MOTION PICTURE SOUND RECORDING

A Capsule History: *By John G. Frayne, Pasadena, California*

Editor's Note: *These pages are devoted to a highlight of the 54th AES Convention, a paper read by Dr. Frayne at the Samuel Goldwyn Theater in Beverly Hills (see also Page 475 for coverage of occasion in Convention report).*

Thomas Edison's invention of the phonograph sparked interest in adding sound to film. Three years later, in 1880, Charles E. Fritts filed a patent application that included a claim: "the method of making a sound record which consists in photographically affecting a sensitive surface in accordance with sound waves." In 1913, E. E. Ries filed a patent application for recording sound on film. (It was granted in 1923.) This patent essentially described the variable-density method of recording sound on film. Meanwhile, in Germany, the Tri-Ergon group developed a system using a glow discharge lamp in photographing the sound. This group was granted about 18 patents on such basic features as the flywheel, printing and photocell reproduction. The May, 1923 issue of *Transactions of the SMPE* ran an article by Professor J. Tykociner of the University of Illinois on photographic sound recording [1]. Professor Tykociner used a mercury vapor lamp as a modulating device and a potassium light-sensitive photocell devised by Professor Jakob Kunz of the same university. A reproduction of this first variable-density track is shown in Fig. 1.

Case Laboratories and Lee De Forest made the first attempts to commercialize these developments [2]. Under Earl Sponable's direction, Case developed the Aeolite glow lamp, which was used commercially for the first time in the Movietone Newsreel at the Roxy Theatre in 1927. The following year, the Fox Corporation, which had bought Case, produced the first outdoor talking picture, "In Old Arizona," using the Aeolite System.

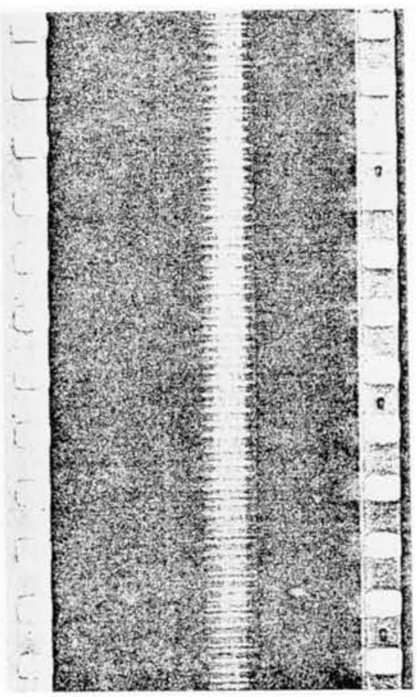


Fig. 1. The first variable density track, recorded by Tykociner

Meanwhile, a rival system using a synchronized disc was being developed at Bell Telephone Laboratories [3]. The Bell System set up Electrical Research Products (ER PI) to commercialize this system. Warner Brothers, then located in Brooklyn, New York, decided to adopt this system under its own Vitaphone copyright, and in 1926 produced *Don Juan*, generally conceded to be the first full-length sound motion picture. Only songs and score were recorded, though; recording dialog was still too difficult. The discs used were 16 inches in diameter and ran at 33⅓ rpm. Playing time corresponded to a standard 1,000-foot reel of film running at 90 feet per minute. Because few theatres were equipped to reproduce sound, the film was not widely shown. By 1927, however, Warner Brothers had developed the techniques for recording live dialog. *The Jazz Singer*, the first full-length talking motion picture, was so successful in the United States and abroad that every major studio rushed to get on the bandwagon.

The Supplanter

At the same time, the Bell Telephone Laboratories had been developing the light valve method of recording a variable-density track. By 1929, all major Hollywood studios were equipped with the dual disc and film systems (Figs. 2 and 3). The first all-talking motion picture using sound-on-film with the light valve was made at Paramount Studios. It was called *Interference* and was released on double film in 1929. As more and more theatres were equipped to reproduce optical sound, the disc method gradually disappeared and was finally abandoned by Warner Brothers in the early 1930's. These early films used the Western Electric condenser microphone. The camera was enclosed in a soundproof booth, which kept camera noise off the sound track but made the cameraman uncomfortable. Because dubbing had not yet been developed, sound effects had to be recorded onstage with dialog.

