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ENGINEERING DESIGNER'S KIT

NR-2™

Adaptive Noise Processor for Mid-Fi Audio Systems

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LINEAR APPLICATION UPDATE

This paper describes a noise processing system designed for non-complementary (non-encoded source) noise reduction of tape or AM/FM sources. The circuit uses low-cost building-block ICs, the LM13600N and the LM387N. No adjustments are required for use except for an initial calibration to the noise level of the source.

Design 11/15/78 Applications

NR-2™ - THE ADAPTIVE NOISE PROCESSOR

- NON-ENCODED SOURCES
- CASSETTES AND EIGHT-TRACK
- MOVIE SOUND TRACK
- FM BROADCAST

BASIS OF OPERATION:

Since the sensitivity of the human ear to noise has a peak in the 5-6kHz region, a reduction of the noise BW (bandwidth) to substantially less than 5kHz will cause a dramatic reduction in the audible noise level. This is particularly true in the case of a tape source where most of the tape-generated noise lies within this spectrum. The human ear also will not perceive noise in the presence of higher level music information of about the same frequency content (masking).

This system, then, reduces the BW of the audio channel unless the incoming information contains sufficient signal amplitude in the 6kHz region to mask the noise.

CIRCUIT OPERATION:

Figure 1 shows a block diagram and Figure 2 the schematic of the Adaptive Noise Processor. The BW control circuitry adjusts the audio path BW dependent upon the amount of audio information present above 6.6kHz. Figure 3 presents a plot of this control path sensitivity vs signal frequency, while Figure 4 shows the effect of an 8kHz input signal on the audio BW. The control circuitry is designed to change the audio BW from its minimum of 800Hz to within 10% of maximum in 1mSec (attack time) and from maximum to within 10% of minimum in 50mSec (decay time).

The LM13600 is configured as a Voltage Controlled Low-Pass Filter as shown in the device data sheet.

SYSTEM OPERATION:

The ANP is connected between the tape player and the amplifier input (or in the tape monitor loop of a receiver). While playing an erased tape or during a signal-free portion of the program material, adjust the sensitivity control until there is a barely perceptible increase in noise level (or until the voltage at the BW Monitor point of Figure 2 just begins to move in a positive direction). Where the ANP is built into a tape deck or other piece of equipment such that the noise level of the source is known, the sensitivity control may be replaced by a resistive attenuator set to the noise level of the source.

Figure 5 shows the set up of an LM3915 Dot/Bar Display Driver used as a BW display to aid in the ANP sensitivity adjustment and as an active display of the filter action.

