The Evolution of Film Sound

from Silent Movies to Dolby Stereo Digital

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Sound on disc

- New York, 1913: Edison used a phonograph synced to the film
- Sound was reproduced via horn with no amplification
- Synchronisation mechanism used a pulley running from the projection box to the phonograph behind the screen
- Quality and synchronisation a problem

Sound on film

- Early experiments used gas sources - sound modulated the gas flow
- Oscillograph method deflected the light source using a mirror mounted on wires in a magnetic field
- Vibrating reed method also tried
- Photoelectric cell (1918) and vacuum tube (1913) improved performance

Movietone and Vitaphone

- Movietone (1927) recorded sound optically on the film
- A sound head was developed to add to existing projectors
- Vitaphone (1926) used 16-inch discs for the sound, synced to the projector
- ‘Don Juan’ (1926) and ‘The Jazz Singer’ (1927) used Vitaphone

The 1950's - Cinerama!

- Cinerama (1952) used THREE 35mm films for a huge projection area
- Screen covered 146° horizontally and 55° vertically
- Seven channel sound was recorded on a separate magnetic 35mm film
- Quality control by Cinerama, Inc.

Anamorphic lenses

- Performed a 2:1 horizontal compression to give a large projected aspect ratio
- Wide screen formats (CinemaScope, VistaVision, Panavision...) demanded the use of multichannel sound
- Sound usually provided as discrete magnetic stripes added to the film
- Magnetic striping was expensive

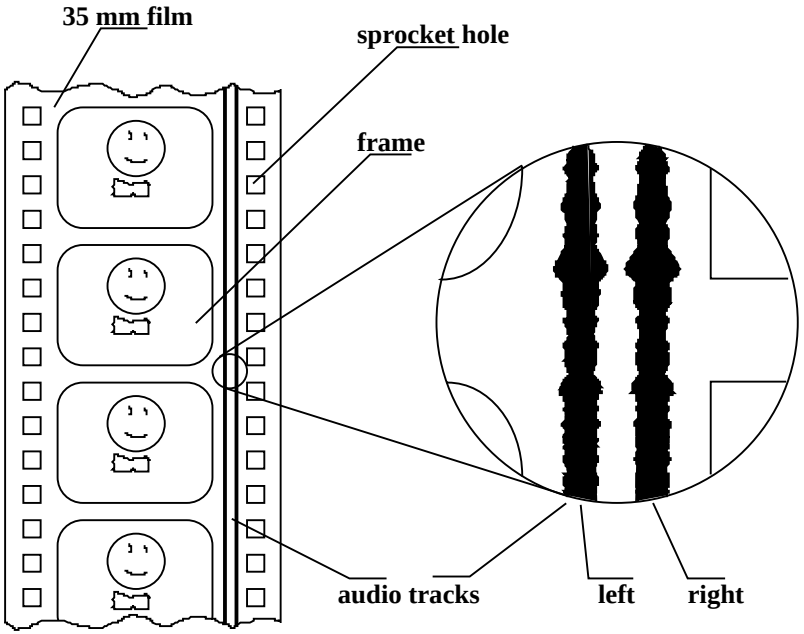
And of course not forgetting...

- ActionScope, Astravision, Camerascope, Cinepanoramic, Cinescope, Cinetotalscope, ColorScope, Cromoscope, Delrama, Duo-Vision, Dynavision, Fantascope, Hammerscope, MegaScope, Naturama, Scanoscope, Sovscope, SpectraScope, Stereorama, Super Vistarama 70, Todd-AO 35...

Perspecta (1956)

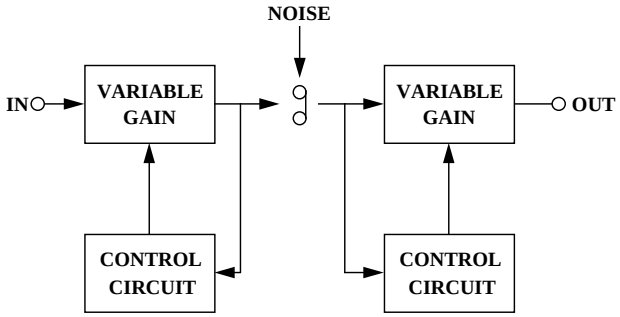
- Low-frequency information added to the mono soundtrack
- A decoder steered the sound to left (30 Hz), center (35 Hz) or right (40 Hz)
- Apparently sounded similar to MagOptical, a four channel system
- Died by 1960, despite effectiveness and very cheap decoding

