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How Movie Sound Works

by Jeff Tyson

Introduction to How Movie Sound Works

Have you ever watched a movie at home with the sound muted? It is amazing what a difference the sound makes in a movie experience. Sound, especially dialogue, makes it easier to understand what is happening. But it also provides texture and emotion to each scene. Most movies would not be interesting at all if you took away the sound. And when we go to the theaters, we expect the sound to be as exciting and encompassing as the images on the screen.

Thanks!
Special thanks to **Bill Peebles**, owner of the Lumina, Rialto, Colony and Studio theaters in Raleigh, NC, for the screen and theater photos and his general assistance.

In this edition of **HowStuffWorks**, you will learn how **analog** and **digital** sound systems work. You will also learn about the three major digital systems:

- Digital Theater Systems (DTS)
- Dolby Digital
- Sony Dynamic Digital Sound (SDDS)

Sound in movies has come a long way. As early as 1889, Thomas Edison and his associates were experimenting with synchronizing sound to moving pictures. In 1926, Warner Brothers released "Don Juan," the first commercial film to have accompanying recorded sound. "Don Juan" had a musical score but no dialogue. The next year, Warner Brothers released "The Jazz Singer" with music, sound effects and a few lines of dialogue. Sound had finally arrived in the movies.

Analog Sound

The mechanism for delivering sound in the early days of cinema was incredibly simple. **Vitaphone**, used in "The Jazz Singer," consisted of a record player playing a wax record. This was known as **sound-on-disc**. The sound recording was usually done after the movie was filmed. The record was played on a turntable that synchronized sound to the film by controlling the speed of the projector. It was a simple but very effective way to add audio to a movie.

In the early 1930s, **sound-on-film** began to supplant sound-on-disc as the technology of choice for adding a soundtrack to a movie. An interesting thing about sound-on-film is that the sound is several frames away from the corresponding images. This is because the audio **pickup**, or **reader**, is set either above or below the lens assembly of the projector. Most analog pickups are in the **basement** (below the lens), while digital pickups are normally in the **penthouse** (fastened to the top of the projector). A test film is run to calibrate the sound to the picture. Once this calibration is done, projectionists can **splice** film together knowing that the sound will synchronize properly.

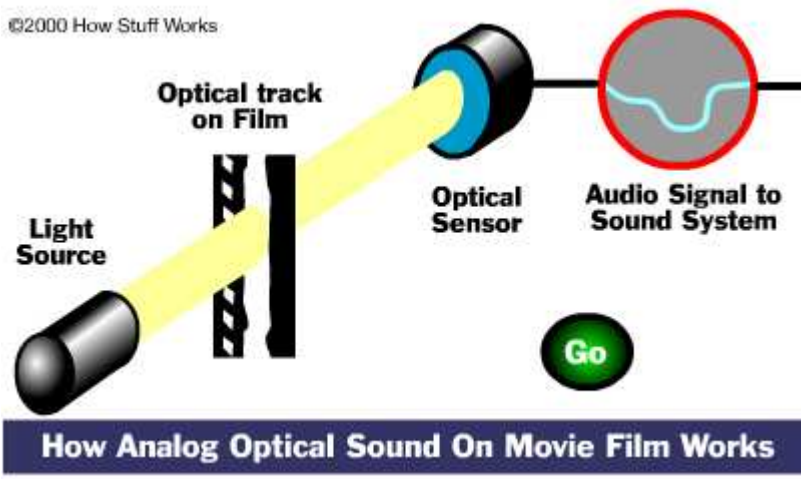
Optical audio pickup

Sound-on-film uses one of two technologies:

- Optical
- Magnetic

The most common method is an **optical** process whereby a transparent line is recorded along one side

of the film. This strip varies in width according to the frequency of the sound. For this reason, it is known as a **variable-area soundtrack**. As the film passes the **audio pickup**, an **exciter lamp** provides a bright source of light, focused by a lens through the transparent line. The light that passes through the film shines on a photocell.



The light is changed to electrical current by the photocell. The amount of current is determined by the amount of light received by the photocell. The wider parts of the strip allow more light, which causes the photocell to produce more current. Since the width of the transparent strip changes the amount of light, this results in a variable electric current that can be sent to a **pre-amplifier**. The pre-amplifier boosts the signal and sends it to the **amplifier**, which distributes the signal to the **speakers**.