A paper by D. Mackenzie in the September, 1928 *Transactions of the SMPE* contains the first published reference to light valve recording [4]. The valve used an Einthoven double-string type of galvanometer. Modulation impressed on the ribbons produced variations in exposure on a fine line of light on the film moving past the beam in the recorder. The light valve laid down a variable time exposure, in contrast to the variable intensity exposure of the Aeolite system. Another basic difference in these two variable-density systems was that the Aeolite, because of insufficient light intensity, exposed the "toe" region of the H & D curve of the then-standard EK-1301 positive film. The light valve using a high-intensity tungsten lamp exposed the

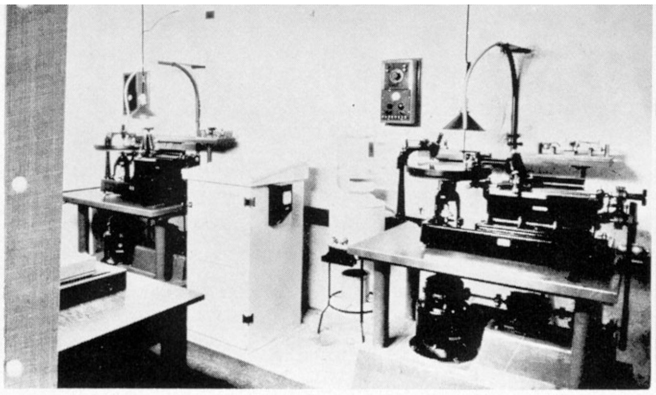


Fig. 2. Dual disc and film recording systems, Hollywood, 1929

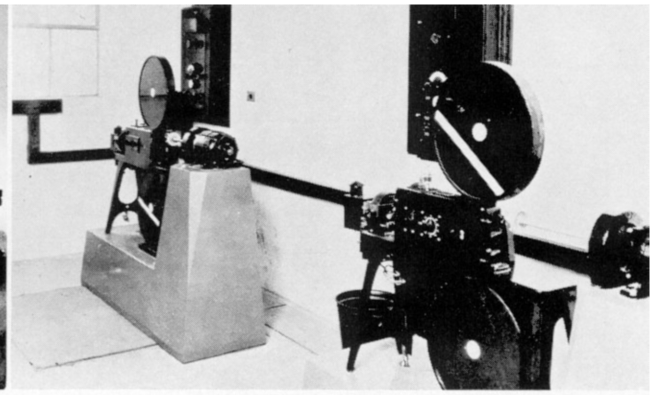


Fig. 3. Film recorders, 1929. Optical tracks supplanted discs

straight-line portion of the negative H & D curve, the print being made on the straight-line portion of the print H & D curve. Light valve recording followed the basic principles of rendering tone values laid down by L. A. Jones of Eastman Kodak Co. [5]. An excellent analysis of straight line and toe records was made by Mackenzie [6] in 1931 and shown in Fig. 4.

While the variable-density systems were being introduced into the motion picture industry, another type of track, now known as variable area, was being developed. In