Optical sound track

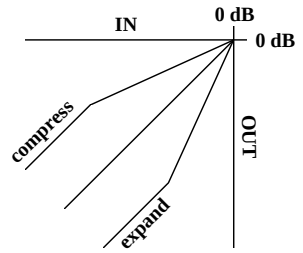


- Audio is recorded as a variable area
- Mono-compatible stereo sound
- Reproduction uses a slit of light projected onto the film
- Two photocells pick up the audio

Compandor noise reduction



Compandor noise reduction system



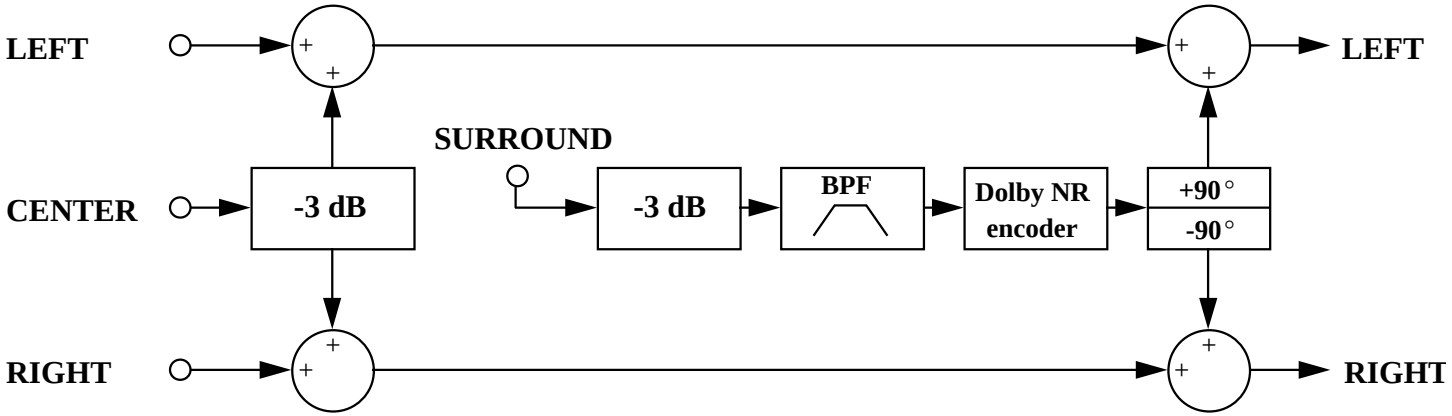
Transfer characteristic

- Gain is varied at record time and reciprocally varied at playback time
- Expansion process reduces tape noise
- Masking of noise modulation is required to avoid ‘pumping’ artifacts

Dolby A noise reduction

- Introduced in early 1970s
- Four band companding scheme provides 15 dB of noise reduction above 10 kHz
- Compression begins at -40 dB
- Hiss, hum, modulation noise, crosstalk and print-through all reduced
- Good for the narrow stereo optical track

Dolby MP matrix

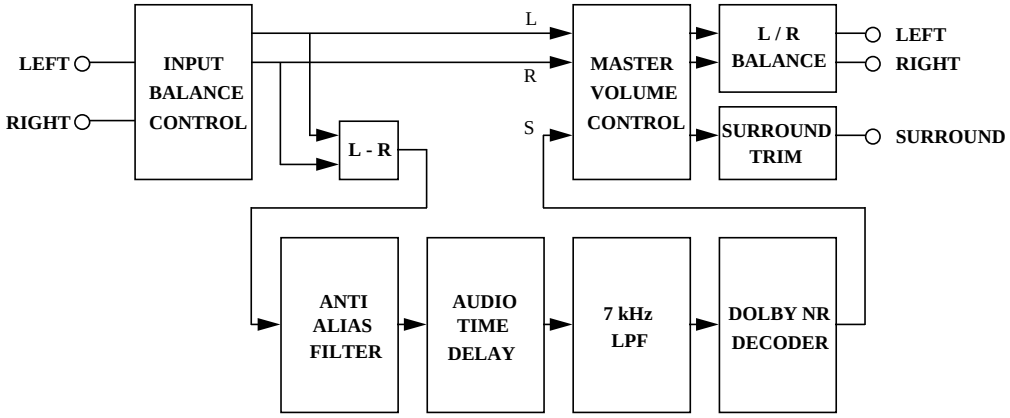


- Center is added equally to left and right
- Surround is compressed, bandpass filtered, and added out of phase to both channels
- Left and right pass unchanged