A variation of this method is known as **variable-density soundtrack**. It uses a strip that varies in transparency instead of width. The more transparent the strip is, the more light shines through. The biggest problem with this method is that the natural graininess of the film can create a lot of background noise.

In the 1950s, magnetic recording became popular. Magnetic sound-on-film had a couple of advantages over optical at the time:

- Magnetic was stereo, while optical was mono.
- Magnetic had better sound quality.

But there were disadvantages, too:

- Magnetic had to be added to the movie after it was filmed.
- Magnetic was more expensive.
- Magnetic didn't last as long as optical.
- Magnetic was more easily damaged.

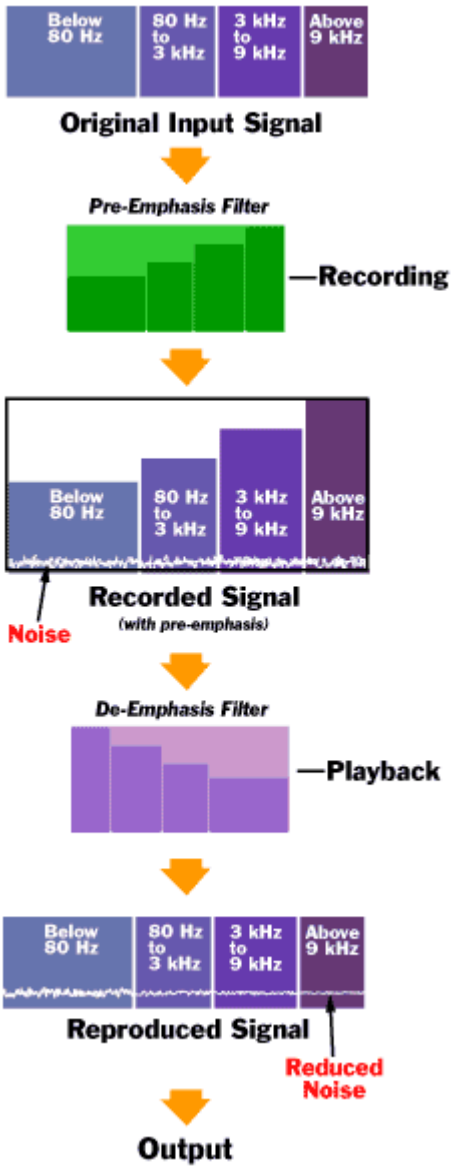
Even though magnetic recording provided as many as six discrete tracks of sound on a film, the expense was simply too much. There had been experiments with stereo optical tracks, but there was too much noise to make that sound system worthwhile. But when Dolby Laboratories introduced **Dolby A** in 1965, a **noise reduction** method originally developed for professional recording studios, the movie industry saw an opportunity to reinvent the optical track.

Dolby A breaks the incoming audio signal into four discrete bands. A technique called **pre-emphasis** boosts the signal of each band above 10 decibels, the level of ambient noise. Each signal then travels through a **compander**, where the signal is compressed to further eliminate low-level noise and is then expanded again. The signals are combined, and the result is much cleaner sound.

The main compromise in Dolby A is a narrower frequency response, resulting in a smaller **dynamic** range. Dolby noise

reduction has evolved from Dolby A to Dolby **Spectral Recording**, an enhanced process that reduces noise twice as much as Dolby A.

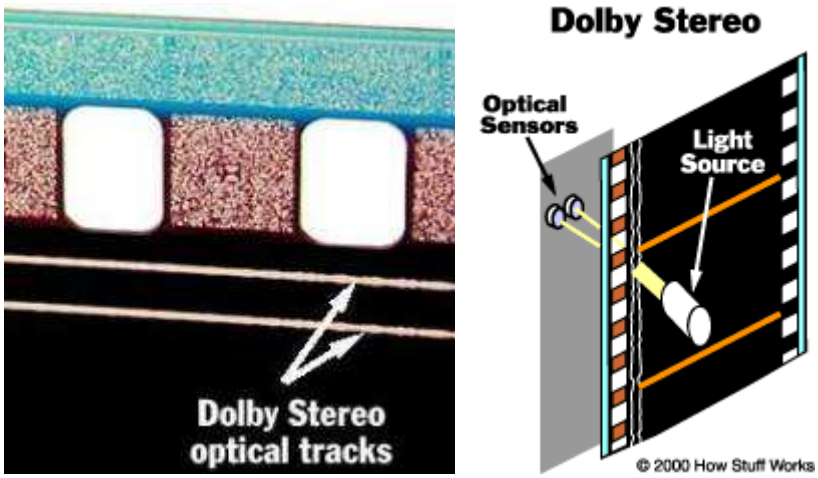
In 1971, "A Clockwork Orange" used Dolby A on magnetic sound-on-film with great success. Eastman Kodak worked with RCA and Dolby in the early 1970s to develop **stereo variable area** (SVA), an optical method that offered stereo sound by using two variable width lines in the space that was originally allocated for one.