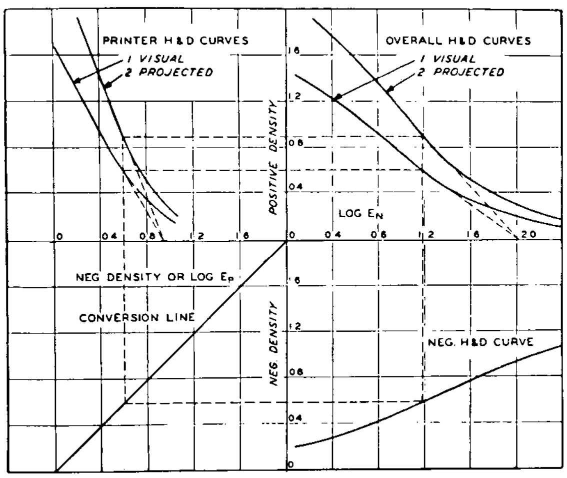
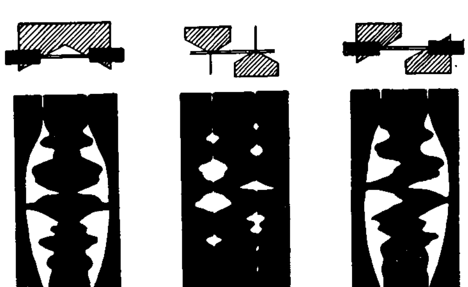


Fig. 4. Analysis of straight line and toe records

the early 1920's, the General Electric Company was experimenting with a rotating mirror type of galvanometer, called the Pallaphotophone (or wobbling light phone). This produced what was then called a variable-width track. It is essentially an oscillographic type of trace, the track consisting of clear bordered by opaque areas. It is not a photographic process per se, although it uses the photographic medium. Typical variable-area tracks are shown in Fig. 6.



(a) (b) (c)

Fig. 5. Three variable area tracks, recorded by RCA galvanometer; a) bilateral; b) Class B push-pull; c) Class A push-pull

The negative track is recorded on a high gamma positive type film in contrast to a low negative gamma film for the variable-density method. Since the major studios had already installed the ERPI variable-density system, RCA bought up RKO Pictures and installed its variable-area system, a refinement of General Electric's earlier efforts [7]. Walt Disney Studios later adopted the RCA system. After that, variable density dominated the industry until the mid-Forties, when the variable-area method became more popular. Almost every motion picture studio now uses variable area recording.

Noise Reduction

The first technical improvement in sound recording was the introduction of ground noise reduction techniques [8]. This was done on variable-density tracks by superimposing a biasing current on the ribbons, reducing the spacing from the usual one mil to a fraction of a mil. As the signal currents increased in strength, the biasing current was cancelled out. This resulted in a low-density area on the negative, and therefore a high-density area on the print, during quiet periods. Since ground noise is a function of film density, this method reduced it by about 10 dB. In the variable-area system, the track is narrowed during quiet periods and is restored to normal width as the sound volume rises (Fig. 5). In 1932, Bell Telephone Laboratories adopted a new vertical-cut disc system in which pre- and post-equalization was used to reduce record noise. This technique was later adopted for studios' original variable-density recordings. At the same time, a 200-mil push-pull track was used to improve signal-to-noise ratio and reduce harmonic response [9].

The graphical method of controlling the processing of variable-density records was replaced in 1939 by a dynamic method known as intermodulation [10]. This consisted of recording a 1 kHz tone superimposed on a 60 Hz tone at

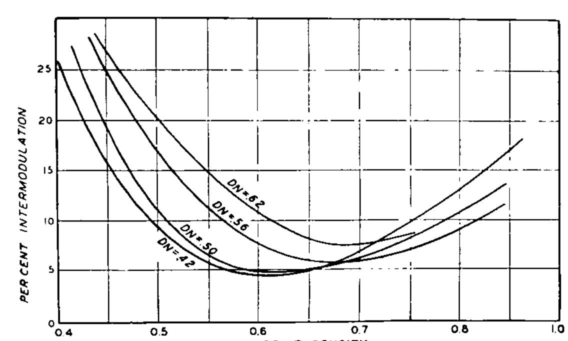


Fig. 6. Results of intermodulation method of controlling processing of variable density records (replaced by graphical method)