If no decoding is performed

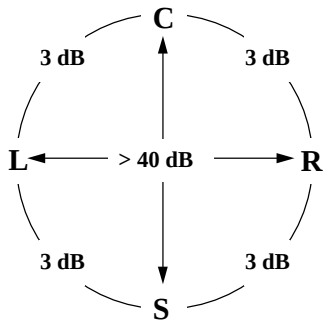
- Center channel information appears equally in both channels, so sound image appears in the middle
- Surround channel information appears out of phase in both channels, so has no clearly defined position in space
- Effect is not distracting - stereo and mono compatibility retained

Dolby Surround decoder

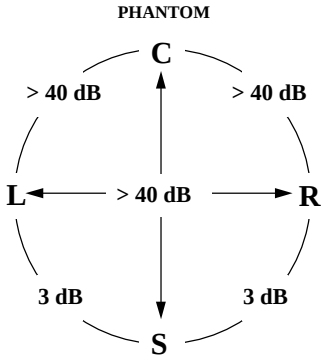


- Subtraction of left and right channels recovers the surround channel
- Delay added to surround (Haas effect)
- Left, right channels are passed unaffected

Stereo separation



Ouput separation - four channels



Ouput separation - three channels

- Separation between left and right, and (phantom) center and surround is good
- Separation between adjacent channels is poor - dialog is not locked to the screen

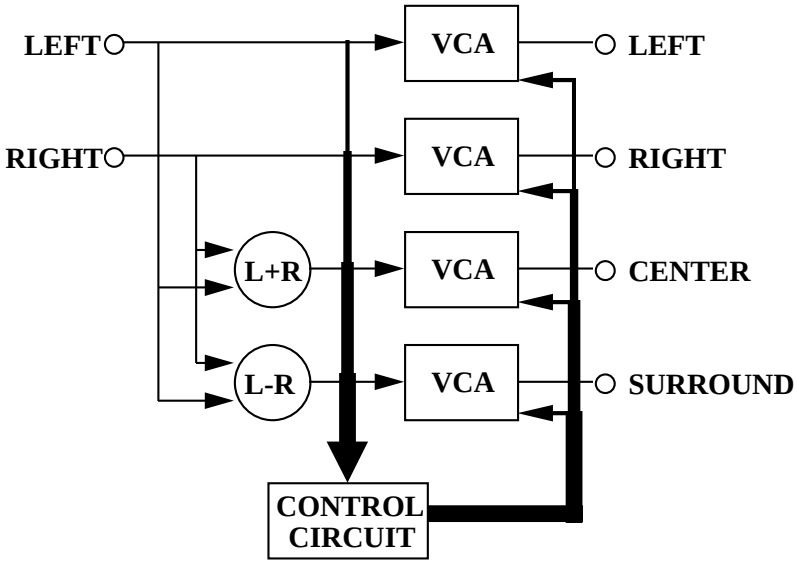
Reducing surround crosstalk

- Time delay ensures that surround signal arrives after front channels
- 7 kHz low pass filter ameliorates azimuth error and makes surround information hard to localize
- Dolby NR reduces noise and high frequency leakage in surround channel

ProLogic decoding

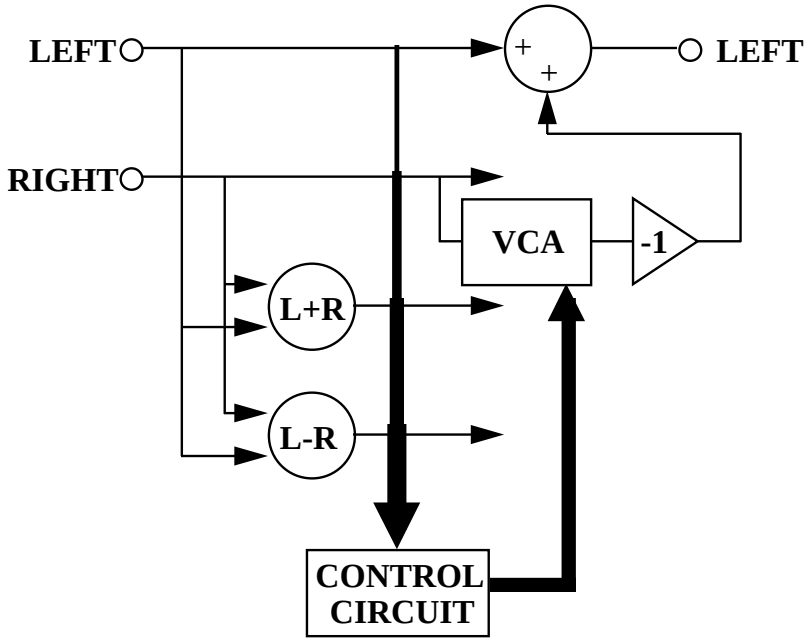
- Brings the theater Dolby Stereo effect into the home
- Provides left, right, center and surround channels with > 30 dB of separation
- Relies on active decoding
- Analog and DSP implementations are available

