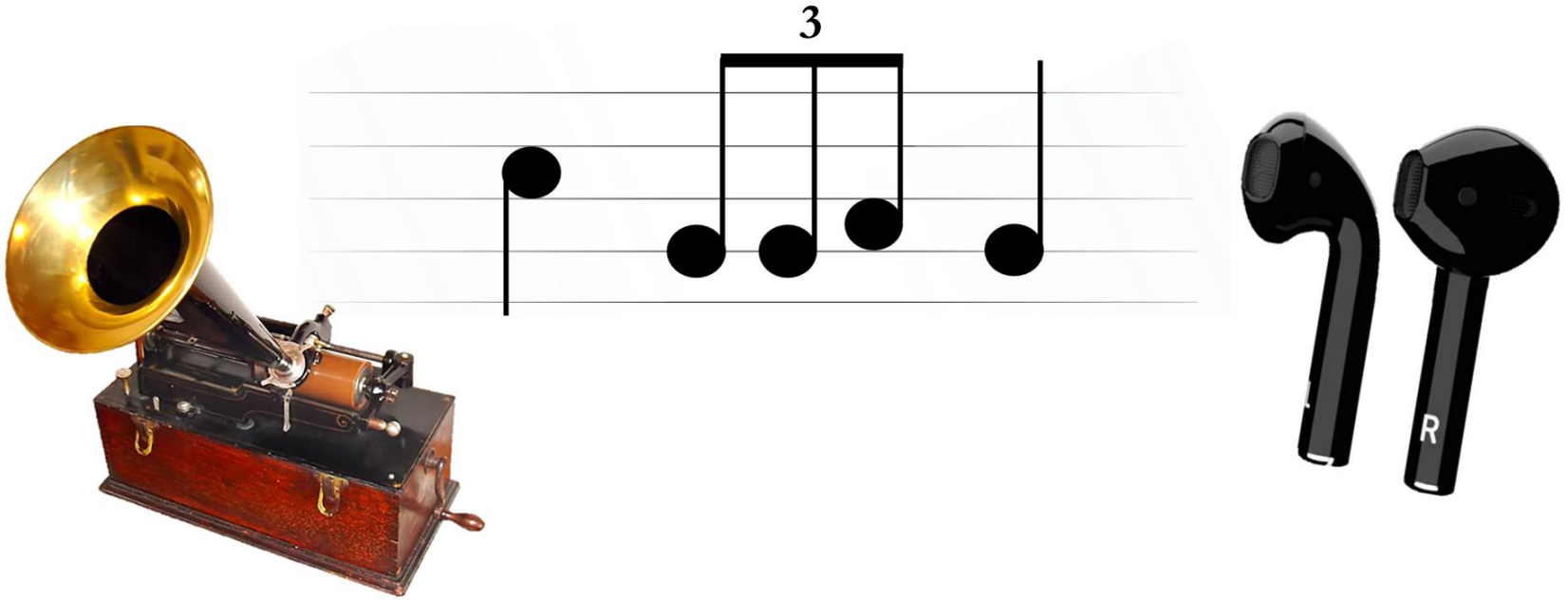


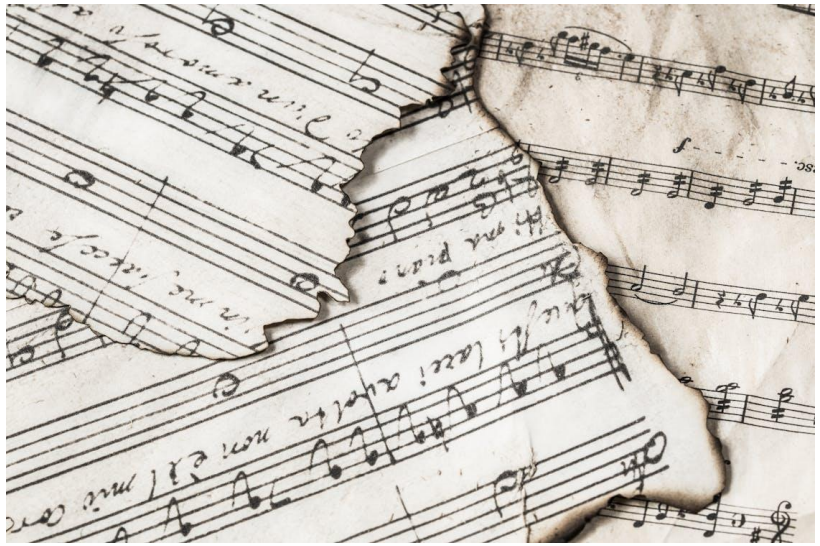
From Horns to Hearables

The strange history of audio recording

Nick Hunn

It’s all about notes

It should be about these:



But mostly, it’s these:

Why did it take so long?

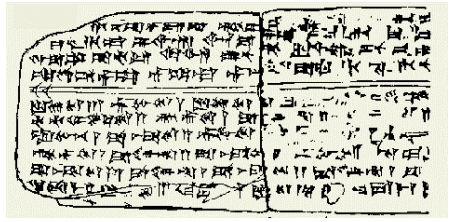
Cave Painting

~ 45,000 BC

Writing

~ 3,000 BC

Musical Notation



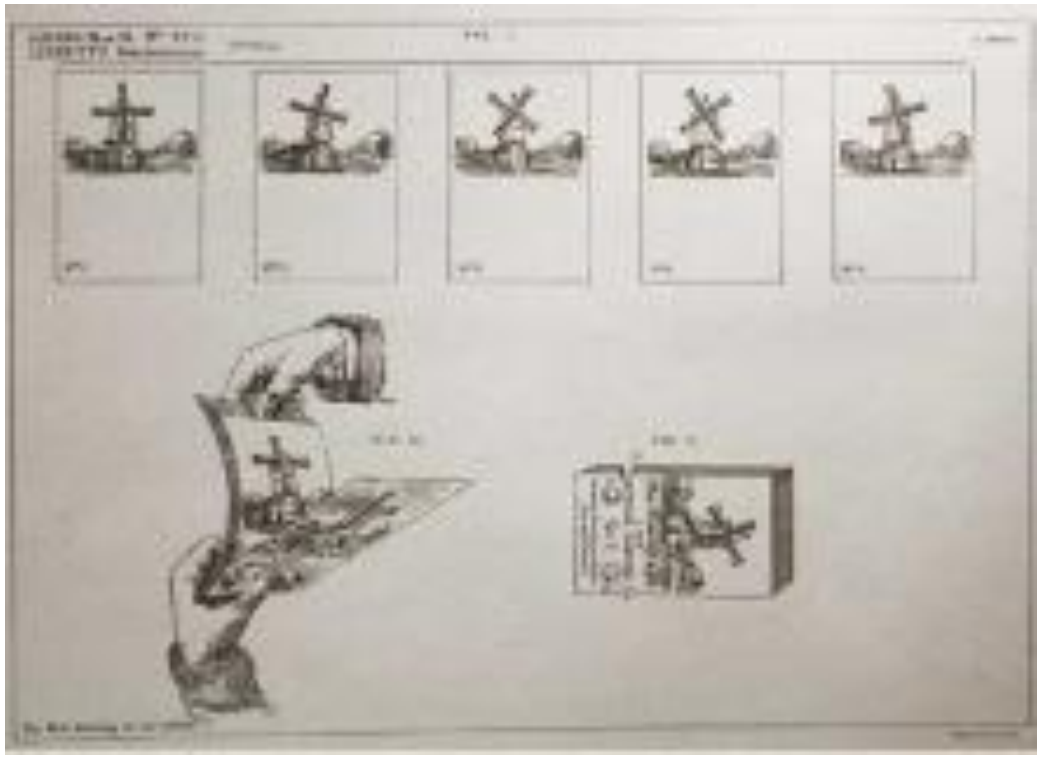
~ 1,000 BC

The Kineograph and Film got there first

The flip book, or cinema de poche, was patented by John Barnes Linnett in March 1868.

Zoetropes were demonstrating retinal persistence in the 1830s.

The first film was Roundhay Garden Scene in 1888.



At 24 frames per second, video is essentially flicker free. Sound isn’t.