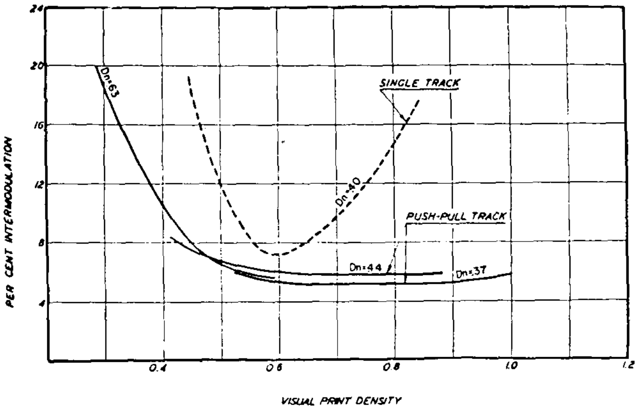
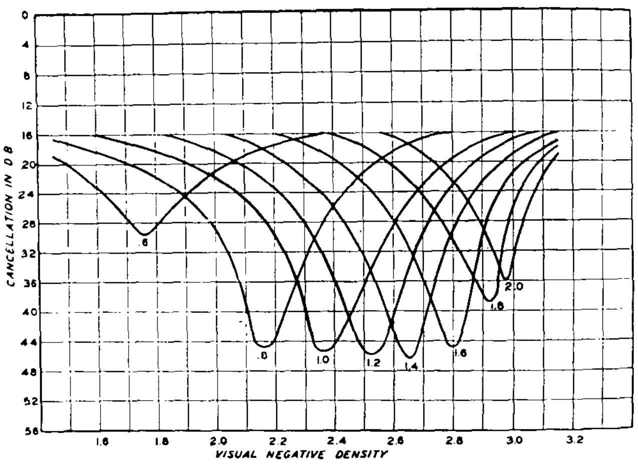
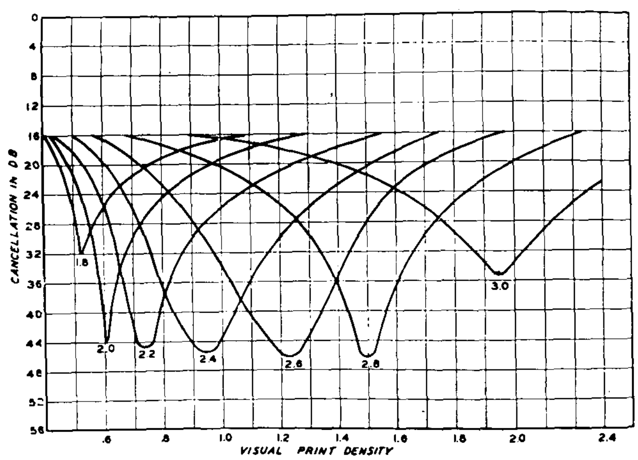


Fig. 7. Intermodulation obtained from single and push-pull tracks

various expoures, developing to various gammas and printing at various exposures. Families of curves are shown in Figs. 6 and 7, giving the lowest values of the 60 Hz tone and indicating the correct processing parameters. About the same time, RCA developed the cross-modulation technique to indicate the correct processing of variable-area tracks for minimum rectification of zero-shift [11]. The curves in



Figs. 8, 9. Tests required for minimum cross-modulation products



Figs. 8 and 9 graphically illustrate the tests required to obtain minimum cross-modulation products. Another improvement in track definition was the use of ultra-violet light in both recording and printing techniques.

In spite of these improvements, signal-to-noise ratio in photographic sound tracks stayed around 50 dB for newly-processed variable-area prints. After three-channel stereophonic sound was recorded live in 1933, Bell Telephone Laboratories began working to put a similar effect on film [12]. Since the engineers wanted to record a large symphony orchestra with a range of 80 dB on a medium whose range was about 50 dB, they had to record the top 30 dB at constant modulation of the film (Fig. 10). In reproduction,