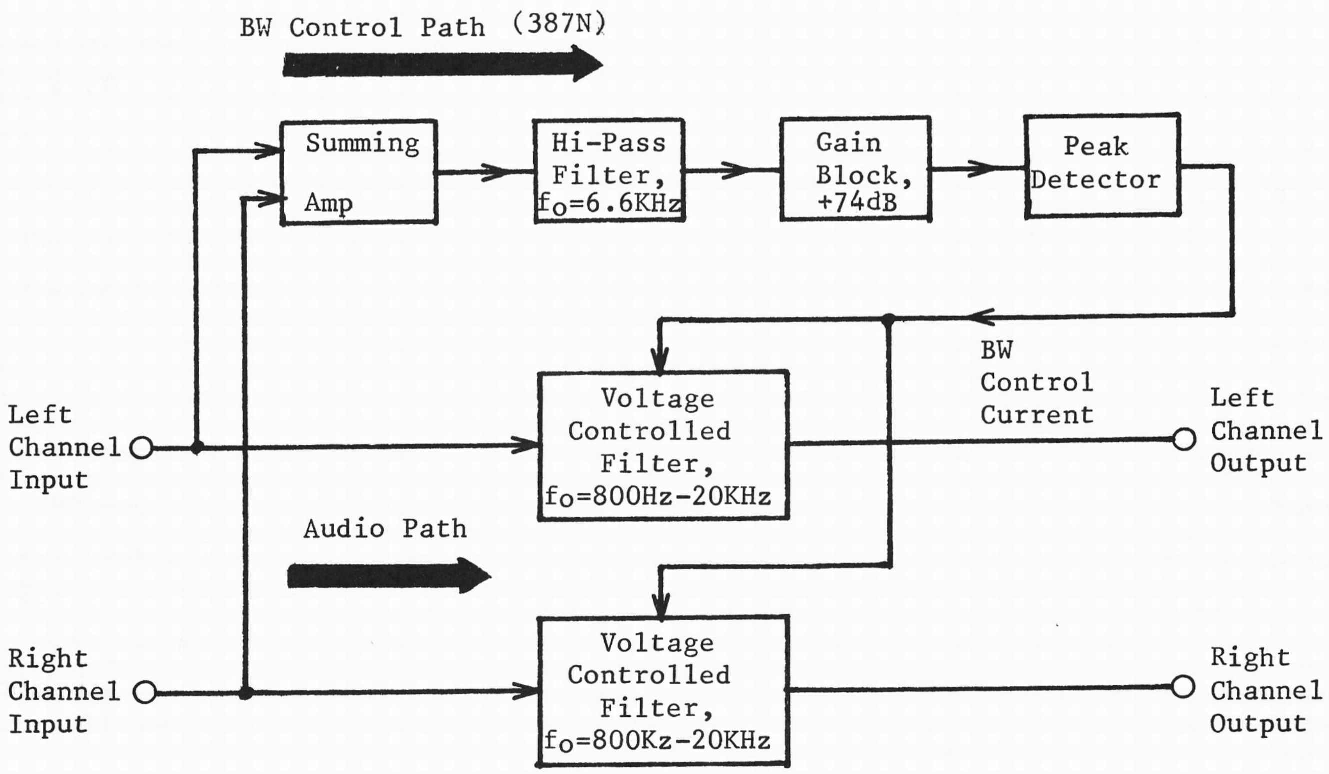

FIGURE 1 ANP Block Diagram.

PERFORMANCE DATA

PEAK DETECTOR: -3dB freq. = 6.6KHz, -12dB/octave (High Pass)

attack time = 1ms.

decay time = 50ms.

gain = 74dB.

VCF: minimum BW = 800HZ

maximum BW = 20KHZ

THD = 0.13% TYP @ 1KHz, 0dBv (.775V), maximum sensitivity setting

THD = 0.3% TYP @ 1KHz, 0dBv, sensitivity setting corresponding to -50dBv*

S/N at BW of 20KHz = -88dB re 0dBv (.775V), unweighted

EFFECTIVE NOISE REDUCTION (CCIR/ARM WEIGHTED CASSETTE TAPE NOISE): -14dB*

*COMMENTS ON PERFORMANCE DATA

The above THD specification measured with the "sensitivity setting corresponding to -50dBv" source noise is supplied as an indication of the circuit performance under typical usage conditions. The measurement is performed by applying a 10KHz sinusoid to the ANP input at a level of -50dBv and setting the sensitivity control such that this signal level is on the threshold of beginning to open the filter BW. The THD measurement is then made without altering the sensitivity setting.

The Effective Noise Reduction specification is measured by playing a biased (erased) cassette tape on a good quality playback deck and measuring the output noise through a CCIR/ARM weighting filter. The ANP (with the sensitivity control properly set for minimum audio BW) is then inserted between the tape deck and the weighting filter and the relative noise level is measured at the filter output.