Frequency Response

50 – 19kHz

30 – 14kHz

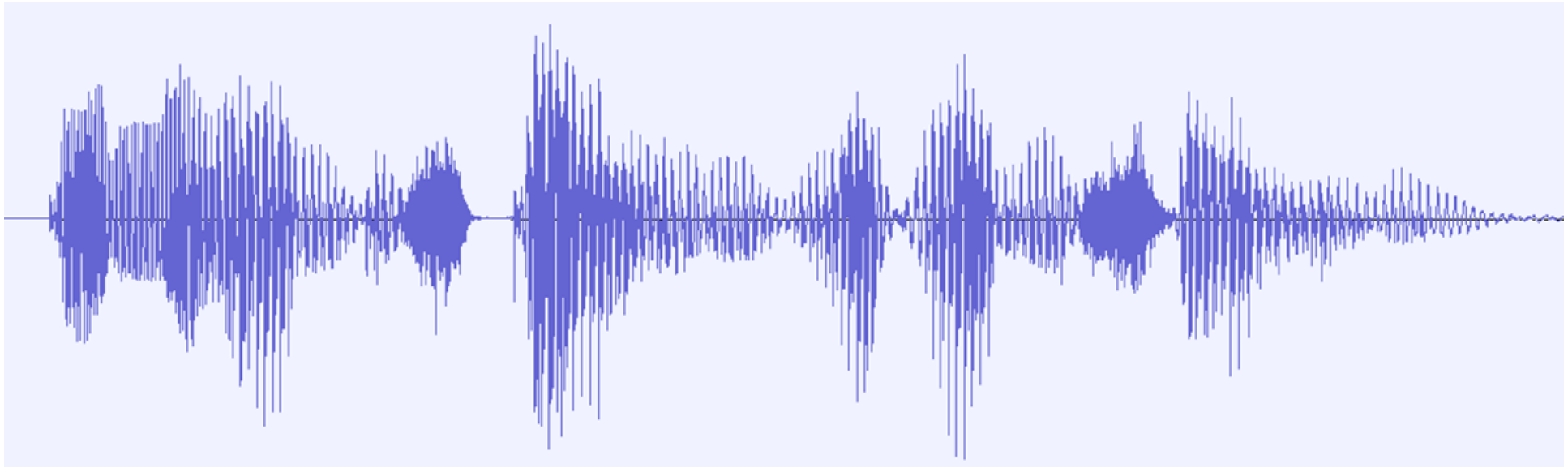
45 – 44kHz

16 – 44kHz

55 – 77kHz

100 – 115kHz

Visualising and Sampling Sound



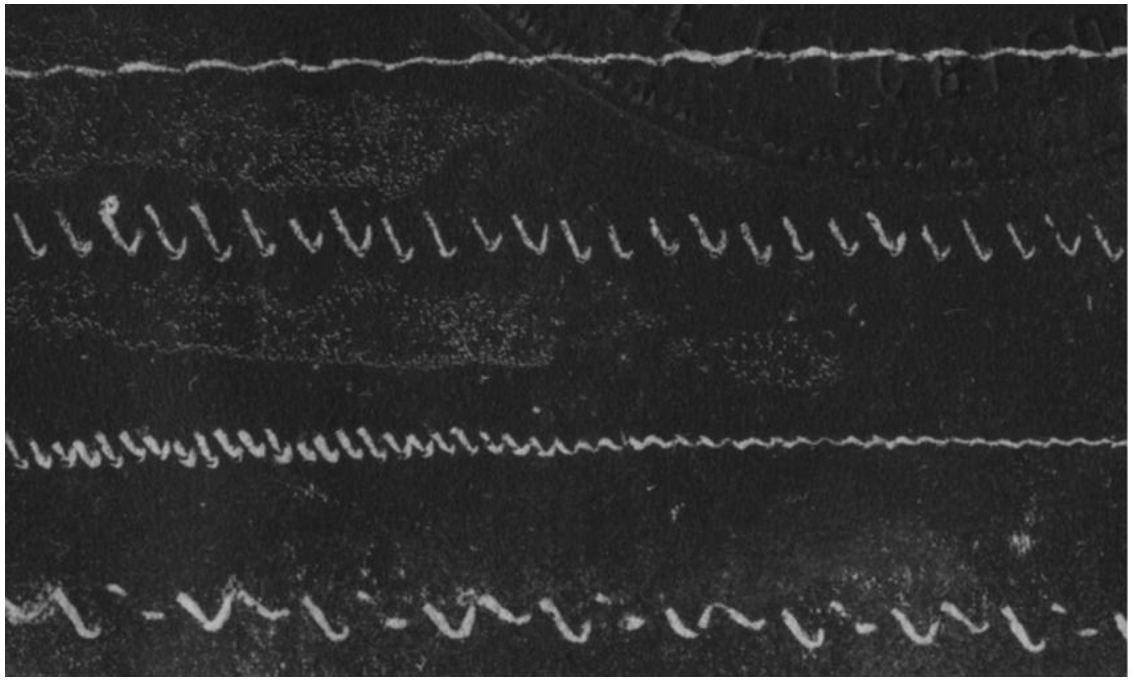
24 Hz 240 Hz 2.4 kHz 24 kHz

The first true recording – the Phonautogram

Edouard-Leon Scott de Martinville made audio recordings on soot coated paper in 1860, leaving them with the French Academy of Sciences.

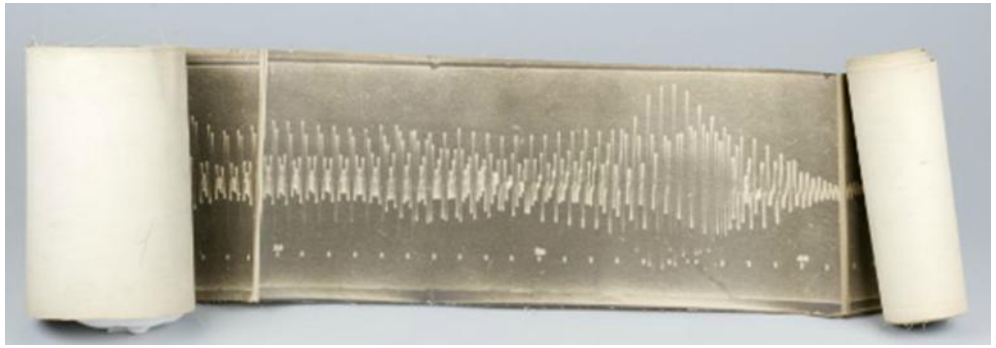
The first human recording

In 2008, engineers at the Lawrence Berkeley National Laboratory managed to convert them to audio, letting us hear the first record of a human voice.



Building on Scott de Martinville’s work

It would be 50 years before audio traces were next captured, with Dayton Miller’s Phonodiek, using a sensitive mirror to expose a trace on photographic film.



10 years later, Maximillian Julius Otto Strutt developed ultra-high speed recorders while working at Philips.

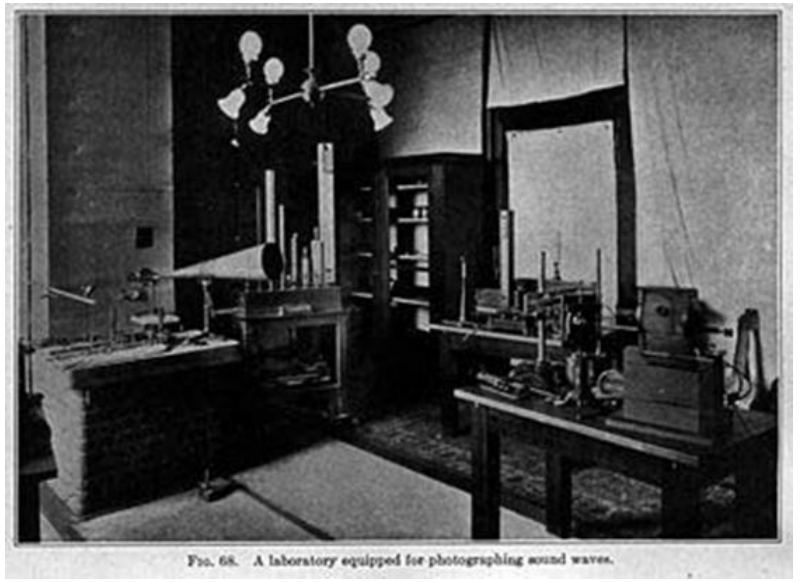


Fig. 68. A laboratory equipped for photographing sound waves.

It was almost 100 years after Scott de Martinville’s work before an oscilloscope with a triggered sweep became available.

First - Generate a Market

Oliver Cromwell

Cromwell closed the theatres, putting musicians out of work.

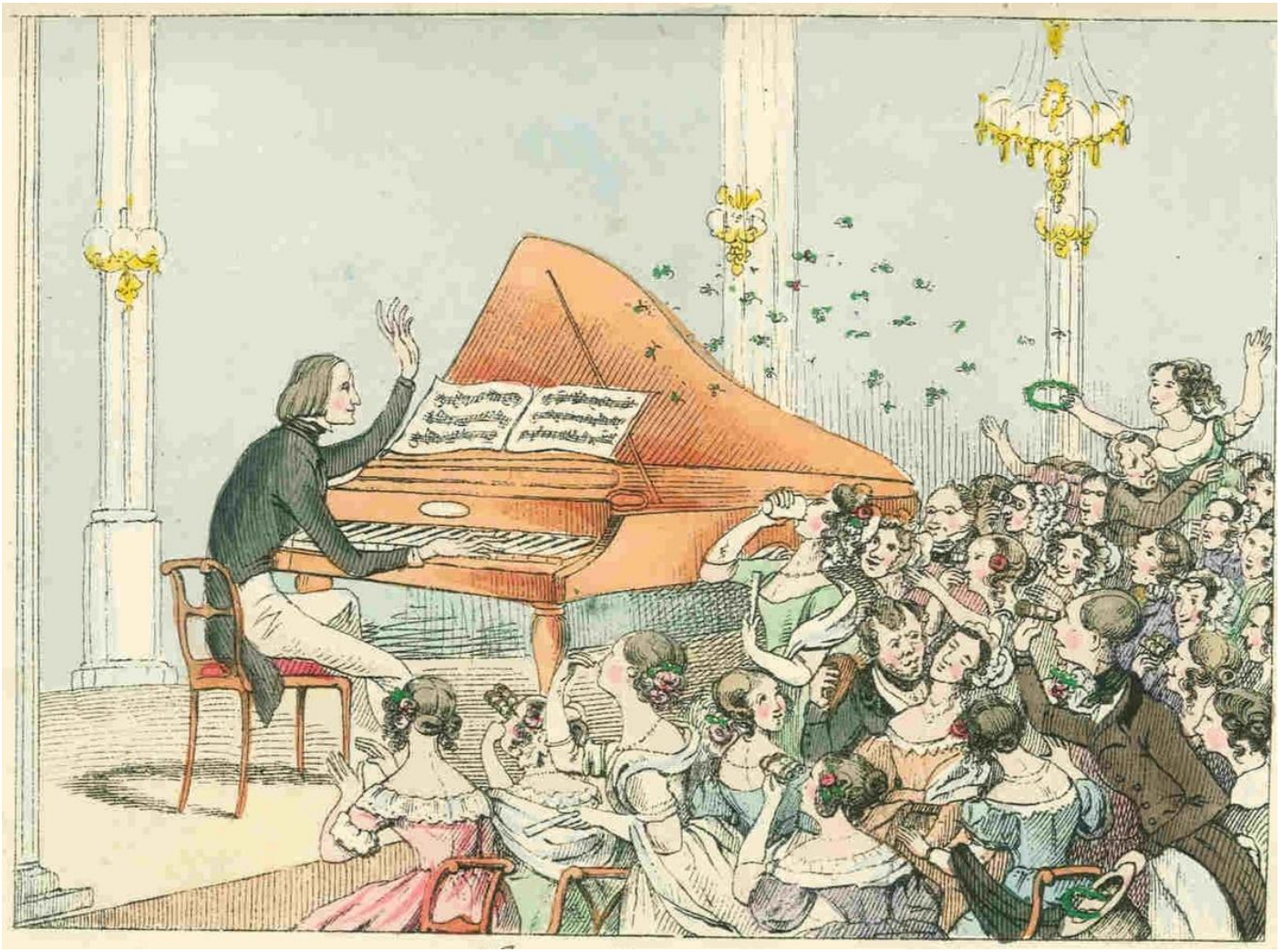
This paved the way for the invention of public concerts.

Which also made the concept of celebrity performers possible.

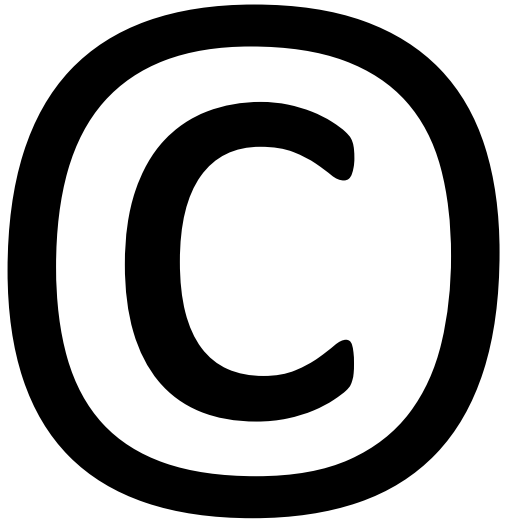
Cromwell also instigated public opera.

