110 dB Dynamic Range For Tape

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IT IS NOW widely recognized that the signal-to-noise ratio of even the best studio tape recorders is insufficient for much of the recording performed today. If a piano played fortissimo is recorded on four-track ½" tape with peaks reaching the 2% distortion level and then played back at the original acoustic level, the hiss is not only audible but objectionable. With other types of program material noise becomes objectionable after the several rerecordings common to the preparation of a prerecorded tape.

For this reason studios are turning to electronic methods for further processing the signal to reduce the noise. One system available is the Dynamic Noise Filter [1] manufactured by Burwen Laboratories. This system reduces noise by attenuating the high and low frequencies in a band-pass filter whose bandwidth is extended with each musical note and contracted between the notes. Due to the characteristics of the ear the noise that is present during each note is masked by the music.

Another signal processor available is the Dolby Laboratories Noise Reduction System [2] which is used in making new tape recordings but is not designed to improve existing noisy program material. The Dolby System compresses the signal in four separate frequency bands before recording in order to maintain a higher signal level on the tape in each band and thereby overcome the noise. A complementary four band expander used for playback restores the signal to its original level and flat response and reduces the noise between notes because lower level signals are played at reduced gain. A simplified high band version of the Dolby System is now coming into use in consumer equipment and prerecorded cassettes.

A new system to be described, the Burwen Laboratories Noise Eliminator, Fig. 1, is also based on the principle of signal compression before recording and expansion after recording. Whereas the Dolby Type "A" System reduces noise from 10 to 15 dB, the Burwen Laboratories Noise Eliminator reduces noise as much as 50 to 60 dB.

Fig. 1—Two-channel Noise Eliminator.

Effect of 50-60 dB Noise Reduction

With such a tremendous increase in the dynamic range the recording engineer gains a new freedom. No longer does the signal level have to be set so the VU meter reaches precisely into the red region and not beyond. An A-B comparison of the source and playback signals in headphones when recording a piano shows no audible difference. In fact the input level can be reduced 30 dB while the output is magnified 30 dB and the audible noise is less than that in a normal recording. When dubbing from a conventional tape a reduction in input level as much as 40 dB still produces a good dub. The greatest benefit, of course, is in making recordings at proper input levels in which case tape noise is audibly eliminated. Swishing noises are not apparent in spite of using a single wideband compressor because the instantaneous signal-to-noise ratio is very high for a wide range of input levels.

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All of this is predicated upon an input signal coming from noiseless studio equipment. In practice, of course, the extremely wide dynamic range of the tape recording system will simply uncover the noise in the studio console that was previously negligible. One possible solution when making multi-track recordings is to record directly from a high quality capacitor microphone preamplifier which can have a dynamic range in excess of 110 dB.

Compatibility

One facet of the Noise Eliminator system being investigated at the present time is the possibility of compressing the signal prior to broadcasting FM or AM or making reel to reel tapes, cassettes, and phonograph records. For highest quality reproduction of a compressed signal the audio hobbyist would have to own at least a simplified version of the playback expander. For those who do not own an expander listening to the compressed signal can still be quite pleasant.

Unlike the Dolby System which changes the frequency response of the compressed signal in accordance with its level, the frequency response of the Burwen Laboratories system is constant. Although the signal is greatly compressed and the VU meter hovers around zero, the psychological dynamic effect of the music is to a considerable extent restored by a moderate amount of low frequency and high frequency pre-emphasis included in the record signal processing. As background music the compressed signal sounds quite pleasant because even very low level passages can be heard.

The principal disadvantage in listening to the compressed signal is the substantial increase in the studio console amplifier noise that can be heard, particularly if the music stops altogether. This problem can be alleviated by occasionally turning down the gain on the compressed signal. Alternatively the maximum gain of the compressor can be limited so that the background noise in the absence of music will not be so high.

Provided the compressors in a stereo system are ganged to avoid changing the directional effect, compressed music, starting with a moderate dynamic range, can be described as fairly compatible. Further development work is under way with the aim of making wide dynamic range compressed music more compatible using automatic signal processing.

Basic System

As mentioned earlier the Burwen Laboratories system is based on a combination of pre-emphasis and compression in the record electronics and expansion and de-emphasis in the playback electronics. It takes advantage of advances in record-

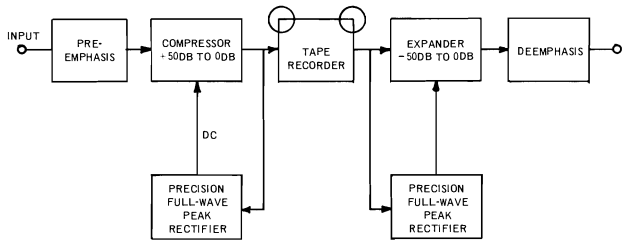

Fig. 2—Simplified system diagram.

ing tape technology made in recent years which result in increased flux density on the tape at high frequencies for a given record head current. Present day recorders having NAB playback response cannot properly take advantage of modern low noise tapes because of the standardized playback response curve.