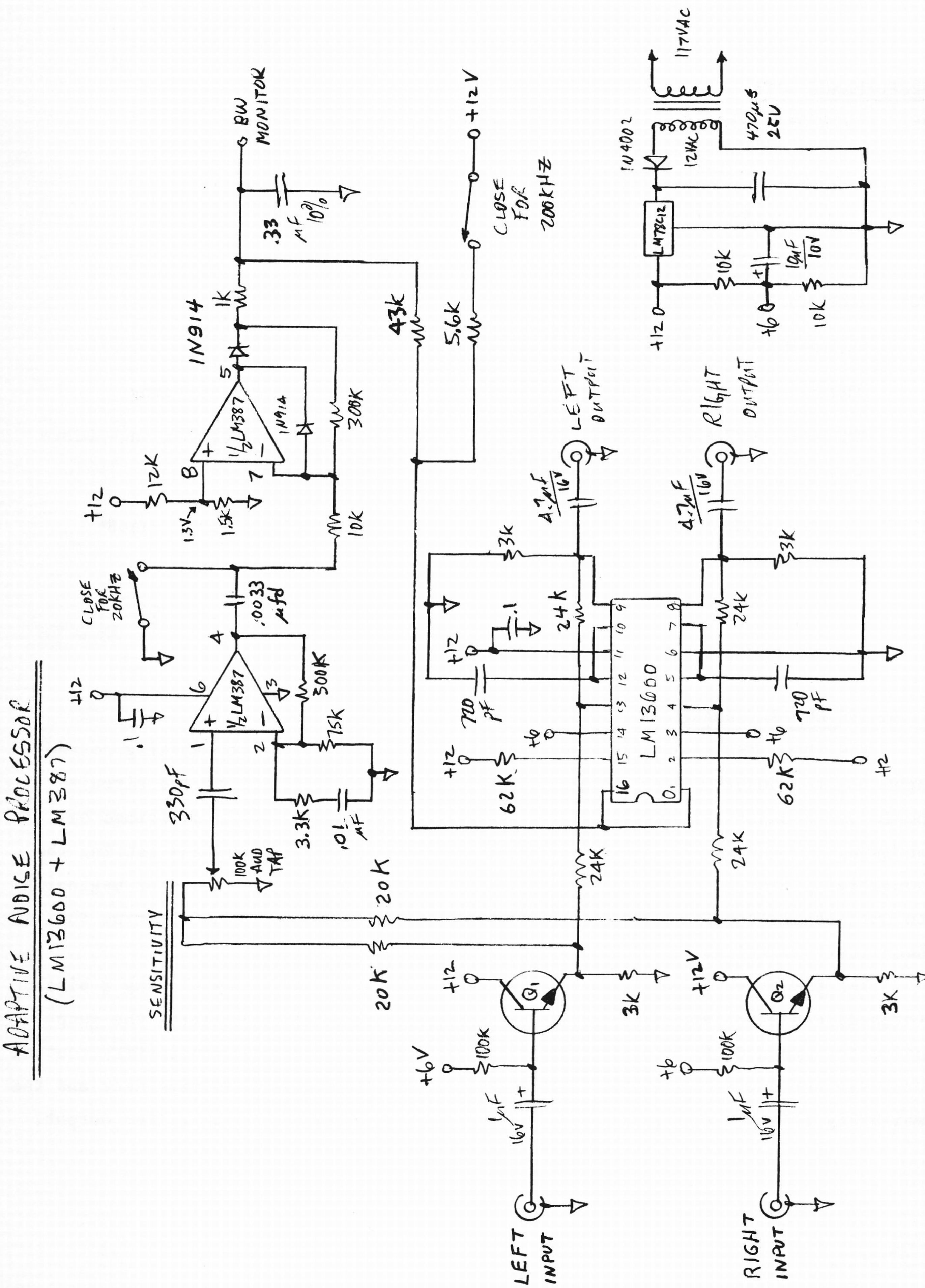

FIGURE 2 ANP Schematic Diagram.

