TECHNICAL INSTRUCTION

GP. 6

THE DOLBY SYSTEM

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Introduction: A and B Systems

The purpose of the Dolby System is to improve the signal-to-noise ratio of a signal recording system or a transmission system e.g. tape or disc recording, land line or radio link. The manufacturers claim that the full Dolby System (Dolby A) gives a 10-dB improvement in signal-to-noise ratio over the audio range 20 Hz to 5 kHz rising to 15 dB improvement at 15 kHz. A simplified system (Dolby B) gives up to 10-dB of improvement at the upper audio frequencies only. Either Dolby System will reduce tape noise without changing the characteristics of the signal.

The Dolby B System is used to reduce the high-frequency noise in domestic recorders and also in commercially-produced cassettes. These cassettes may have 4 tracks on 1/8-in tape running at 4·75 cm/s and inherently have a poorer signal-to-noise ratio than is acceptable. Cassette recorders using the Dolby System typically have a signal-to-noise ratio of 46 dB unweighted, 55 dB weighted.

Recording without Dolby

Fig.1 represents a programme (a) with a 40-dB dynamic range which is to be recorded on a system

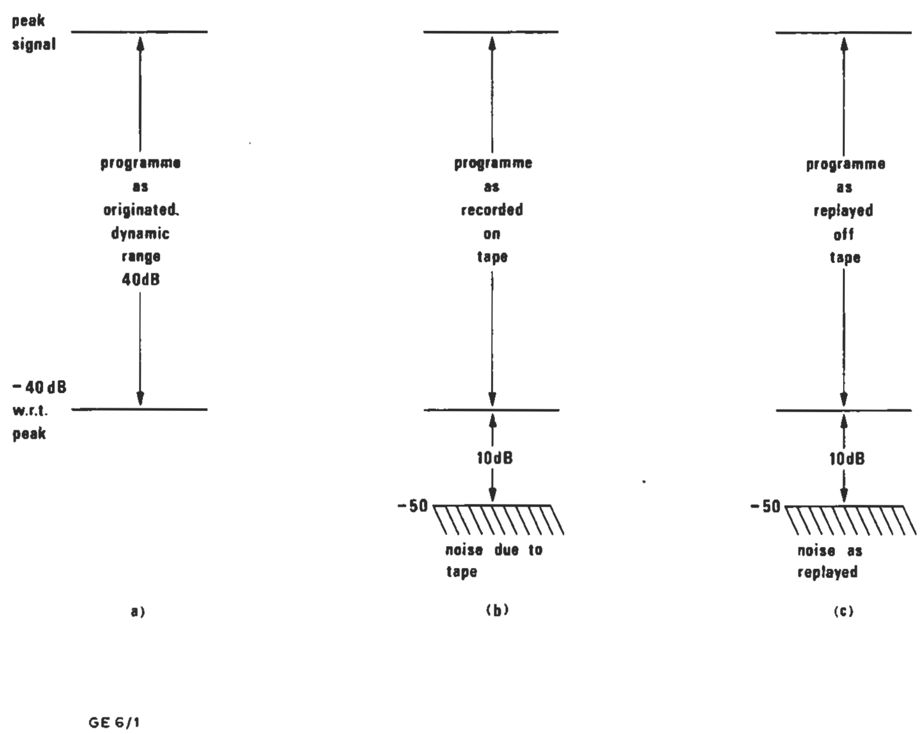

Fig.1. Noise due to recording without Dolby system.

with a tape background noise which is 50 dB below peak signal level (b). It is assumed that any other noise in the system (e.g. replay amplifier noise) is negligible compared with the noise on the tape due to the recording process. The peak signal-to-noise ratio of the signal on the tape is thus 50 dB and as there is no further deterioration in the replay amplifier this is also the signal-to-noise ratio of the programme as reproduced (c).

The most common use of the Dolby A System is in multiple tape recording where one signal may pass through the record/replay process several times or where a large number of tracks are mixed to make one or two tracks. The Dolby System can be used whenever the best signal-to-noise ratio that can be achieved would benefit by 10 dB of improvement over the full audio frequency range.