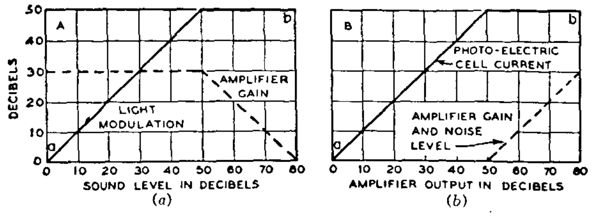


Fig. 10. Noise reduction in film, ca. 1933: relationship between a) amplifier gain and light modulation to sound level and b) photocell output and noise level to sound output in compandor

the gain of the amplifier system remains constant over the lower 50 dB, increasing 1 dB for each decibel of output up to the 80 dB level. The result is an effective 30 dB of noise reduction. In this compandor system, the amplified output of each microphone is bridged to a modulator in which a tone is modulated by the signal envelope, the output being fed into the control circuit of the compressor. The combined output of the modulators of the three tones (250, 630 and 1600 Hz) is recorded on a fourth control track (Fig. 11).

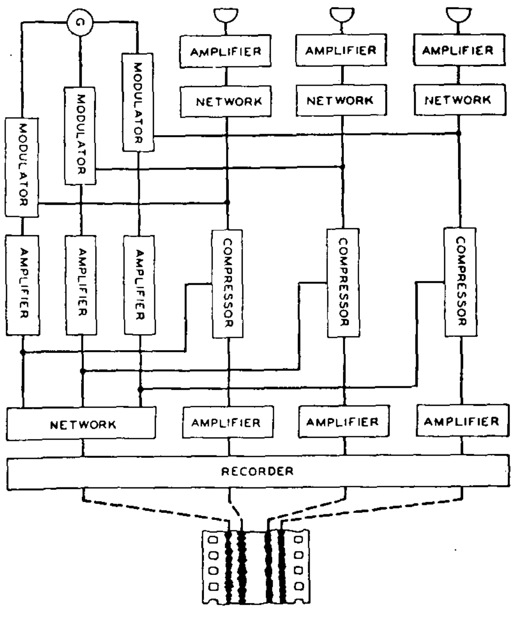


Fig. 11. Stereophonic recording channel and resulting sound tracks

In reproduction, the process is reversed (Fig. 12). This restores the correct linear volume relationships. Pre- and post-equalization networks were also effective in reducing high-frequency noise components. This system was demonstrated at the Pantages Theatre, Hollywood, in 1940. But after World War II, when magnetic recording came on the scene, no serious effort was made to commercialize the compandor stereo system. In passing, it might be noted that

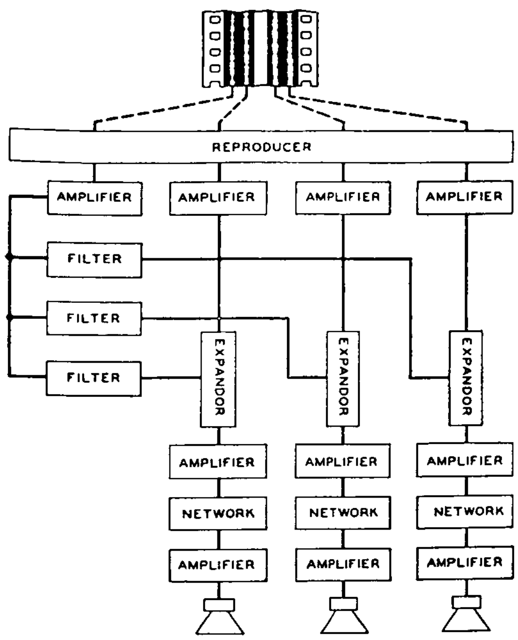


Fig. 12. Schematic diagram of stereophonic reproducing channel

this experimental work by the Bell Telephone Laboratories was chiefly an attempt to achieve true acoustic perspective in reproducing what a listener would hear from the stage.