Lisztomania

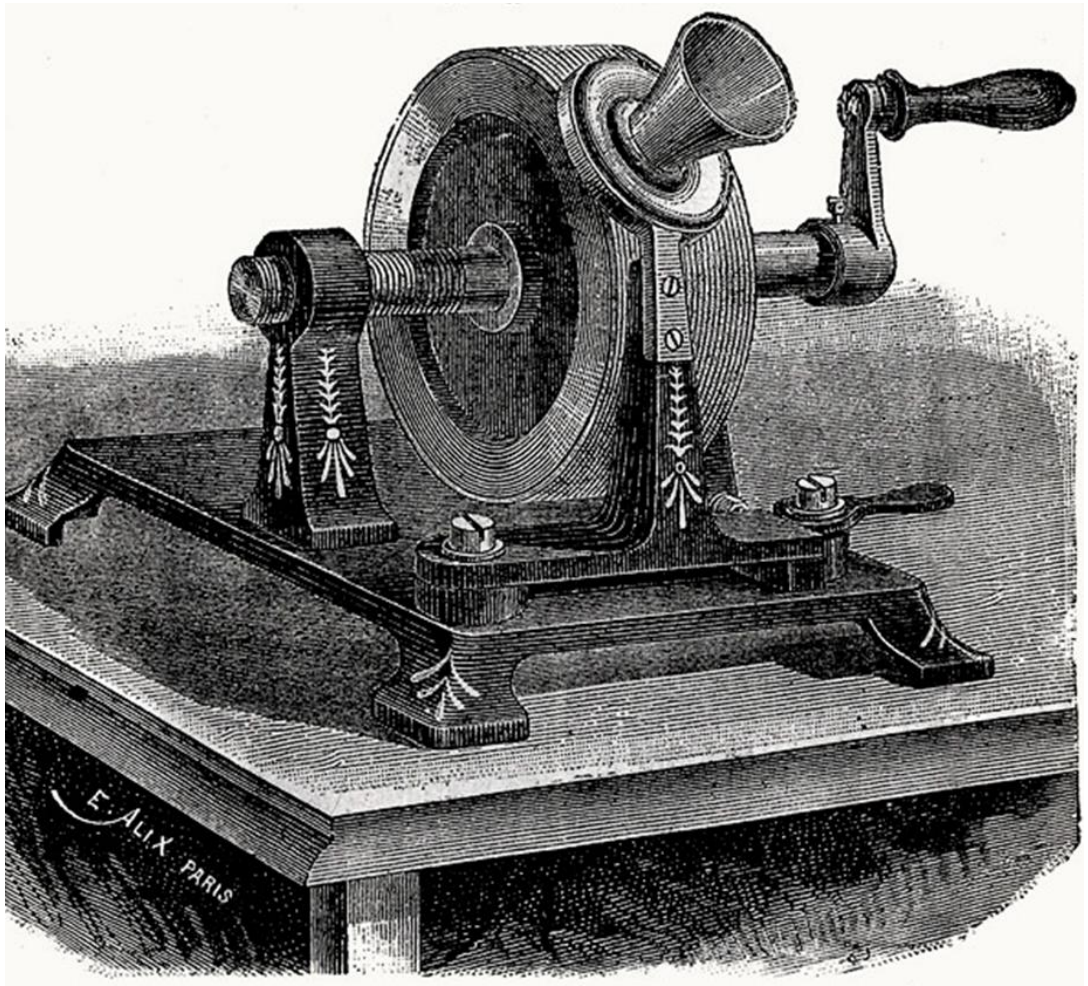
The practice of throwing underwear at the stage goes back to Liszt's first European tour in 1830.