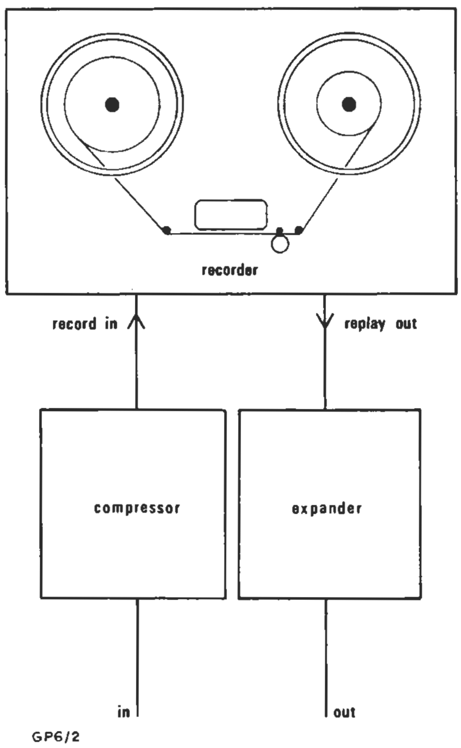

Fig.2. Basic block diagram of Dolby System used with a tape recorder.

Recording with the Dolby System

The Dolby System uses two processors. In a tape recording system one is connected before the record amplifier and the other after the replay amplifier as shown in Fig.2. The record processor is basically a compressor and the replay processor is an expander. The expander has an input-output characteristic which is an exact mirror image of that of the compressor. Thus the action of the replay processor upon the outgoing signal is the reverse of that of the record processor upon the incoming signal.

Fig.3. shows how the Dolby System acts upon signal and noise produced within the recording system. The record processor lifts the level of low-level signals but has no effect upon high-level signals. In the diagram a 40-dB dynamic range is compressed to 30 dB. The background noise, tape hiss, is now at a level 20 dB below that of the lowest recorded signal. During the replay process, the signal from the tape is passed through an expander. This restores the 40-dB dynamic range by reducing the level of all low-level signals without changing that of high-level signals. As the system cannot differentiate between low-level signals and recorded background noise, the noise is reduced in level too.

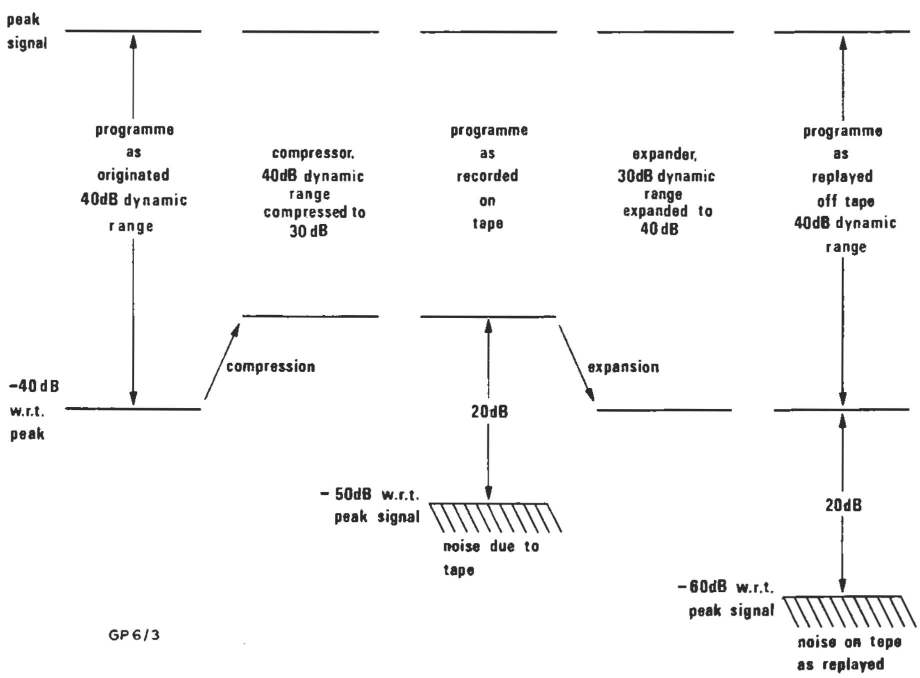

Fig.3 Noise due to recording with Dolby System.

Principle of the Dolby System

The input/output characteristics of the record and replay processors are shown in Fig.4. It is an important requirement of the Dolby System that one process is the mirror image of the other. Thus the two characteristics together produce a linear characteristic.