Surround Sound

Surround sound first showed up with Walt Disney's "Fantasia" in 1941. To show the movie with surround sound, a movie theater had to spend $85,000 for a special setup that included custom loudspeakers and required two projectors, one running the film and one track of audio plus a second one dedicated to four special audio tracks.

Because of the expense, the full surround-sound system was only installed in two theaters: one in Los Angeles and the other in New York. Many theaters offered surround sound as magnetic-based sound became popular, allowing four or even six channels of sound. Dolby A noise reduction allowed films to have stereo optical tracks, but even Dolby A couldn't compensate for the level of noise if more than two optical tracks were put on the film. A major breakthrough in surround sound came when **Dolby Stereo** was created.



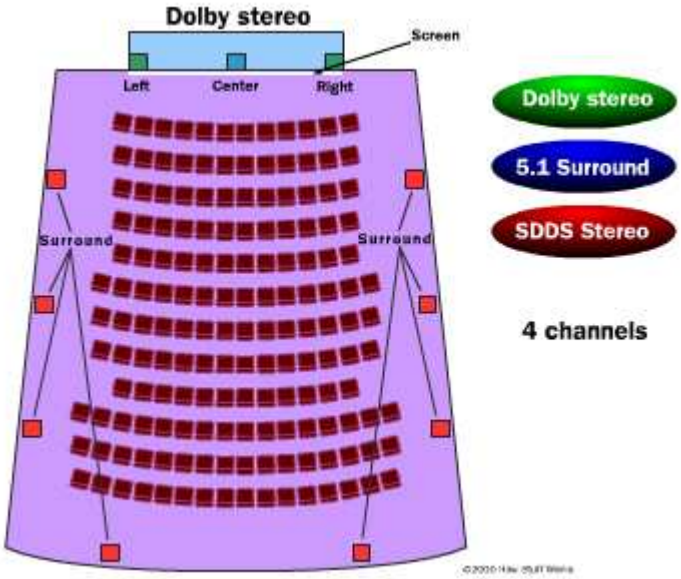
Film with Dolby Stereo optical encoding

Using an amazing process called **matrixing**, Dolby devised a way to use the two optical lines on the film to create four distinct channels of sound:

- Left
- Right
- Center
- Rear

Matrixing works like Boolean logic by comparing the information on the left and right optical tracks to determine which speaker to send the signal to. For example, if a signal on the left track AND the right track is encoded completely out of phase, it is considered surround sound. When the pickup in the projector reads the optical tracks, it decodes this signal as surround sound and sends it to the rear and

side speakers in the theater. If the in-phase signals from the left track AND the right track are identical, it sends the signal to the center channel. Otherwise, it sends the left track signal to the left front speaker and the right track signal to the right front speaker.



It is interesting to note that **Dolby Surround** and **Dolby ProLogic** are the home versions of Dolby Stereo. The same principle applies in these home systems. Four tracks of audio information are condensed into the space of two tracks. If the system does not have a surround-sound decoder, the tracks are treated as normal stereo (right and left) tracks. The key difference in Surround and ProLogic is the center channel. A Dolby Surround system uses the right and left speakers to create a phantom center speaker. This works fine if you are sitting exactly halfway between the two speakers. ProLogic sends the center channel sound to an actual center speaker.