With celebrity came money, marketing and…



Edison’s Phonograph - 1878



Weight: 10 kg
Recording Capacity: 60 words

Market take-off – the four contenders

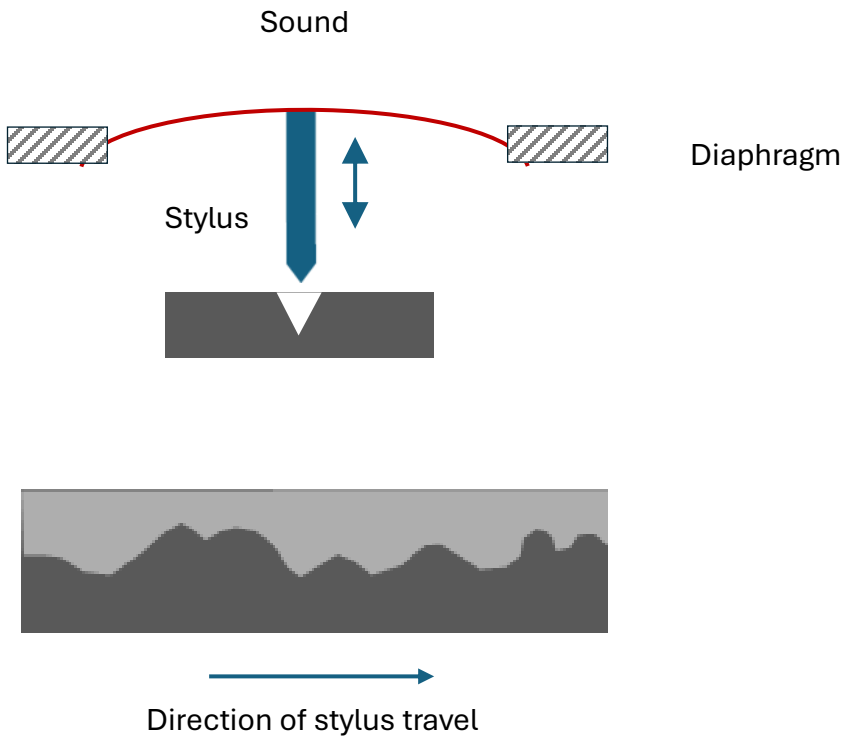
Edison’s Phonograph
1888

Berliner’s Gramophone
1887

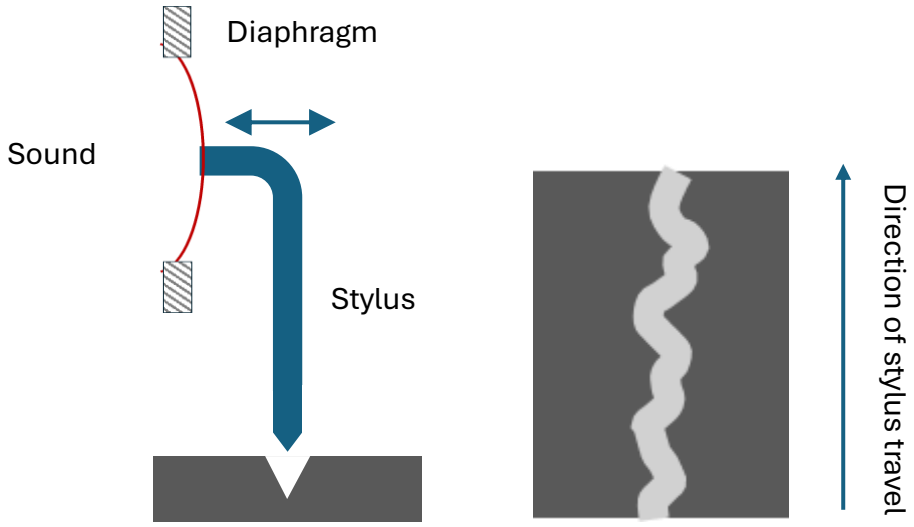
Poulsen’s Telegraphone
1898

Votey’s Pianola
1896

The core technology - Edison vs Berliner

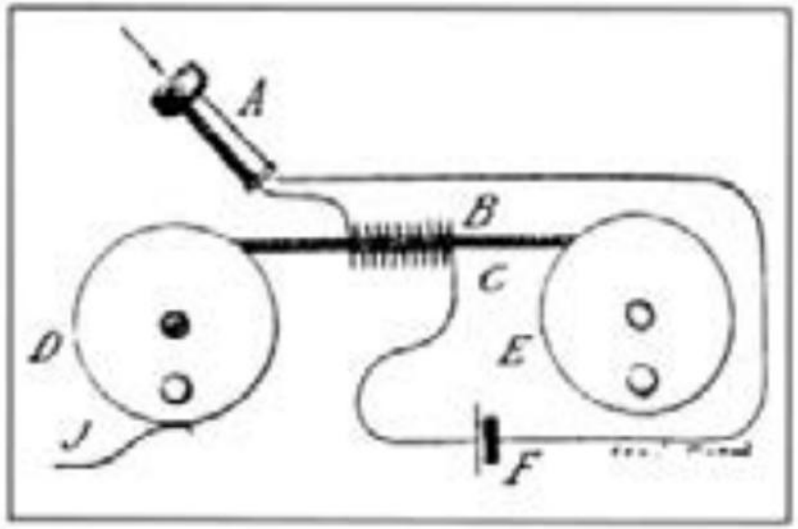


Edison - Vertical Grooves

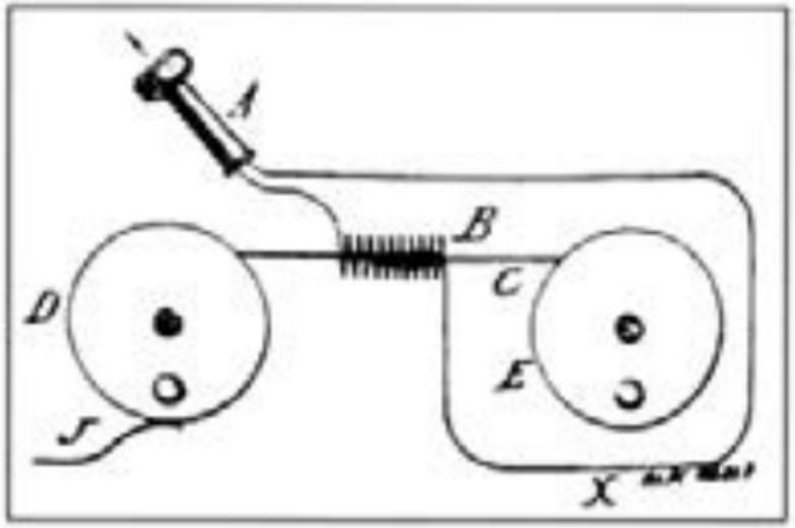


Berliner - Lateral Grooves

Oberlin Smith's Wire Recorder - 1888



Record



Playback

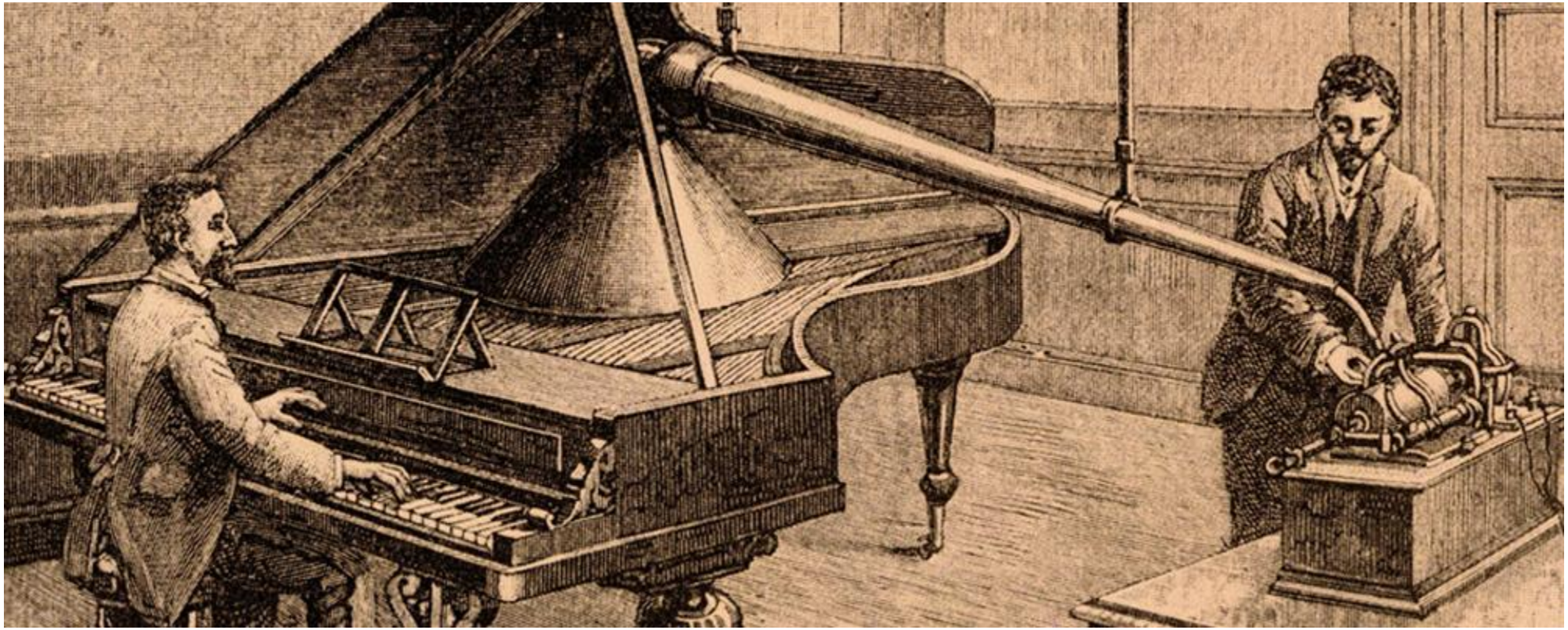
Valdemar Poulsen would make the first viable recorder in 1898

“Dragon’s Den” question time

	Record	Playback	Primary Market	How Loud?	Easy to Use	Price
Edison – Phonograph	Y	Y	Voice	Quiet	N	High
Berliner - Gramophone	N	Y	Music	Quiet	Y	Low
Poulsen – Telegraphone	Y	Y	Voice	Quiet	N	High
Votey - Pianola	N	Y	Music	Piano / Forte	Y	High

Which would you invest in?

The birth of the Sound Engineer



An early recording studio

The primary role of the sound engineer was to make sure the right player was in front of the horn. The ability to lift and carry musicians was an advantage.

Better microphones and valve amplifiers began to replace horns, but with no way to edit recordings, everything was still live.

Enjoying the end product

Lean Back and Listen

Advertising began to focus on male consumers

And Pianolas got everywhere

Carrying Pianolas in the Outback - 600 Miles from Melbourne, Australia, c. 1909

Player Pianos are a largely forgotten success

- In 1920, over 50% of all pianos sold in the US had player functionality.
- By 1926, player pianos could record the pianist playing, including their timings and dynamics.
- They were used to replace pianists in public concerts.
- Composers like Conlon Nancarrow continued to write specifically for Pianolas, using more keys than human fingers could play.
- The Pianola roll laid out the ground for MIDI, where the composing screen is called the “Piano Roll”.

Then the car, electricity and radio arrived as rivals. The world, and America in particular, became addicted to music coming out of machines.

The rise and rise of Victrola

In 1906, the Victrola company designed an internal, folded horn, turning Berliner's player into an upmarket piece of furniture.

In today's prices, it sold for around $7,000.

In today's business terminology, Victrola would be a unicorn.

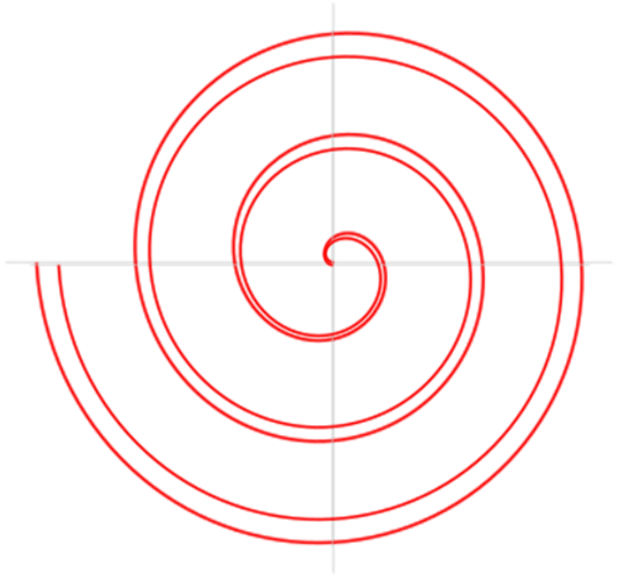
The world’s most famous dog - Nipper

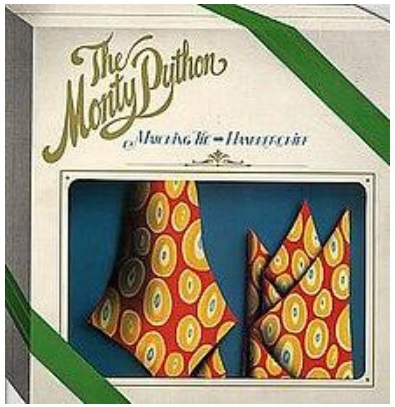
Doubling the playing time

Put a track on both sides.

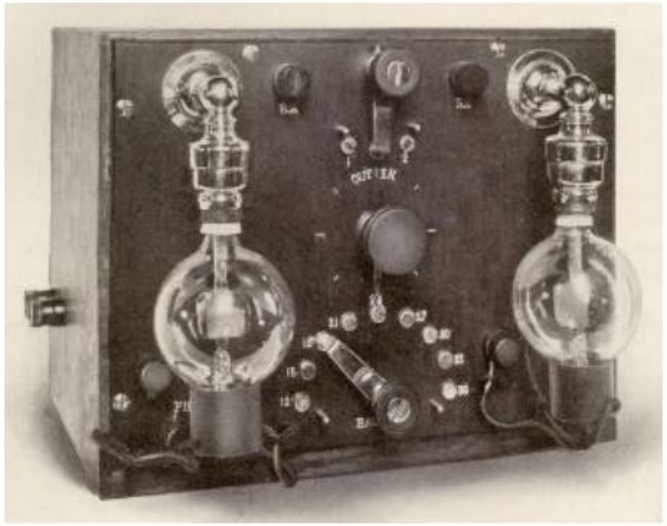
The first double sided record appeared in 1908.

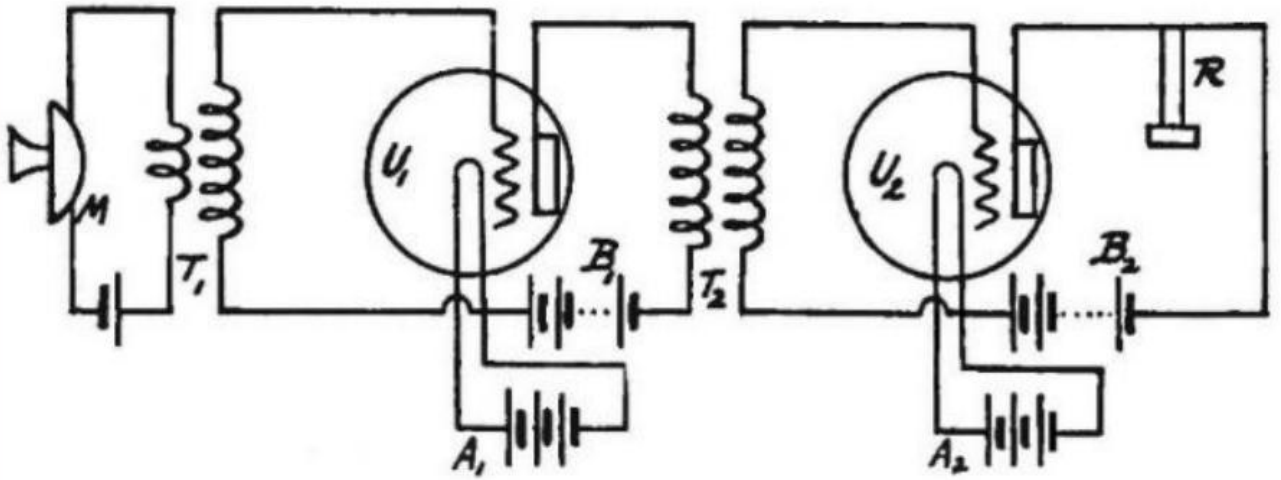
By 1921, every record had an A side and a B side.





Enter Amplification





A 1912, two-stage audio amplifier from Lee de Forest.

But there wasn’t any way to play the amplified sound.

Better Days Ahead for the Loudspeaker

Using Cement Horn with Radio Amplifier, Inventor Floods Miles of Countryside with Melody, Giving Entire Rural Community Unique Entertainment

How residents of Waterford, Va., enjoy outdoor radio concerts regularly, thanks to the ingenuity of M. C. Hopkins, inventor of a novel loudspeaker that makes music audible nearly three miles away. Armstrong Perry, famous radio writer, is shown in inset above

The invention of the loudspeaker

In April 1925, Edward Wente of Western Electric, and Chester Rice and Edward Kellogg of AT&T separately patented the moving coil loudspeaker.