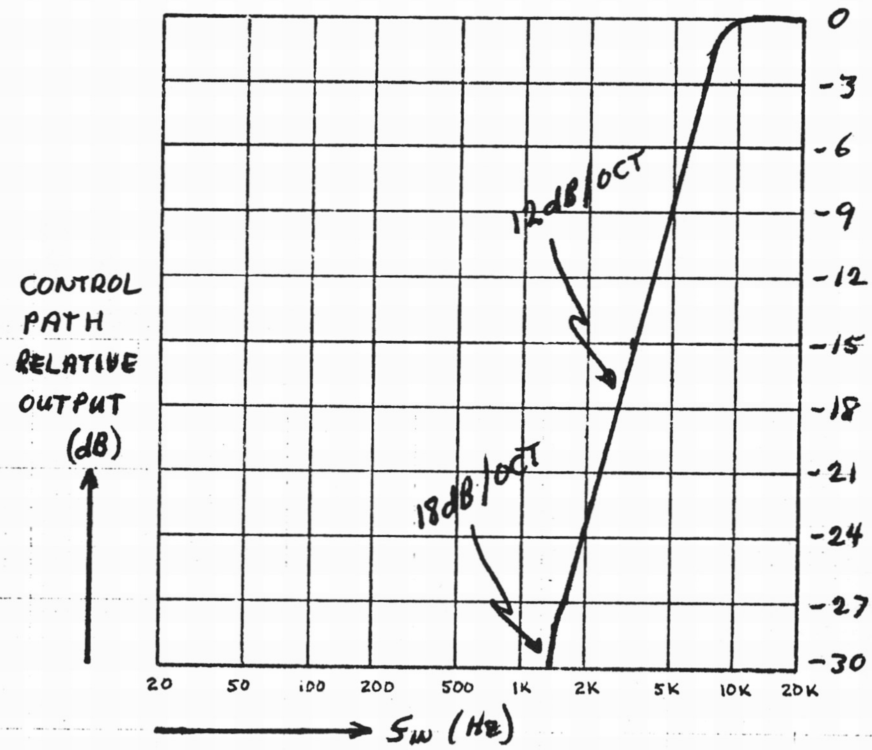

FIGURE 3 Control Path Sensitivity vs Signal Frequency.

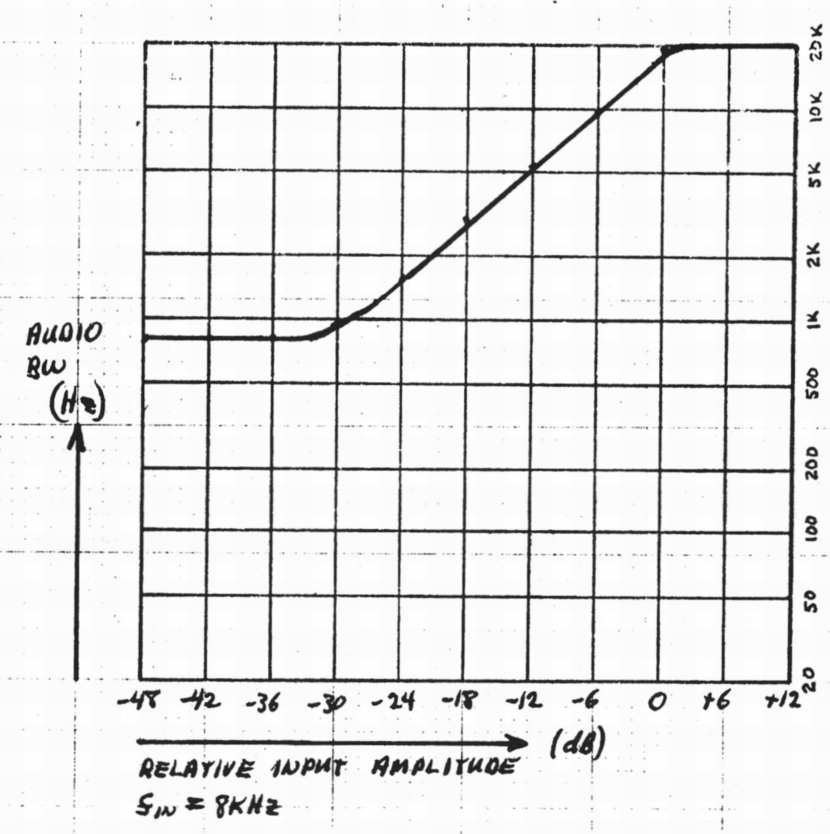

FIGURE 4 Audio BW vs 8KHz Input Signal Amplitude.