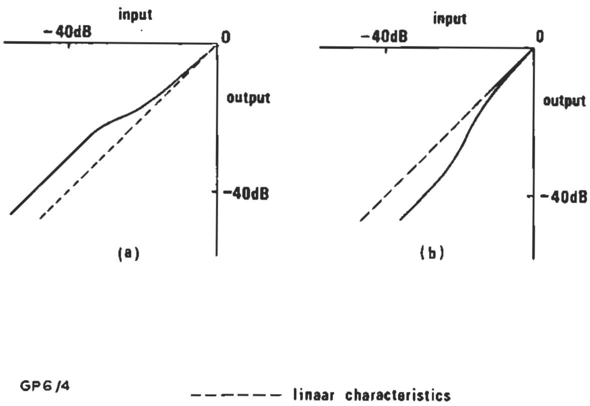

Fig.4. General form of (a) record characteristic and (b) replay characteristic of Dolby System.

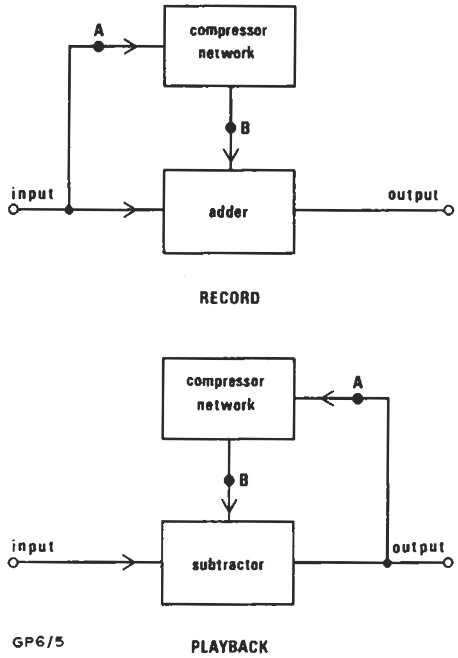

Fig.5. Method of obtaining complementary input-output characteristics in Dolby System

Signals smaller than 40 dB below peak signal level are raised in level by 10 dB. Signal levels between peak level and 10 dB below peak level are unaffected. For signals with levels between –10 to –40 dB relative to peak level the amount of compression changes smoothly from nil to 10 dB.

These two complementary characteristics are produced by using identical compressor networks in the record and replay processors, the record process using addition and the replay process subtraction as shown in Fig.5.

In some written information about the Dolby System the item called *compressor network* in Fig.5 is referred to as the *differential network* and its output is called the *differential signal.* Fig.6 shows how the amplitude of the differential signal varies as the input to the network changes from 0 dB to –40 dB.

Consider a signal passing through the record processor. If it is a high-level signal, say approaching peak level, the differential network produces a negligible signal at point B in Fig.5 to feed into the adder. Thus the through signal is unaffected. If the input is a low-level signal, say at –40 dB, the output of the differential network (at point B) is such that the adder output level is raised by 10 dB.

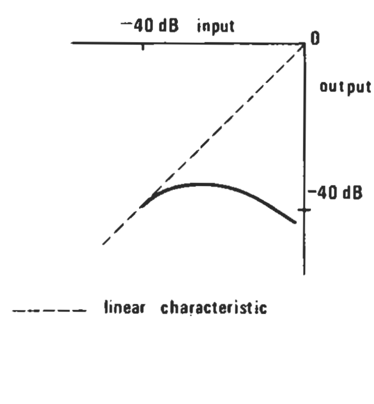

Fig.6. Input-output characteristic of the compressor or differential network.

Dolby System A

Detailed Operation

Fig.7 shows the record chain in the Dolby A System. After passing through an input transformer, a level control and a low-pass filter (to prevent any undesired signal e.g. bias which may be present from affecting the system) the signal divides into two. One part passes directly to the output adder. The other part passes through the compressor or differential network. At the output of the differential network low-level signals have been boosted slightly in level and high-level signals have been reduced in level by 30 to 40 dB. Thus, when the two signals are added, low-level signals are boosted in level but high-level signals are unaffected as shown in Fig.8.

In the replay chain (Fig.9) the differential signal is used in a similar manner to a negative feedback signal. High-level signals, from peak level to 10 dB below peak level produce negligible differential signal and hence are not changed by the replay processor. For low-level signals, the amplitudes are reduced by the same amount that the record processor increased levels.