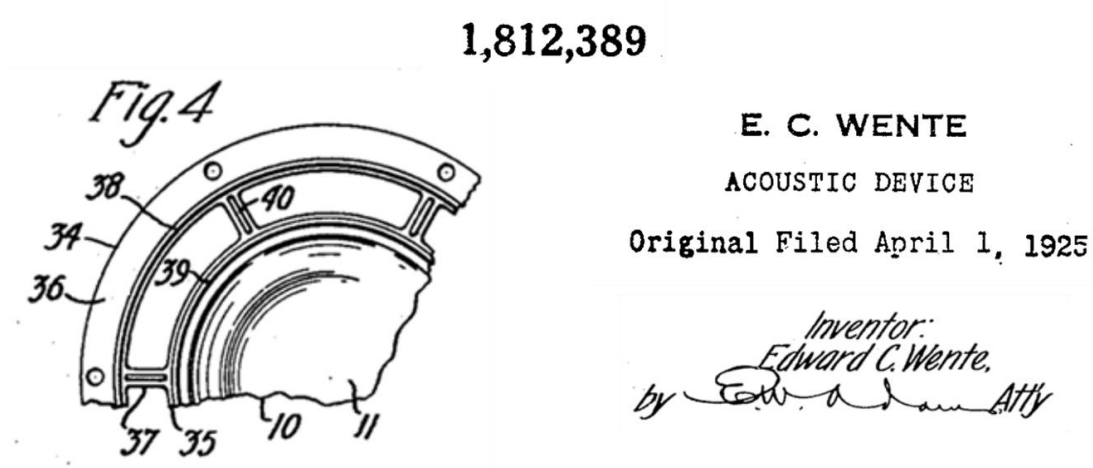

1,812,389

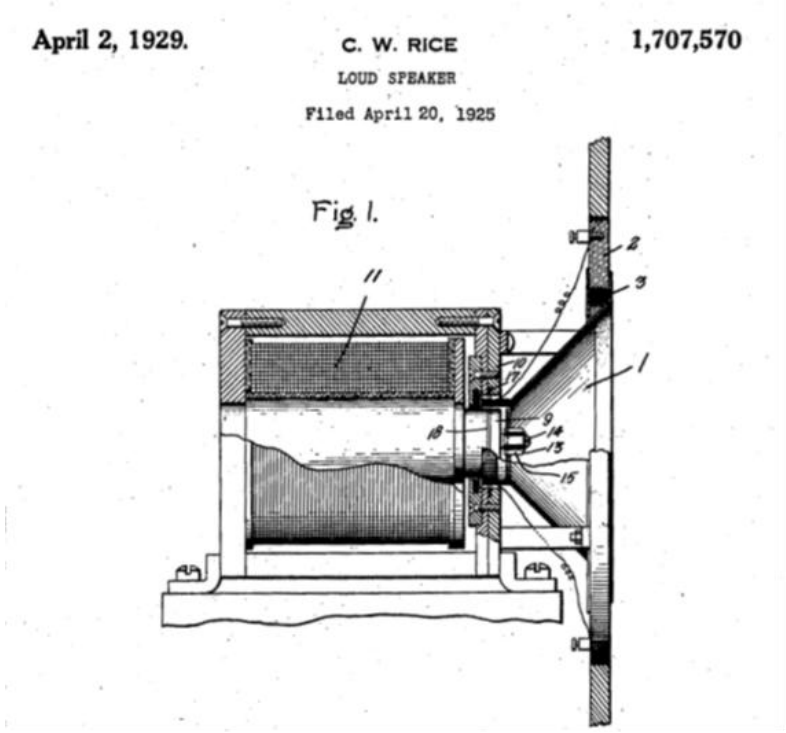
Fig. 4

E. C. WENTE

ACOUSTIC DEVICE

Original Filed April 1, 1925

Inventor:
Edward C. Wente,
by ... Atty


April 2, 1929. C. W. RICE 1,707,570

LOUD SPEAKER

Filed April 20, 1925

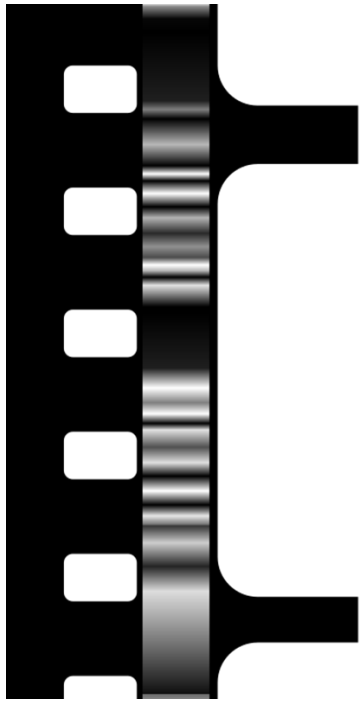
Fig. 1.

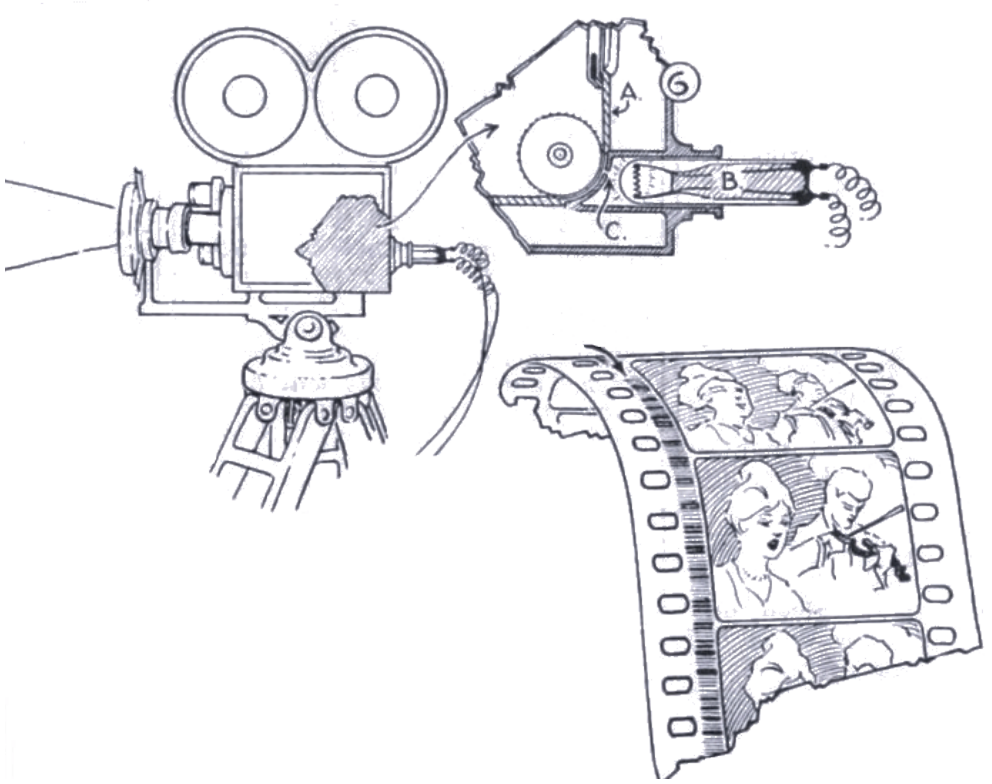
Audio reproduction finally had its missing part

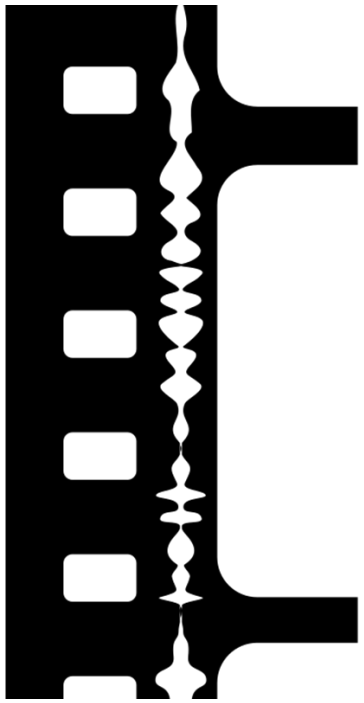
1925

1936

The end of the silent film





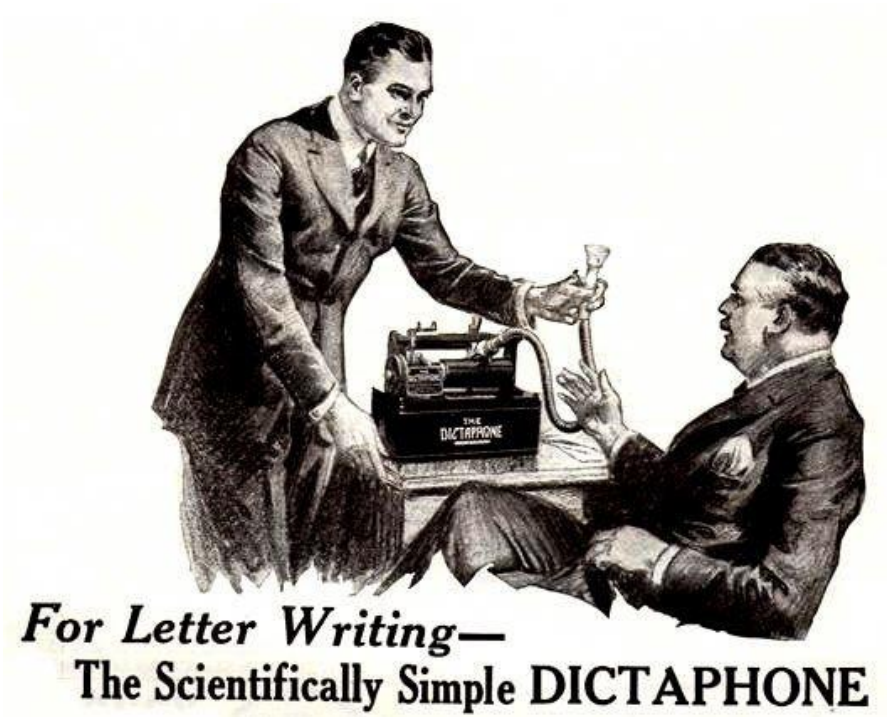


Variable Density

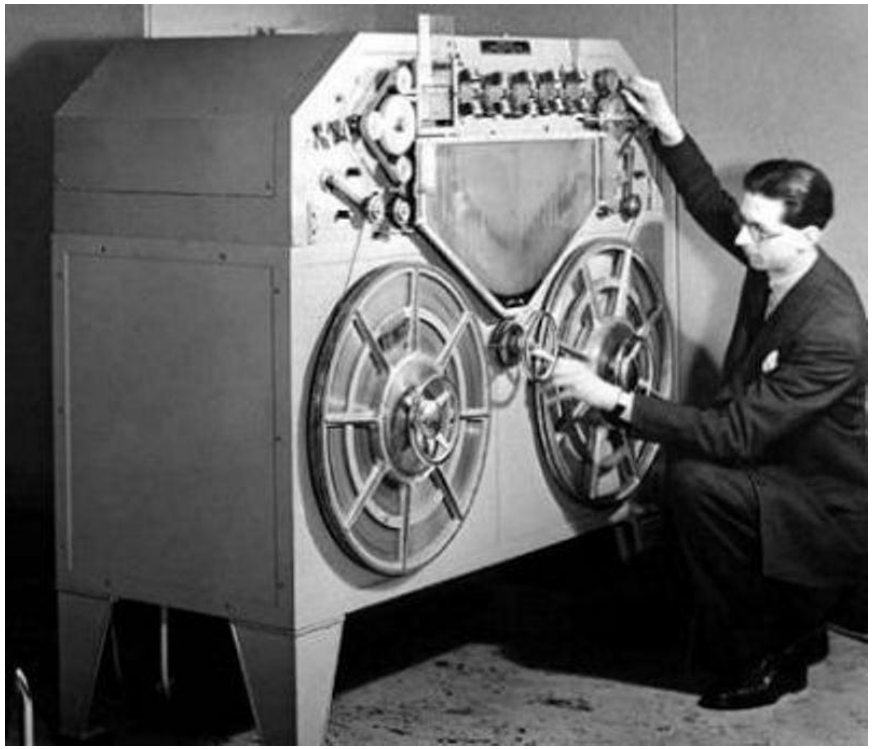
Variable Area

Photophone, Phonofilm, Vitaphone and Movietone

What about Tape Recorders?