Fantasound

While Bell was working on compandor stereo, RCA developed Fantasound, the system used in *Fantasia,* for Walt Disney Studios [13]. The original recordings were made with 8 push-pull variable-area channels. Six separate channels were used for closeups of various orchestral groups. A seventh channel recorded a combination of all six, while an eighth recorded a distant pickup of the orchestra. The Ave Maria number was later recorded with three channels. In re-recording, the original tracks were transferred to three channels. These, plus a control track, were made on a separate 35 mm film. The control track contained frequencies of 250, 630 and 1600 Hz, which were used to enhance the limited volume range of the sound tracks. Fantasound differed from the Bell Telephone Laboratories system in that the latter was designed to preserve the acoustical perspective of the original orchestra, whereas *Fantasia* set out mainly to create effects that reflected the mood of the animated pictures on the screen. It was the first film that used a surround system to enhance the overall audience reaction.

While the Bell compandor stereo and Fantasound systems aroused interest in the motion picture industry, there was no immediate follow-up. The first commercial use of stereo in the theatre was the Cinerama system. This used a separate 35 mm magnetic-coated film carrying the stereo and surround tracks. It was followed by the successful Todd-AO 70 film carrying the picture and the coated magnetic tracks. This system employed five independent stereo tracks plus a control track, and used five loudspeaker systems behind the wide screen (Fig. 13).

After World War II, and the success of the Ampex magnetic tape developments, the motion picture industry began to use the magnetic medium for in-studio recording. Studios tended to use 35 mm full-coated tape: they were fully-equipped with expensive 35 mm sprocket-type recorders and reproducers, and synchronization of ¼″ tape with sprocket-type cameras and projectors was yet to come.

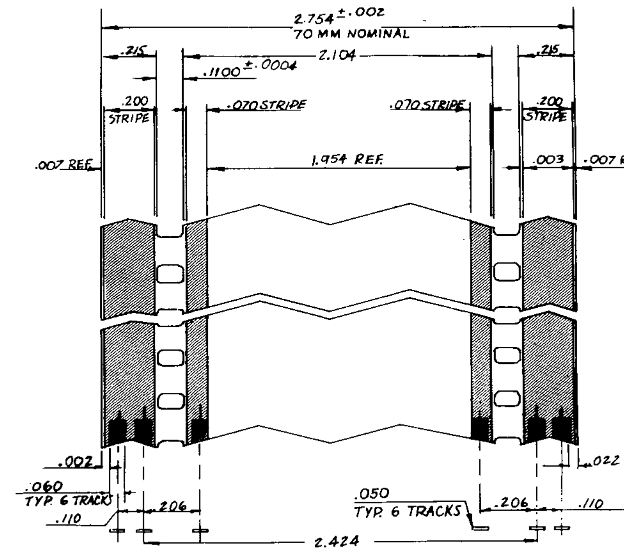


Fig. 13. Todd-AO 70 film coating, track layout

CinemaScope, the brainchild of 20th Century-Fox, was the first serious attempt to introduce stereo into ordinary release prints. It was combined with an anamorphic system of lenses on camera and projector to give the effect of a wide screen. There were three stereo tracks and a narrower control track (Fig. 14). The magnetic tracks were super-

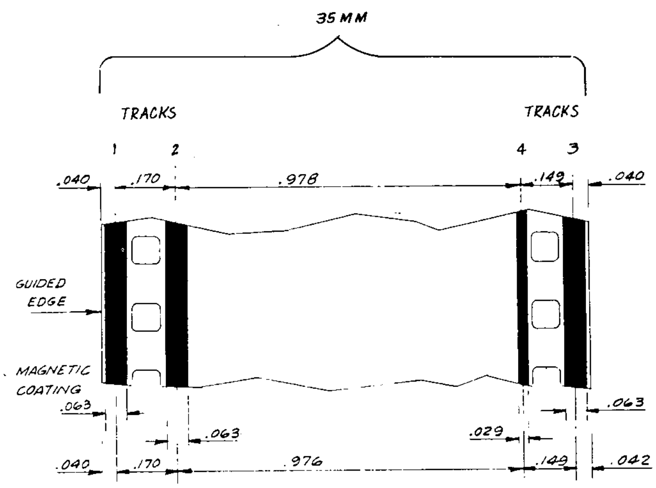


Fig. 14. Cinemascope: three stereo tracks and control track

imposed on the 35 mm film by a striping process. CinemaScope was never very popular. For one thing, striping each individual release print was much more expensive than printing a photographic track. Magnetic tracks, either standard or CinemaScope have, for all practical purposes, disappeared from the screen.