Differential Signal and Differential Network

The system as so far discussed has one important drawback. If two signals of different frequencies one at high-level and the other at low-level, occur at the same instant of time, the processor must deal with them both in the same way, although only the low-level signal may require processing. The Dolby System

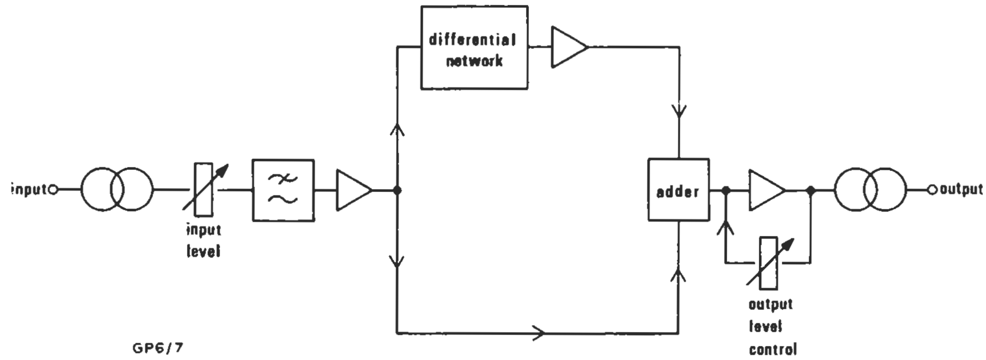

Fig.7. Dolby System in record condition.

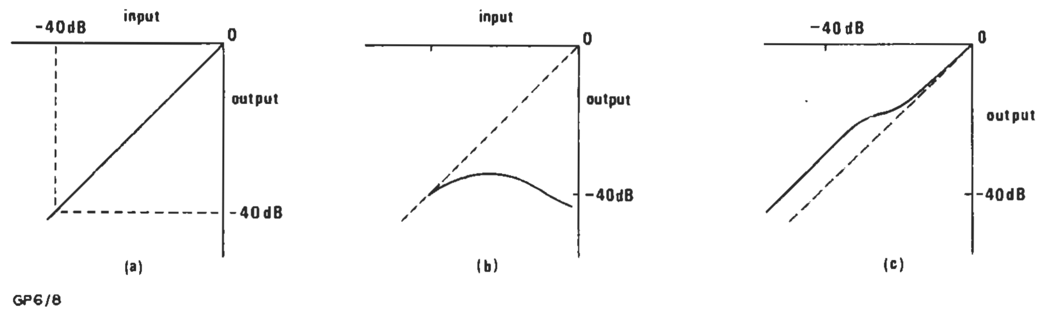

Fig.8. Derivation of record characteristic

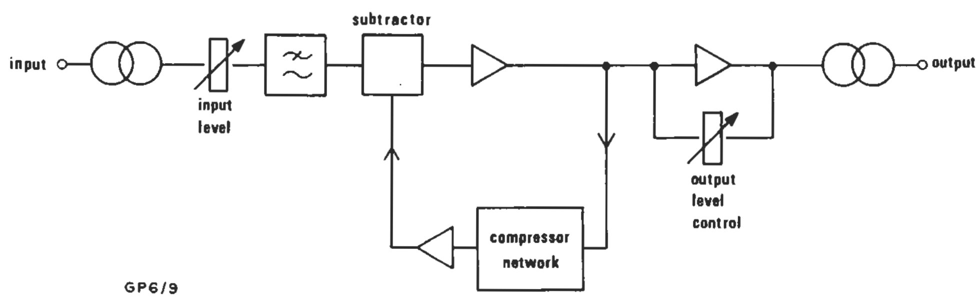

Fig.9. Dolby System in replay condition.