Wax



Wire

The advent of magnetic tape

1932 – Hardware by AEG, Tape by IG Farben

The Second World War

Europe: September 1939 – September 1945

Hollywood: December 1941 – September 1945

Wizard of Oz - November 1939

Fantasia – July 1941

Professional recording – Ampex, via Bing Crosby

By 1950, magnetic tape was being used for radio broadcasts in the US.

Shortly after that, four track recorders were available for high quality music recording.

Tape editing and overdubbing became the norm with the recording industry.

The market for home recorders still wouldn’t take off.

Adding stereo to records - 1956

EMI patented single groove stereo in 1931.
Which came as a surprise to RCA, when they were told just before they launched stereo.

It had been done before – binaural in 1952

On Demonstration at the Harvey AUDIOtorium

The Newest
AUDIO DEVELOPMENT!

LIVINGSTON BINAURAL ARM

Less Cartridges **$35.00**

The latest contribution to the new field of stereophonic, binaural reproduction. A practical transcription arm which plays either binaural or standard discs, and uses standard cartridges. Already several record manufacturers are in production making binaural recordings.

Complete Line of Livingston Arms, Loudness Control, and Pressure Gauge, in Stock

Partial List of COOK BINAURAL RECORDS—Now Available

12 inch Microgroove . . . 12 min. Playing Time per Side

No. 1051BN—Michael Cheshire	Organ Selections	EACH
No. 1036BN—Frank Glazer	Paganini-Liszt Variations, Piano	
No. 1092BN—Hufstader Singers	Choral Selections	
No. 12213/4BN—Wilbur DeParis	Rampart Street Ramblers	**$5.95**
. . . and others	(Modern Dixie)	

Series 30 Binaural Test Record — for Synchronization and Stylus Spacing **$2.00**

Two arms good, one arm bad

By the end of the ‘50s, new technology didn’t offer much to consumers.

Audio quality had probably got close to the limit of human hearing.

It felt that the industry had gone as far as it needed to go.

What was left to be improved?

Who remembers these?

1957 – the Transistor Radio.

Consumers voted with their hearts

The audio quality was **AWFUL**

but…

Music had become **PORTABLE**

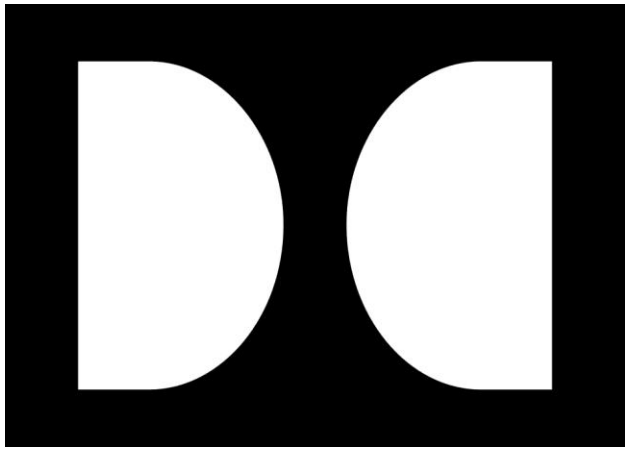
Enter the Sony Walkman

Compact Cassette -1963

Sony Walkman - 1979

Personal copying was about to keep the studio lawyers awake at night.

Ray Dolby made them sound much better

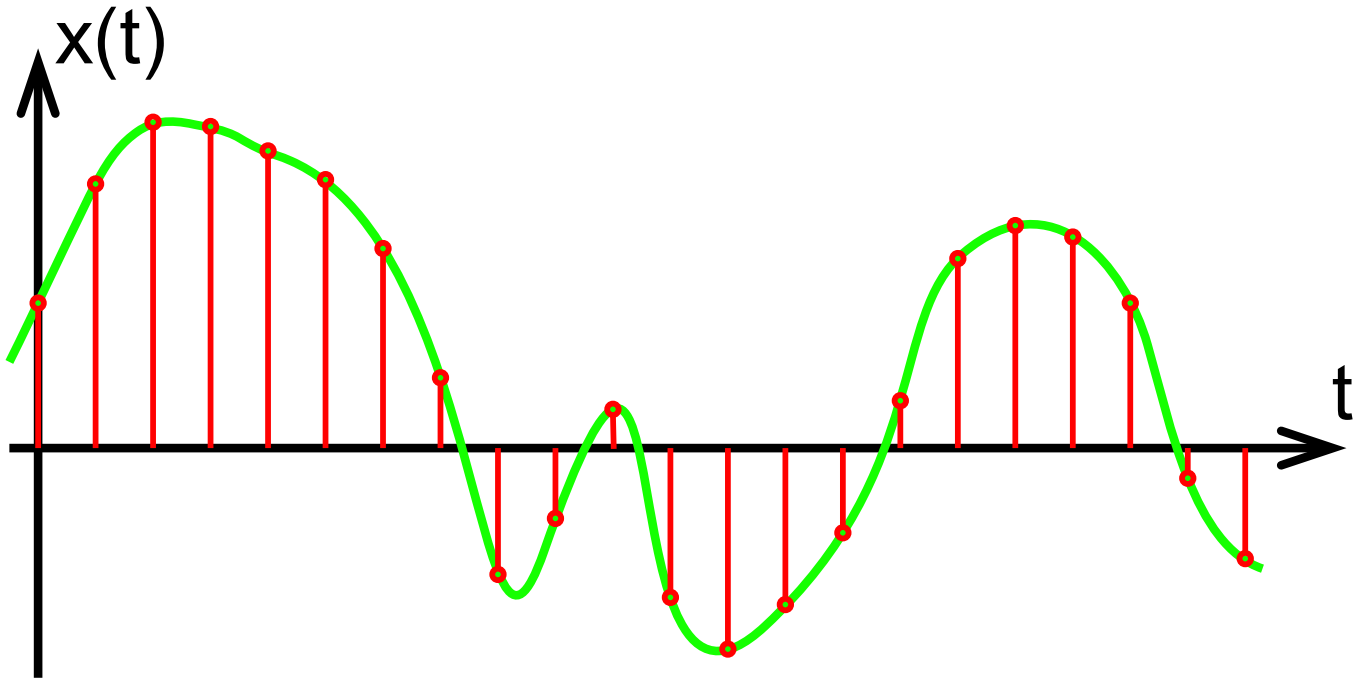


Dolby developed a noise reduction system that removed the hiss from tapes.

Dolby B and C companders elevated compact cassettes to the hi-fi market.

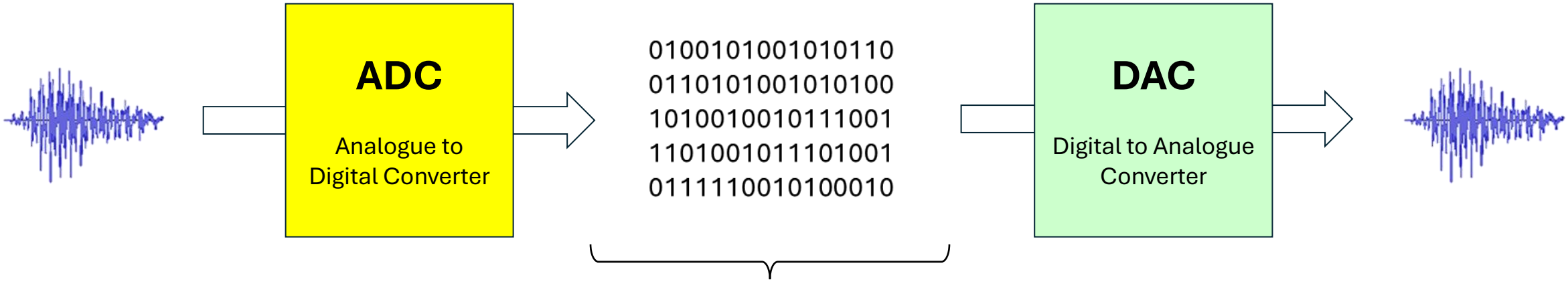
The Digital Age

The principles of digital audio



The more samples you take, and the higher the resolution of each measurement, the closer the reconstructed audio signal will be to the original.