Since their demise, the industry has been working on a compatible stereo system that uses the photographic medium. As early as 1955, Frayne [14] demonstrated a two-channel photo stereo release print which carried two separate tracks in the standard sound track position (Fig.

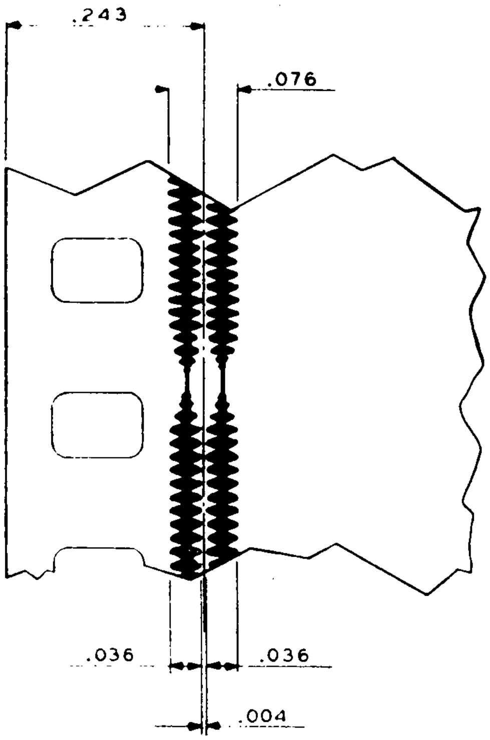


Fig. 15. Two-channel photo stereo print demonstrated by author

15). Variable-area recording was employed, but the system would work equally well with variable density. In this demonstration, the original recordings were made with a two-microphone channel system. A third channel was created by mixing the two channel outputs into a center channel. On reproduction, a third channel was similarly created by combining outputs from the dual photocell. The result was a three-loudspeaker stereo system (Fig. 16).

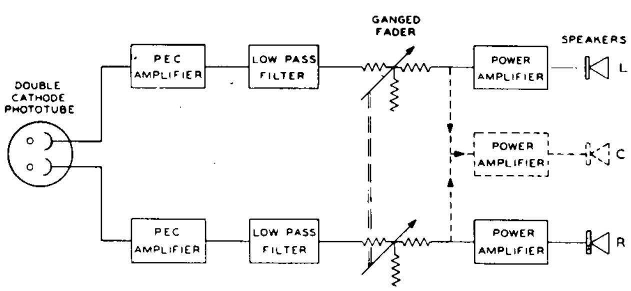


Fig. 16. Stereo reproducing channels for 2- and 2½- channel systems

Revival

This system remained dormant until 1973, when R. E. Uhlig described the use of the Dolby noise reduction system to enlarge the signal-to-noise ratio and thus overcome the loss in volume caused by the reduction in track width that the Frayne proposal made necessary [15]. The Dolby noise reduction system, originally applied to magnetic tape tracks, applies equally well to optical tracks. In a later paper, Uhlig proposed a further improvement for the photographic stereo system: a phantom third track was incorporated by combining the output of the two tracks and feeding it to a central loudspeaker [16]. This has the advantage of localizing dialog at center screen while permitting the use of a three-speaker system for reproducing music and sound effects.

An excellent paper on the Dolby system as applied to optical sound tracks appeared in the September, 1975 *Journal of the SMPTE* [17]. The author says that a flat recording and reproducing characteristic using the Dolby noise reduction system gives an improved signal-to-noise response, an improved high-frequency response with lower distortion. He also claims that the print is compatible with unconverted theatre playback equipment.

The photographic medium is still a highly satisfactory and economical way to record sound on release prints. Adapting stereo to this medium will probably guarantee its continued use in the future.

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