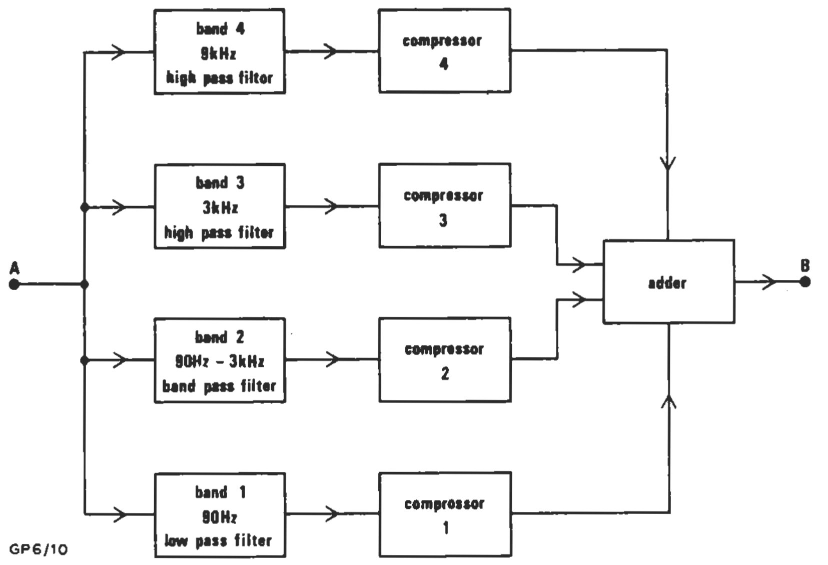

Fig.10. Division of audio spectrum into bands in Dolby A System

minimises this difficulty by using four compressors connected in parallel each preceded by a filter network to ensure that each compressor handles a limited range of frequencies as shown in Fig.10. Compressors 3 and 4 both act upon a signal in the region above 9 kHz to give an increased differential signal at these frequencies.

Each band is intended to deal with a different type of noise as follows:

If a high-level signal (programme) and a low-level signal (noise) occur simultaneously at nearby frequencies, the high-level signal masks the noise and processing of the low-level signal is not necessary. Thus processing is required only when there is no over-riding higher level signal in the band.

The ideal solution would be to divide the audio range into an infinite number of bands but four bands give an acceptable compromise between effectiveness and cost.

Band	*Frequency Affected*	*Type of Filter Used*	*Noise Affected*
1	80 Hz	low-pass	hum and rumble
2	80 Hz - 3 kHz	band-pass	cross-talk & print-through
3	3 kHz	high-pass	hiss and modulation noise
4	9 kHz	high-pass	hiss and modulation noise

Fig.11 shows how each one of the four identical compressors functions Each compressor consists of a main chain and a side chain.

The main chain consists of a compressor network followed by an amplifier/limiter.

The side chain takes the output of the main chain, rectifies it and integrates the resultant varying d.c., which is used to control the degree of compression. In the absence of any other circuitry, the output of the compression network would increase more slowly than the increase in input. This is because the d.c. from the side chain, and hence the amount of compression, rises as the main chain output level rises. The function of the limiter in this side chain is simply to give protection against any large-amplitude pulse which may occur when the compressor is handling a low-level signal. The limiter limits only during the brief period after the start of the pulse and before the compressor gain is reduced. Limiting does not cause any significant distortion of the signal because

1. it occurs for such a short time
2. the extreme overload conditions which cause it occur rarely
3. the limiter is in the side chain and does not operate on the main signal path

There is also, however, another signal which is fed forward from the input of the compressor network to the amplifier driving the full-wave rectifier. When the signal into the compressor is of low level this additional signal has no effect on the side chain. As the input level increases, however, the feed-forward signal begins to effect the side chain and hence the compression network, causing the output of the compressor network to fall.

Thus two factors affect the amplitude of the differential signal:

(i) the compressor controlled by the side chain;

(ii) the feed-forward signal

The overall effect was shown in Fig.6.

Dolby B System

Introduction

Dolby A System is too expensive (about £250 per complete processor) to be considered as a means of improving the signal-to-noise ratio of a domestic tape recorder. The Dolby B System is intended to satisfy the domestic market and deals only with tape hiss and other high-frequency noise. It contains only about 30 to 40 components and costs less than £50. 10 dB of improvement in signal-to-noise ratio is achieved at 5 kHz falling to 6 dB at 1200 Hz and 3 dB at 600 Hz. A comparison of the improvements given by the two systems is given in Fig.12.