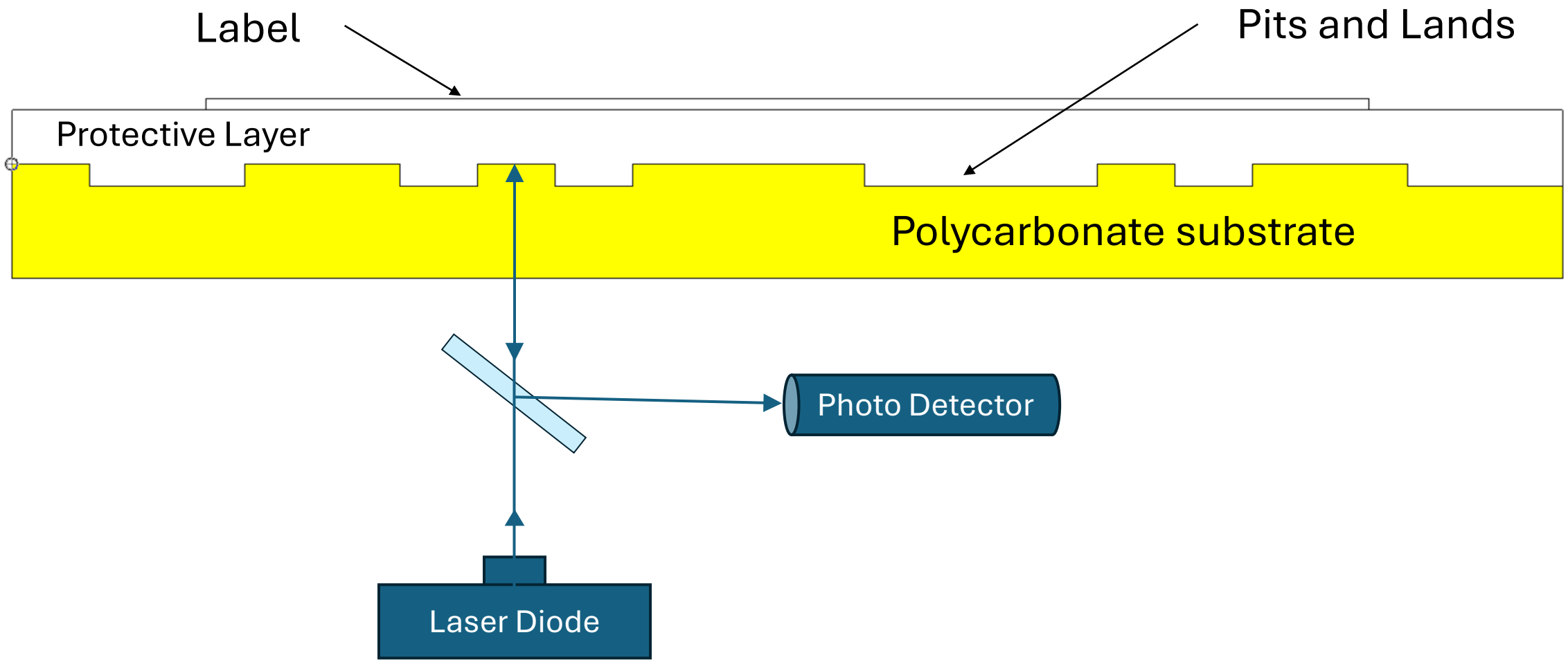
The elements of digitisation



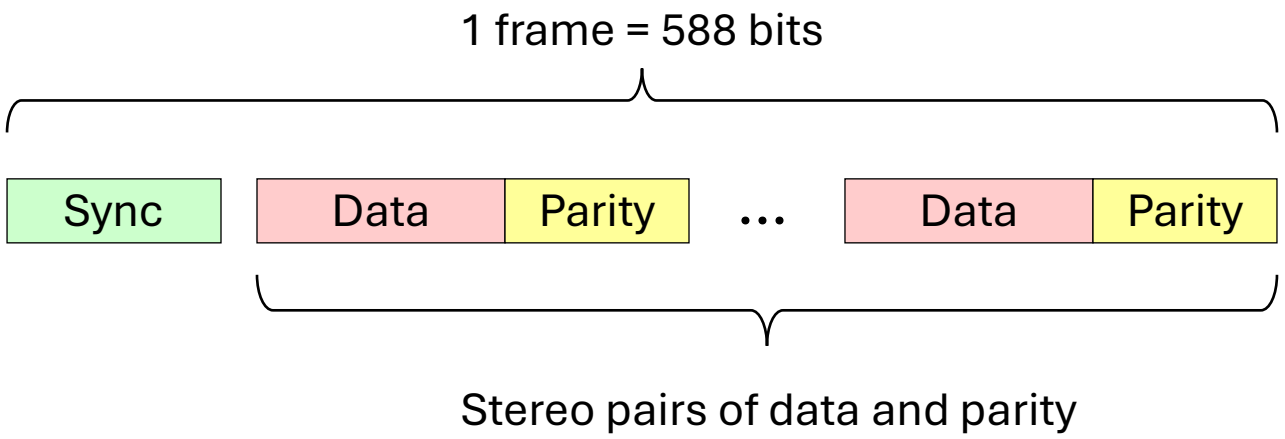
16 bits (2 bytes) give 65,535 possible values

Studio masters typically record at 24 bits – 16,777,215 values

The structure of an Audio CD - 1982



It’s not just audio data on the CD



Synchronisation data tells the processor where each data frame starts.

Parity bits help to identify any corruption in the audio data.

Album lengths hadn’t changed much

The industry was still selling around the same length of music for the same price.

1948 – 46 min

1972 – 60 min

1982 – 74 min

MP3 – Compressing the files

MP3 is part of a video compression standard called MPEG-1 (1992), but rapidly become the codec of choice for music file sharing.

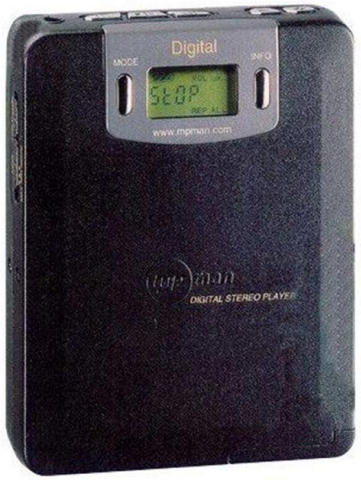
Lossy codecs reduce the size of music files by throwing away data which we can't hear, or are less sensitive to.

Psycho-acoustic codecs use perceptual noise-shaping to detect and remove:

- Sounds we can't hear
- Sounds which are masked by other sounds
- Sounds which we hear less well than others

MP3 can reduce a file size by a factor of ten. So, a user can store lots of songs.

MP3 Players and the iPod



Sae-Han MPMan 1997

Rio PMP3 1998

iPod 2001

Coping with piracy

- The recording industry thought that CDs would be impossible to copy.
- When MP3s came along, they tried to enforce Digital Rights Management software in players.
- When that failed, they tried arresting users.

Music Streaming – iTunes, Pandora and Spotify

- Napster – P2P sharing 1999 – 2001. Made a lot of money for lawyers.
- SoundJam MP (which became iTunes)
  - Initially with DRM, then DRM-free at a higher price in iTunes Plus
  - The recording industry didn't think it would take off, so granted Apple a licence.
  - Now replaced by Apple Music
- Pandora – launched in 2000, initially concentrated on internet radio.
- Spotify was formed in 2006 and has dominated the market.
- Tencent is the second largest subscription base, followed by Apple.

It's all legal now, and largely out of the control of the recording industry.

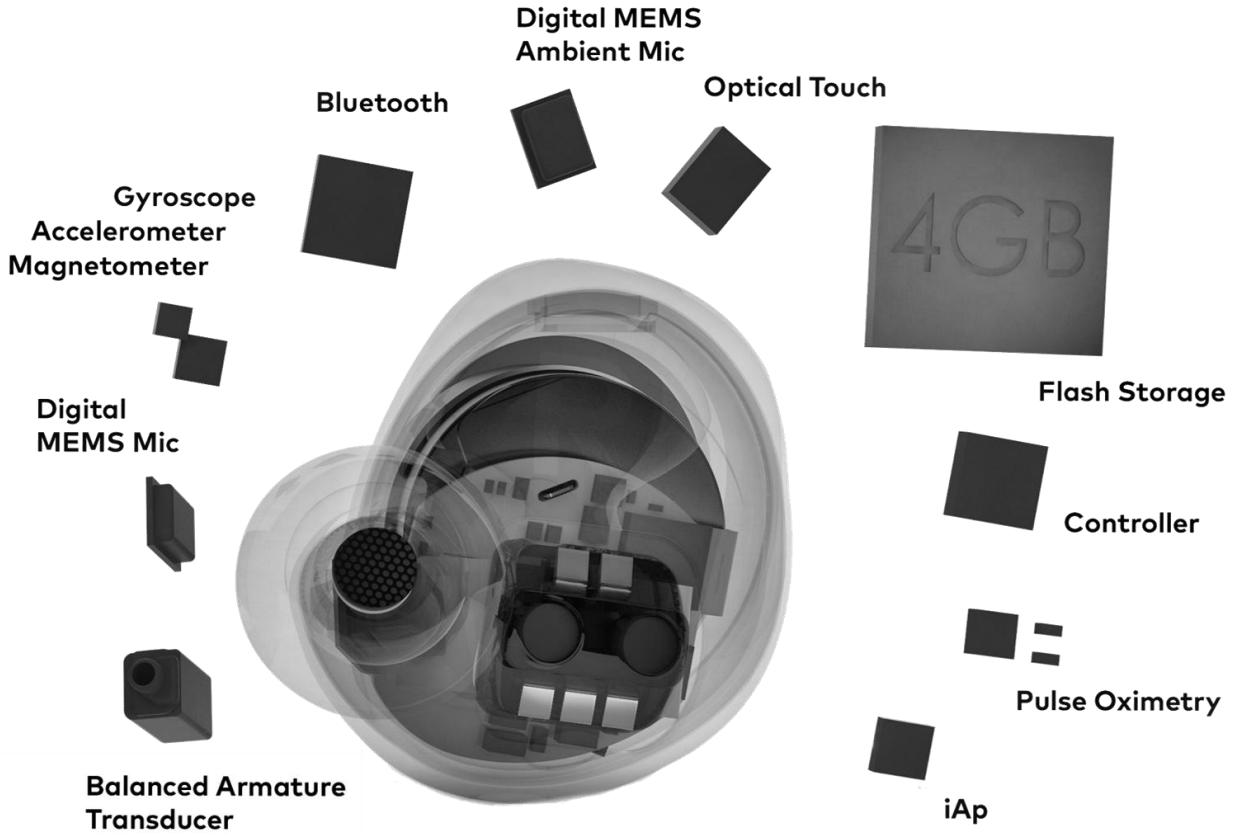
While the lawyers fought, Bluetooth cut the cable

A2DP - Advanced Audio Distribution Profile

- Stereo
- 48kHz sampling

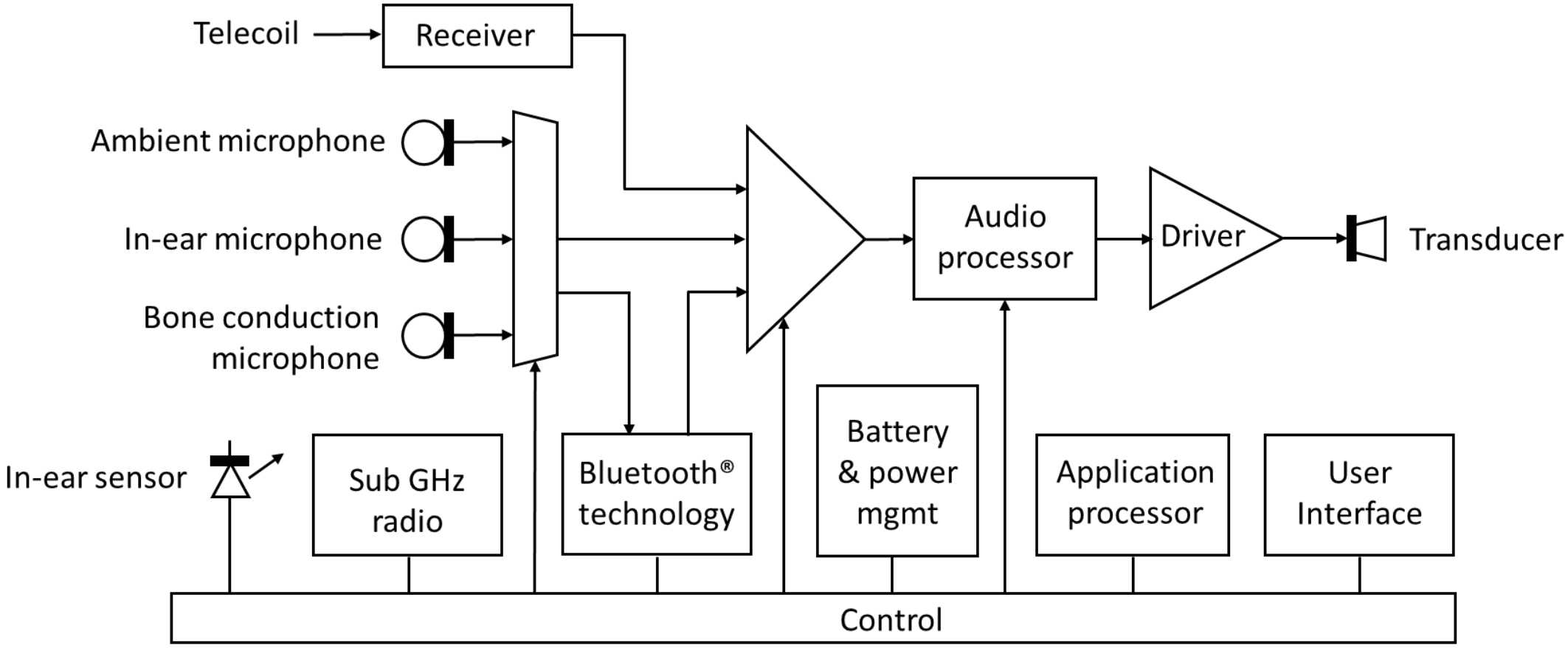
Hearables

Bragi highlighted the possibilities of with their DASH earbud in a 2014 Kickstarter campaign.