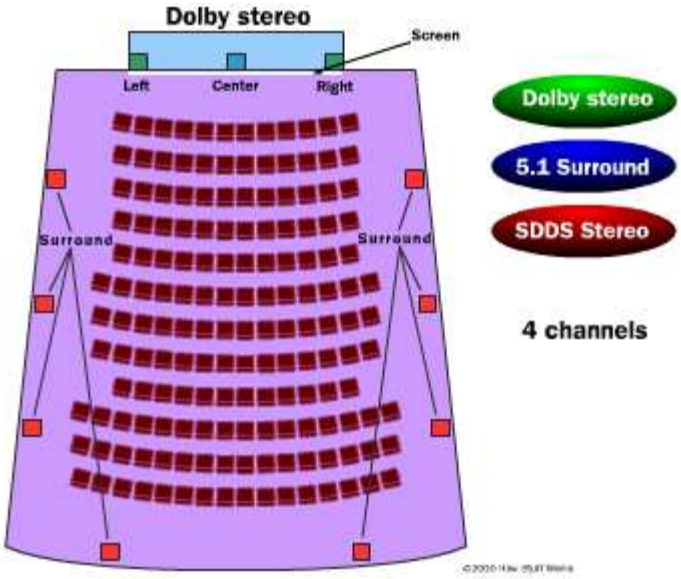
With the advent of digital sound, the capability to offer **discrete** channels of sound has grown tremendously. "Discrete" means that each channel of sound is encoded separately from every other channel, instead of the averaging process used in matrixing.

For more on surround sound, check out **How Surround Sound Works**.

Digital Theater Systems

The first commercial use of digital sound on a large scale debuted with the release of "Jurassic Park." It is called **DTS**, an acronym for **Digital Theater Systems**, the name of the company that patented the process. At its essence, DTS is an updated version of the classic sound-on-disc technology used in the early days of cinema. DTS employs a special optical **time code** that is part of the film. The time code is a series of dots and dashes along the side of each frame between the image and the analog optical sound tracks.

A special **optical reader** is mounted on the projector. The film is threaded through the reader before it enters the projector. Similar to the analog audio pickup, the DTS reader uses a **light-emitting diode** (LED) to focus light on a lens, through the film and onto a photocell. This creates pulses of current that the reader decodes as the time code. It sends this information via a serial cable to a computer. The computer controls an audio system with three CD players. The movie soundtrack consists of six tracks (right, left, center, left-surround, right-surround and subwoofer) compressed on one or two CDs, depending on the length of the movie. One CD holds about two hours of audio in the special compressed format used by DTS. The third CD player is used for a CD that contains current DTS movie previews.



Both the film and the soundtrack CDs have an identifying code. The computer checks these codes to make sure that the correct soundtrack is played for the movie being shown. To make sure that the audio does not lag due to accessing the CD, the system **buffers** the audio in memory using the **FIFO** (first in, first out) method. Because the computer is constantly analyzing the timecode and matching the audio from the CD to it, the sound is seldom out of sync with the picture. And, since the sound is not actually encoded on the film, movie-goers don't hear that annoying "pop" that sometimes occurs when the audio pickup encounters a splice.

The downside to DTS is:

- It requires additional steps in the production process to create the CDs.
- DTS relies on additional equipment to operate.
- The soundtrack CDs occasionally do not arrive at a theater with the film reels.

In the event of a failure of the DTS computer or CD players, the film still has the analog tracks. **DTS Stereo**, which is compatible with Dolby Stereo audio pickups, is the process used to create the analog tracks. As with all digital formats, the optical analog tracks are only used under certain conditions:

- when there is no digital information (such as the local theater information or some previews)
- when the digital format is incompatible with the local equipment (for example, a DTS film in a Dolby Digital setup)
- when the digital equipment fails
- when the digital information on the film is unreadable

DTS has lasted much longer than anyone expected. The original concept was viewed as a temporary solution while theaters made the transition to digital. But the ease of use, relatively low cost and the simple fact that many theaters have already made the investment in the format have combined to keep DTS a viable alternative to the sound-on-film digital formats.

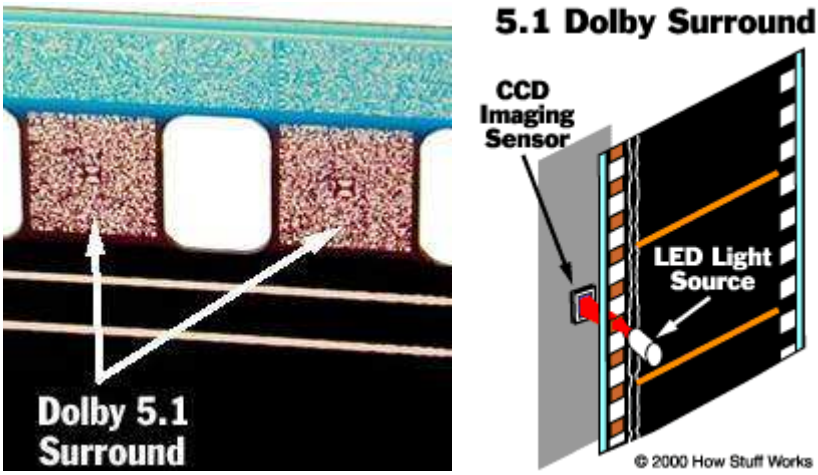
Dolby Digital

Quite possibly the most popular of the digital formats is **Dolby Digital**, which is also known by several other names:

- **Dolby Digital 5.1** (more on 5.1 below)
- **Dolby AC-3** (Dolby's third audio-coding design)
- **Dolby SR-D** (Spectral Recording Digital)

Dolby Digital reader

Dolby Digital uses the space between the sprocket holes to encode information. Look at the photo below and notice the gray dots between the holes. If you look closely, you can even make out the Dolby Digital logo in the center of each segment!



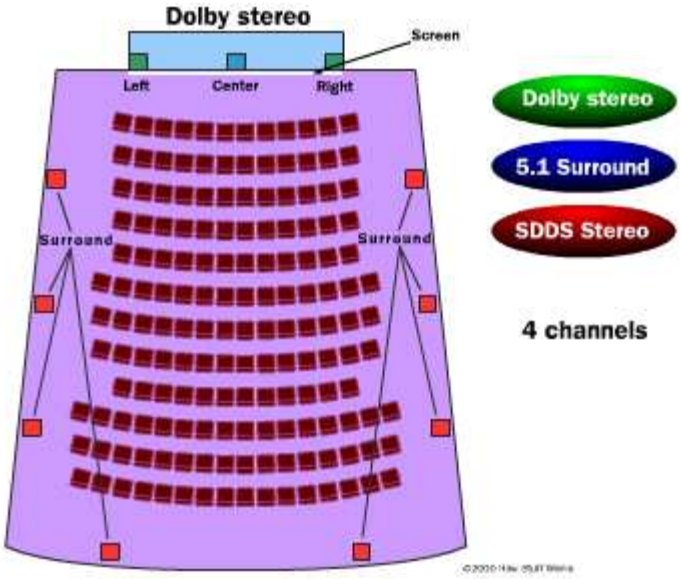
Film with 5.1 channels encoded

The Dolby Digital reader mounts on top of the projector (some projectors now have the reader built right in) and scans the film as it passes through. Light from an LED shines through the film onto a CCD. The image, containing little specks that represent 1s and spaces that represent 0s, is sent by the reader to a DSP-based Dolby Digital Processor unit that turns the binary data back into sound.

Just like DTS, Dolby Digital uses six tracks:

- Center
- Left
- Right
- Left surround
- Right surround
- LFE (low-frequency effects)

This configuration is commonly referred to as **5.1**, for five main channels plus an effects channel. The effects channel uses a subwoofer and is often called the **boom** channel because its main use is for explosions and other powerful, teeth-rattling sounds.

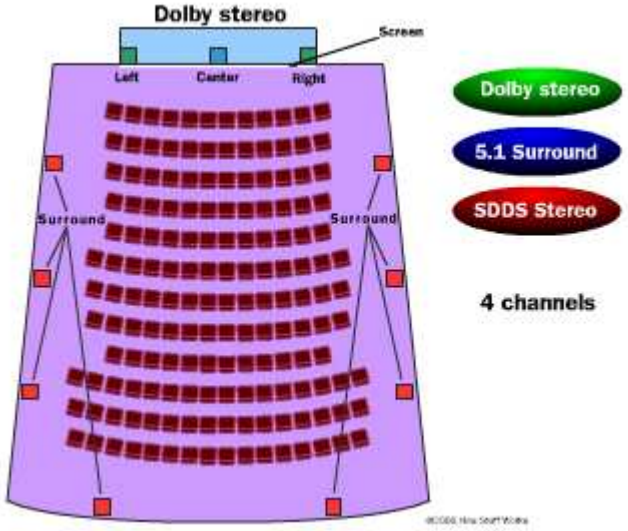


In the event of failure of the Dolby Digital reader or problems reading the digital information, the film has Dolby Stereo analog tracks.