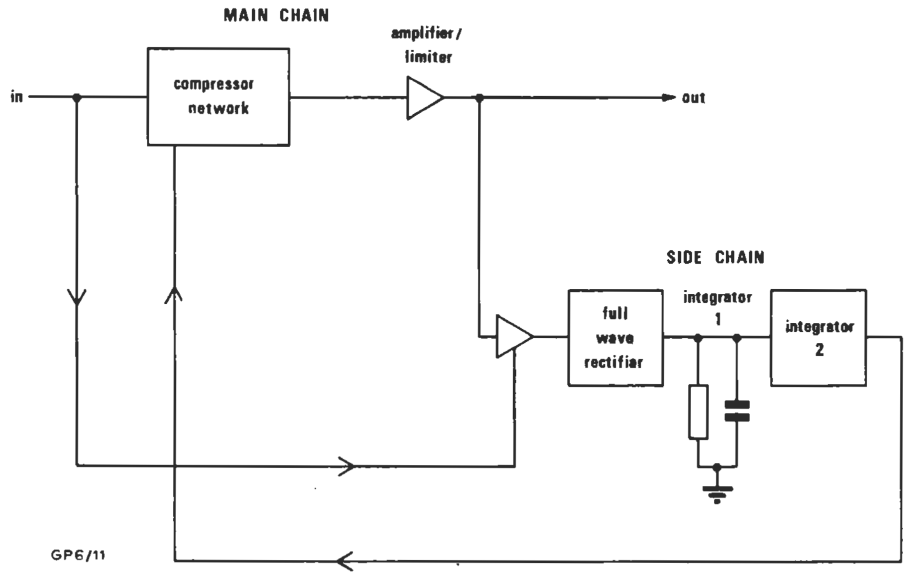

Fig.11. Dolby A compressor for differential signal (one of four)

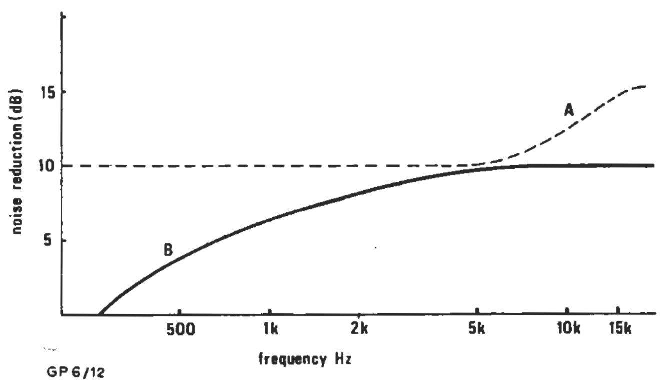

Fig.12. Comparison of improvement by Dolby A and B systems.

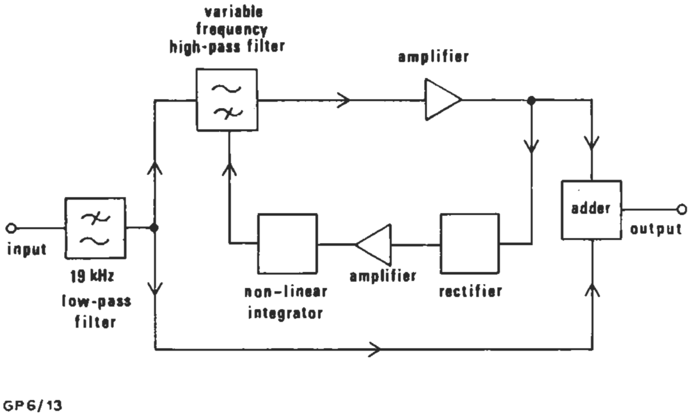

Fig.13. Block diagram of Dolby B noise-reduction system.

The Dolby B System works in the same way as Dolby A in that low-level signals are increased in level during the record process and are reduced in level during the playback process. The important difference between the A and B systems is that Dolby B operates in one frequency band only instead of the four of the A system and provides reduced benefit below about 5 kHz.

Detailed Operation

Fig.5 in the explanation of Dolby A also applies to Dolby B. Fig.13 shows the B version of the differential network in greater detail.

The signal passes through a 19-kHz low-pass filter, then divides. The direct path goes straight to the adder. The path of the differential signal is via a variable-frequency high-pass filter and amplifier to the adder. The side chain (rectifier, amplifier, and integrater) provides a d.c. signal to the gate of an FET to alter the cut-off frequency of the variable filter.

If the input to the Dolby B equipment is at a low level, the cut-off frequency of the high-pass filter is reduced and a large part of the input signal (from about 2 kHz up) is processed.

If the input to the Dolby B equipment is at high level, the filter passes only the extremely high frequencies and the Dolby effect is small.

Thus, Dolby B uses a variable bandwidth system which has the advantages of a multiple-band system without the complexities of filters and multiple circuit paths.

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