Gain riding



- Provides directional enhancement
- Dialog appears only in the center
- Dialog fails to mask gain changes in other channels
- Audible pumping

Signal cancellation



- Blending of inverted signals
- Sound is spatially redistributed
- Power remains constant
- No pumping artifacts

Advantages of ProLogic

- Directional enhancement has constant power - no pumping
- Dominant signals appear in their correct places
- Separation between any two channels is greater than 30 dB
- Dialog is locked to the screen

- A certification provided by THX on the quality of a theater's sound system
- Background noise, isolation, reverberation time, viewing angle, projection, equipment and installation must be certified
- Theater is tested anually for compliance - throwback to Cinerama

The next step - digital

- Dolby Stereo is well established
- New format must be compatible - optical stereo track is retained
- Film format is not as restrictive as other formats, e.g. NTSC television
- Space exists at the side of the picture for digital information
- Bandwidth concerns

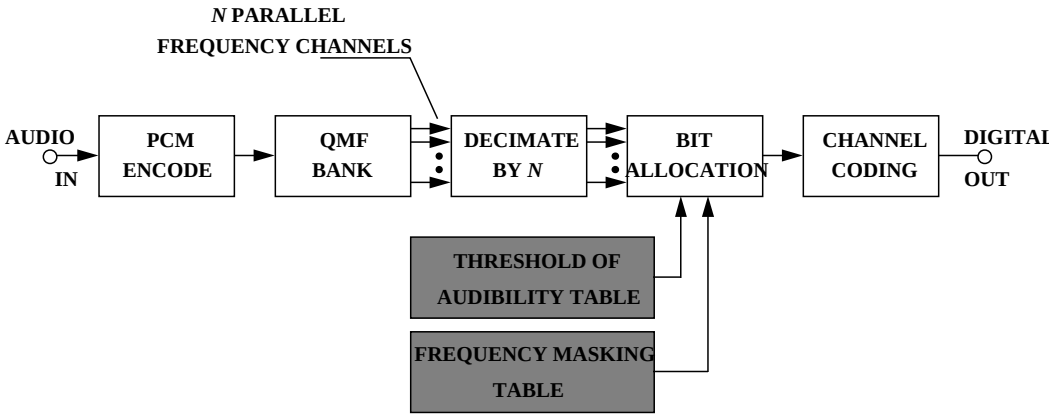
Size of the data stream

- CD audio has two 16-bit channels
- Sampling rate is 44.1 kHz
- Total data rate: 1.4 Mb/s
- Five discrete audio channels plus subwoofer channel requires a data rate of greater than 3.5 Mb/s
- Compression is necessary for multiple channels and > 2 hour playing time

Psychoacoustics

- Human ear has well-known properties
- Threshold of audibility determines if a single sound is audible at all
- Masking threshold determines when a sound is made inaudible by a loud sound of similar frequency
- Encode audible material to sufficient resolution, discarding inaudible sounds

Subband audio coding



- QMF filter bank splits signal into bands
- Psychoacoustics is used to allocate the total available bits for the minimum noise
- Quantization noise remains inaudible

Dolby Digital / AC-3

- Discrete 5.1 channel system
- Data rate: 380 kb/s
- Data is squeezed between sprocket holes on the film
- Data rate is low enough to be encoded on FM analog audio track of LaserDisc
- Push to get AC-3 accepted for HDTV

DTS and SDDS

- Compression ratio lower than AC-3
- 5.1 channels of sound are supplied on two compact discs
- Disc playback is synced to film using an optically-recorded timecode next to the (fallback) stereo optical track
- Sound-on-disc all over again!

Conclusions

- Dolby, DTS and Sony must battle it out
- Only AC-3 has a data rate low enough for inclusion on LaserDisc
- Low data rate also makes AC-3 attractive for satellite broadcasting
- Single-chip AC-3 decoders are now available
- Next step: Digital VHS sound?