When a high resolution, low noise tape is used the high frequency pre-emphasis in the record amplifier is reduced so that the flux recorded on the tape relative to middle frequencies is no greater than with ordinary tape. The net result is a very slight improvement due to the lower particle noise of the tape and possibly a 1 or 2 dB increase in overall output. At speeds of 7½ and 15 ips it is possible to improve the signal-to-noise ratio by from 6 to 12 dB simply by pre-emphasizing and de-emphasizing the high frequencies more than in a standard tape recorder.

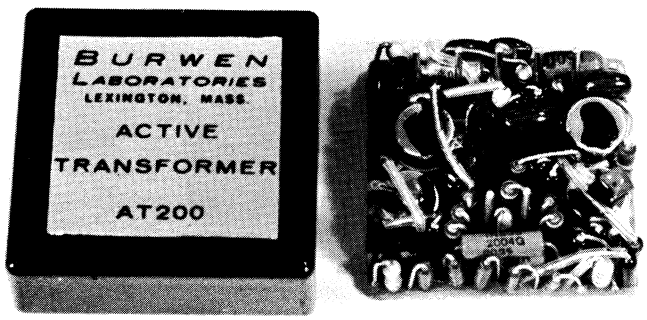

Fig. 3—The active transformer module.

In the basic system diagram, Fig. 2, the record compression system is shown on the left of the tape recorder and the playback expansion system on the right. The record signal first passes through a pre-emphasis network which increases the high and low frequency gain and then into a variable gain amplifier used to compress the signal by as much as 50 dB. The gain of the compressor is determined by its output signal which is fed to the record input of the tape recorder and simultaneously to a precision full wave peak rectifier.

The peak rectifier converts this signal to a d.c. gain control voltage which is smoothed by a multistage nonlinear filter. This circuit is designed for rapid compression when the input signal suddenly increases in amplitude but has a slow enough decay to prevent modulation of the signal at audio frequencies.

After the signal is recorded on the tape and played back at unity gain it is expanded in a complementary manner using a variable gain amplifier having a gain from -50 to 0 dB. The control voltage for this expander is derived from a precision full wave peak rectifier exactly the same as on the record side and which receives an input signal, the tape playback, similar to the record signal. Following the expander the high frequencies and low frequencies are de-emphasized to produce flat response for the entire system.

The combination of pre-emphasis and compressor gain of 50 dB or more increases the high frequency signal content on the tape by over 60 dB for low level signals. On the playback side the gain is reduced by the same amount and accordingly the unweighted noise level is reduced between 50 and 60 dB.

Because the compressor follows the pre-emphasis network its own noise is less significant and the tendency of the pre-emphasis network to overload the tape on high frequency input signals is greatly reduced because the compressor tends to hold the signal more nearly constant. Unlike the signal emerging from a conventional volume limiter the signal on the tape must have variations in peak amplitude. Otherwise the playback expansion side of the system could not determine how much to expand the signal. The action of the compressor and expander is smooth and precise and the dynamic error at any frequency and level is typically under 1 dB.

Of particular importance in this system is the fact that there is no alteration of the frequency response even if the gain of the tape recorder is not exactly 0 dB. The only effect is a change in output level and there is not even any appreciable expansion or compression of the signal. While it is necessary to maintain a reasonable signal level at the input of the expander if the system were used for FM reception for example, the signal level could easily be set by ear with sufficient accuracy without transmitting a calibration tone.

In the Noise Eliminator system, Fig. 1, two channels are contained on a single 19" x 1¾" rack panel. The system is built using encapsulated epoxy modules such as that in Fig. 3 which are also available for building into studio tape recorders. This is an automatically switched system in which the same components used for compression in the record electronics are used for expansion in the playback electronics. When the equipment is used for two-channel recording the compressed playback signal passes directly through the instrument so it can be used for monitoring from tape. Monitoring the compressed signal is quite useful in that it readily shows up defects in the program material. Switching from record to playback can be either via front panel switches or remotely from the tape recorder.

The input and output levels are +4 dBm at 0 VU but can be adjusted internally for other levels. A d.c. coupled differential input amplifier called the "Active Transformer" is used in place of the usual input transformer and the d.c. coupled system output will feed any load from 150 ohms to an open circuit with negligible change in frequency response.

Future Uses

The general usefulness of the Burwen Laboratories Noise Eliminator system has only begun to be explored. Besides reducing noise in studio masters and consumer recordings, processing the compressed signal through the studio console can produce some interesting effects. For example, boosting the bass and treble a few dB will result in expansion upon playback during orchestral crescendos which increase the dynamic effect of the music without causing the usual boominess due to excessive bass. Mixing compressed signals together can produce an effect whereby a predominant instrument can cause an increase in the level of all the others after playback expansion. Reverberation in a compressed signal sounds as though it has been increased because the number of dB the music level can decay in a given time has been reduced.

It is anticipated the availability of wide dynamic range recording will have a substantial impact upon the recording industry and it may even spark a new generation of low noise equipment. AE

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