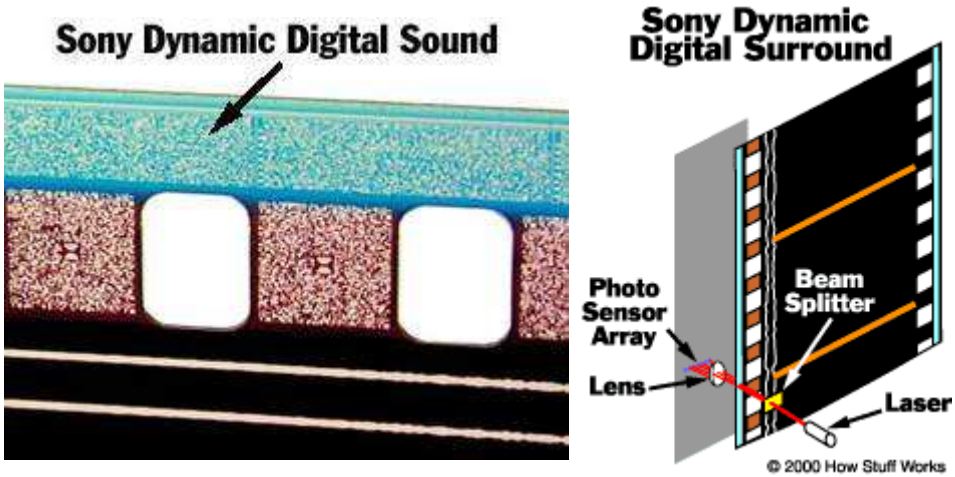
Sony Dynamic Digital Sound

The latest entry in cinema digital sound comes from an entertainment industry giant. **Sony Dynamic Digital Sound** (SDDS) uses the outside edge of the film to stripe digital audio information. Unlike any of the other formats, analog or digital, SDDS provides error correction through the use of an identical **redundant** stripe on the other edge of the film. SDDS supports increased surround-sound options by offering eight channels of sound:

- Center
- Left
- Right
- Left center
- Right center
- Left surround
- Right surround
- LFE



The SDDS reader uses a laser to direct focused beams of light. The light passes through the film, through a lens that magnifies the light and finally is received by an array of photocells. Wherever there are dark areas on the film, the photocells in that part of the array do not receive any light. Any photocell that does receive light emits a small amount of current. SDDS reads each cell as a 1 or 0 based on whether or not it is generating current. As the film streams by, this creates a constant stream of binary information that the reader sends to the digital processor.



Film with Sony Dynamic Digital Sound encoded

Because it requires additional digital sound equipment, SDDS is more expensive to implement than DTS or Dolby Digital. Both formats convert their digital signals to analog after decoding, but SDDS uses a digital connection to send the decoded signal to a proprietary sound processor. Even so, the addition of two more channels of sound make it a very attractive format.

As you may have noticed in the images of film in this article, more than one sound format is usually recorded on the film. Since each format uses a different portion of the film, it is very economical for the distributor to include at least two of the digital formats on the same film. Virtually all commercial films today have Dolby Stereo as the analog format, and some films actually have all three digital formats as well!

You may be wondering why THX is not listed. Although commonly confused with a movie-theater sound system, THX is not a sound format -- it's something else entirely. See How THX Works to learn about it.

For more information on movie sound and related topics, check out the links on the next page.

Lots More Information

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- How Surround Sound Works
- How THX Works
- How Home Theater Works
- How Digital Cinema Works
- How Analog and Digital Recording Works
- How Movie Projectors Work
- How Movie Screens Work
- How Movie Distribution Works
- How Blue Screens Work
- How Centropolis FX Creates Visual Effects
- How Industrial Light & Magic Works
- How Video Formatting Works
- How the Oscars Work
- How DVDs and DVD Players Work

More Great Links

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- Dolby Digital
- Digital Theater Systems
- Sony Dynamic Digital Sound
- Motion Picture Sound History
- DTS FAQ
- A virtual tour of The Dukes Lancaster
- Film Sound History
- Dolby: Surround Sound Past, Present, and Future
- Technical Guidelines for Dolby Theatres
- The Evolution of Dolby Film Sound
- Dolby Motion Picture
- Dolby Home Theater

Cool Movie Links

- The Movie Sounds Page
- Seating Concepts - Seating, Theater & Auditorium Solution
- The Lumina
- Theater Tour - Photographs and History of Los Angeles Movie Palaces
- Movie-List - trailers!
- QuickTime Movie Trailers
- Rotten Tomatoes Movie Trailers
- Movie-Trailers.com
- What is "Home Theater"?
- Al Jolson Society Official Web Site