We’re still waiting for a major manufacturer to equal their vision.

What's in a hearable / hearing aid?



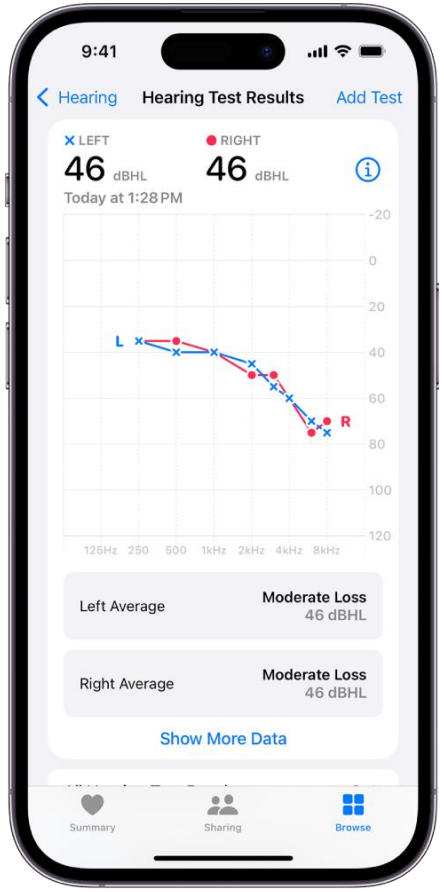
Apple’s AirPods

AirPods became the fastest selling consumer product EVER.

We’re still waiting for the recording industry to start offering binaural recordings.

Audiograms and hearing enhancement

- Users can now perform basic hearing tests using earbuds and phones to generate an audiogram.
- This may indicate hearing loss, or be used to adjust equalisation for general listening.
- Automatic Noise Cancellation and other audio algorithms can reduce external noise to enhance hearing.



Bluetooth LE Audio

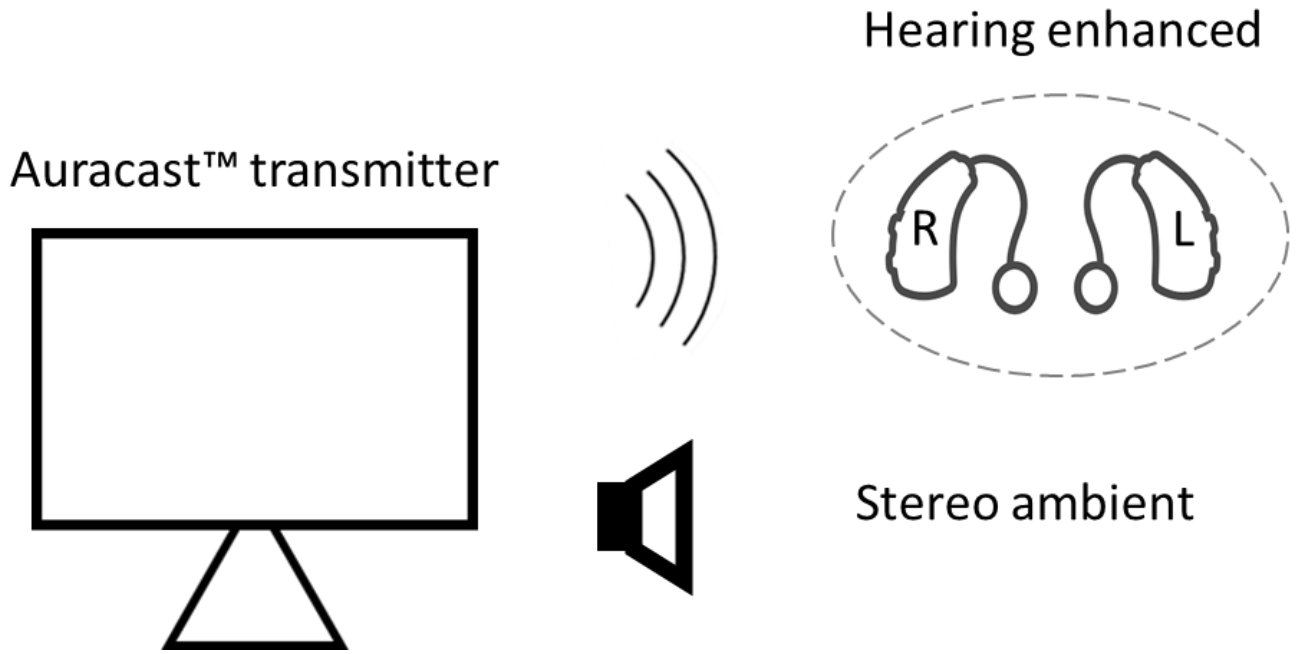
A new generation of tools for the wireless transmission of audio.

- An improved codec for both voice and music – the LC3.
  - (most users can’t tell the difference between an LC3 encoded track and the original)
- Supports mixed music streaming and voice recognition.
- Lower power – longer battery life.
- Separate transmission of left and right audio streams.
- Very low latency lets means it works with live sound.
- It allows sharing audio with Auracast™.

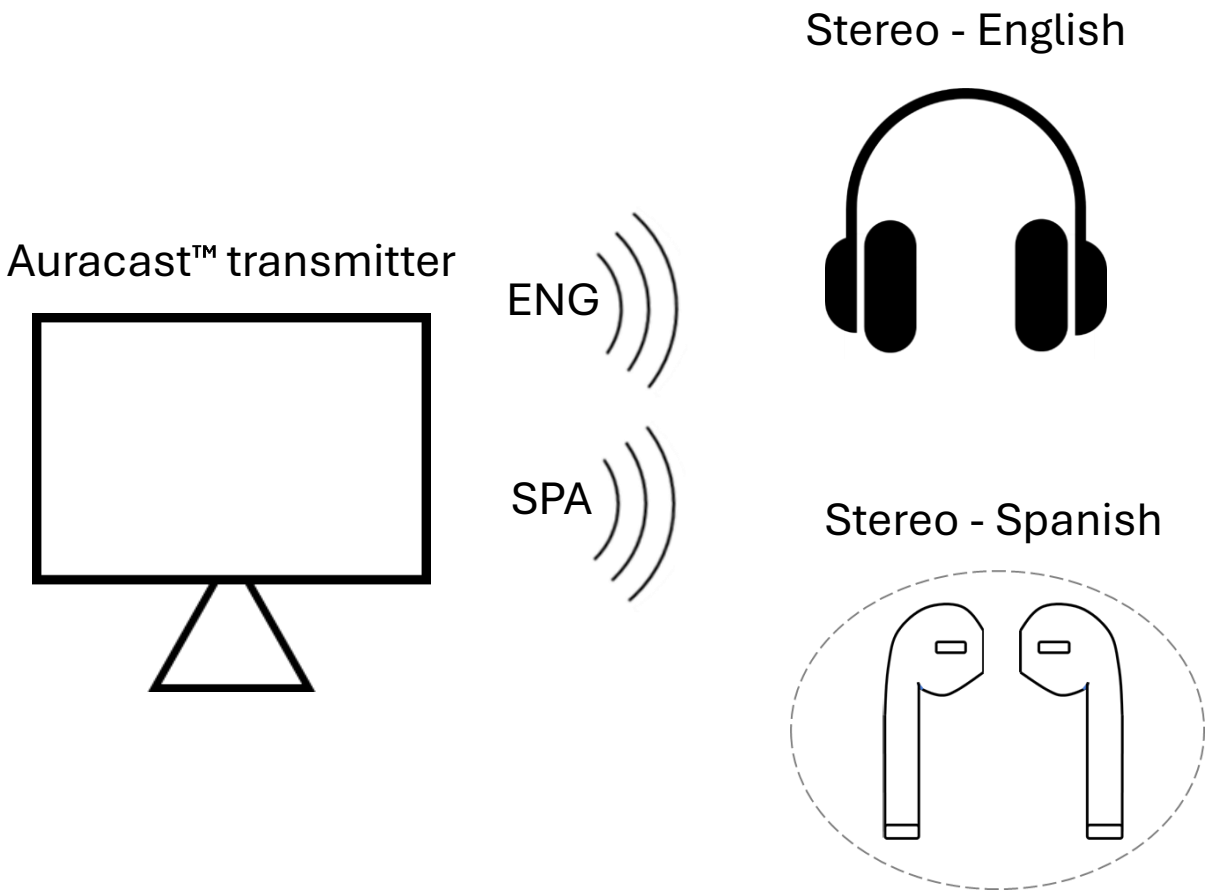
Auracast™

- Auracast makes it possible to share audio between multiple devices.
- Multiple headphones, hearing aids and speakers can all render the same audio stream.
- Low latencies of 20ms mean that Bluetooth has no perceptible delay from ambient audio.
- Auracast transmitters can stream multiple languages at the same time.
- Each receiver has its own, personal volume control.

Auracast ™ supports multiple volume requirements



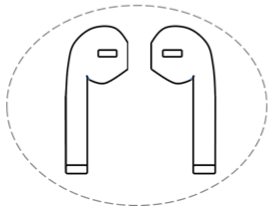
And multiple audio streams



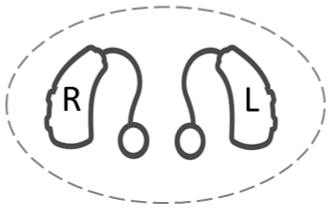
Multiple broadcasters can coexist

Auracast™ receiver #1

Auracast™ receiver #2



Auracast™ receiver #3



Auracast™ receiver #4

Auracast™ receiver #5

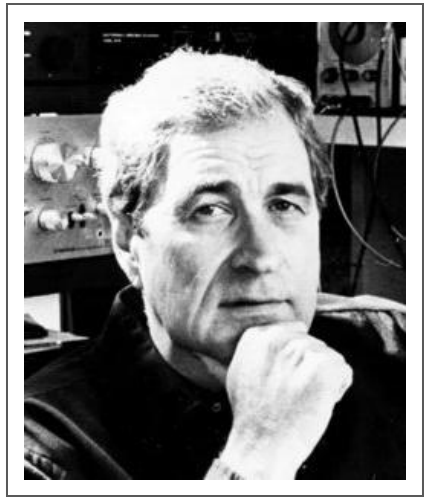
What’s next?

- Better codecs – Hi-res and lossless
- Spatial Audio
- More concentration on voice
- Hearables which go beyond sound, with biometrics
- Intelligent battery boxes
- The fall of the smartphone

Who is the real parent of sound?

“They all laughed when Edison recorded sound”

Edward Wente



Ray Dolby

Thank You

Questions?

www.nickhunn.com