discs 30cm in diameter (Image credit: Kevin586, CC BY-SA 3.0).



years were crucial, for during that time, the VCR battle had begun and as a result, LaserDisc would struggle to compete in the market. It would ultimately take another couple of decades before the market was ready for an optical disc format for video...

Betamax: the first digital audio recorder

In the meantime, Sony recalls Nakajima's first two years were somewhat subdued, with the company deciding to get out of the expensive LSI (large-scale integration) chip business (albeit temporarily) in 1973. Nevertheless, that same year, Nakajima and his team were reportedly just far enough away from 'head office' that they could work more or less without interference – and so with little fanfare, they got to work on a digital audio recorder. The result was dubbed the X-12DTC - it worked, but required two-inch (5cm) wide tape and reportedly was the size of a fridge. Sony showed off the machine at the 1974 Japan Audio Fair, but that's as far as it went.

However in 1975, the Sony

Betamax video cassette recorder (VCR) hit the market. Being a consumer-grade device, it didn't match the bandwidth of professional video recorders, yet the Betamax VCR still had a recording bandwidth of 3.2MHz – it was this fact that twiggged team member Agira Iga into wondering could the far-more-compact Betamax be made to record digital audio. They still needed to design a PCM adapter unit to convert the original audio signal into a digitised video-like signal the VCR could handle, but the following year, the PCM-1 PCM Processor was born and combined with the Betamax VCR, became the first commercial digital audio recorder. However, the PCM-1 reportedly also copped flak from some users for producing weird 'humming' noises that would require additional research for Sony to eventually overcome.

What about PCM and LaserDisc?

It was now 1976, the year the VCR format war kicked off, as JVC launched its 'VHS' system to take on Sony's Betamax. However, even at this stage, Sony had signed up

Left: PCM converts continuous analog audio voltages into discrete (fixed-rate) digital samples (Image credit: Aquegg-commonswiki, CC BY-SA 3.0).

to its next bet, the Philips-MCA optical disc system. Again, the idea of applying PCM digital audio, this time, to a LaserDisc player was floated and by the end of 1977, Sony had constructed a 12-inch (30cm) LaserDisc disc that played only digital audio. While a normal 30cm-diameter LaserDisc was good for as little as 30-minutes of analog video, this PCM audio disc could, in theory, hold an impressive 13 hours 20 mins. Not surprisingly, such a large disc capable of so much audio-time raised a few questions.

Sony and Philips meet

They say 'timing is everything' and it was in the northern-hemisphere summer of 1978 when Sony received an invite from Philips engineer Lou 'Compact Cassette' Ottens to come and view a new little optical disc the company was working on. As it turned out, Sony wasn't alone in the idea of an optical digital audio disc – the new Philips disc was 11.5cms and reportedly good for one hour's recording. According to Sony, they saw the value of it immediately and an agreement was forged between the two companies to commercialise the disc, with work beginning in August 1979.

While these two tech titans clashed over the Compact Cassette a decade before, they'd actually maintained a successful working relationship for the better part of two decades to this point. What's more, this new venture was essentially the ideal collaboration – Sony's expertise in digital audio was now second-to-none and Philips' reflective optical disc was exactly the tech needed.

The 'Compact Disc'

As with most relationships, there were squabbles along the way (including deciding on the audio bit

Right: In 1995, Sony dropped the 'Discman' name in favour of its 'CD Walkman' brand (Image credit: Lcarsdata, CC BY-SA 3.0).

Far Right: Initial Sony portable CD players were branded 'Discman



Above: The first portable CD player arrived just five years after the first cassette Walkman (Image credit: Binarysequence, CC BY-SA 4.0).
Left: The WWII 'SIGSALY' encrypted telephony system was the first use of digital PCM audio (Public Domain).

depth and the size of the disc itself). However, a more pressing issue was development of the laser pickup unit and the LSI chips to handle new complex concepts such as data error-correction. Nevertheless, prototypes of the new 'Compact Disc' system began appearing in 1981. The two partners had finally settled on a 120mm-diameter optical disc delivered stereo (two-channel) digital audio with a sample rate of 44.1kHz at 16-bit depth and a maximum run-time of 74mins 42seconds.

The problem now was convincing the record labels it was a good idea. Not surprisingly, a good number were against it to begin with, since LP records had improved significantly over the previous decade (not to mention the cost spinning up brand-new CD production would require).

In the end, however, they came on-board and on 1 October 1982, with much fanfare, Sony launched the world's first CD player, the CDP-101, alongside a CD copy of Billy Joel's 52nd Street, one of 50 CDs launched on the day, all manufactured by Philips.

CDs go portable

The difference in audio quality between the Compact Cassette and Compact Disc was instantly

recognisable – to the extent that Sony's Walkman, while still hugely popular, had a major new technology competitor to deal with. Not surprisingly, the desire to do with the Compact Disc what they had achieved with the Compact Cassette became a mandate for Sony to shrink the CDP-101 into something akin to the Walkman.

However, while shrinking an analog cassette tape system was one thing, shrinking digital technology that included PCM digital-to-audio

decoding, error correction and did so using only battery power was something else. The key would be LSI chip design. According to Sony, while LSI had made the CDP-101 a reality, the rapid scale of development at the time meant that by September 1983, it could build the CDP-101 into a box one-tenth of its original size. In November 1984 and with the rest of the technology miniaturisation complete, Sony launched the D-50, the world's first portable CD player and dubbed it the 'Discman'.

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The phenomenon continues

Today, the vast majority of digital audio we listen to features some form of lossy compression, whether it's MP3, AAC or whatever. However, that compressed audio, especially if its music from your favourite band, will invariably have started its digital life as a PCM stream of data recorded onto a storage format.

PCM still remains the pre-eminent form of digital audio and continues to be used to store archive-quality recordings. It's not known whether Alec Reeves knew of

the work Denon or even NHK had achieved in PCM recording before he passed in 1971, but you'd think he'd have been just a little bit chuffed.

In the next installment of this series in APC we're heading into the 1990s as digital audio takes over and portable devices appear in all forms, but as a new century dawned, few would be prepared for a once-struggling computer company fast finding its feet again to create the next revolution in portable audio. ■