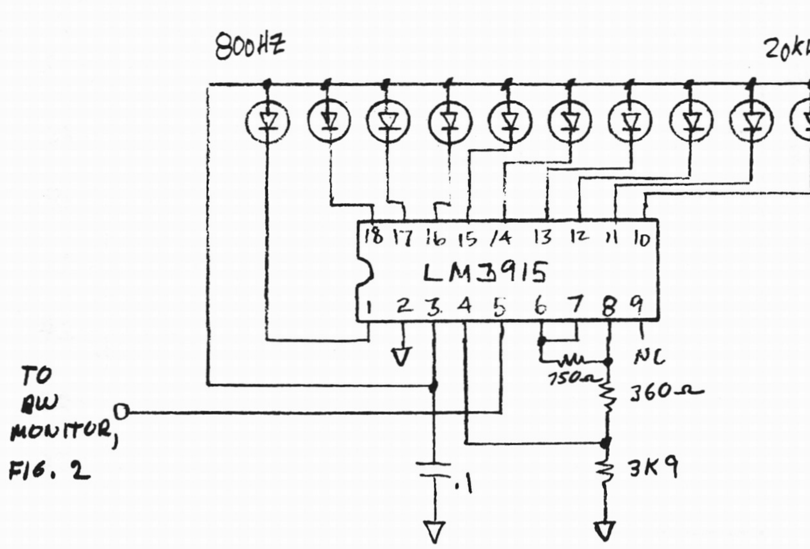

FIGURE 5 LM3915 Audio BW Display.

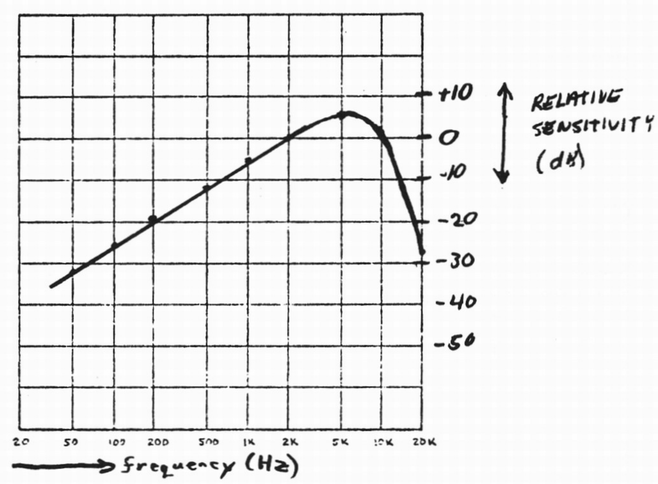

FIGURE 6 CCIR Noise Weighting.

APPENDIX - ABOUT NON-COMPLEMENTARY NOISE-REDUCTION SYSTEMS

Many people are understandably wary of non-complementary noise reduction systems since, by definition, such systems must have some effect on the music content of the processed signal. This is in contrast to a complementary system (such as the well-known Dolby® Noise Reduction System) where the encode-decode process will, ideally, yield an output which is a perfect replica of the original signal. Fortunately, much research has been done by organizations such as Burwen [1], Phillips [2], and Scott [3] to minimize the deleterious effects while maximizing the noise-reduction effectiveness of such a system. This work has resulted in establishing the following important parameters:

1. The BW of the audio path must be controlled such that the amount (loudness) of noise passed by the system is such that the music content of the signal is capable of masking it. Figure 6 shows the CCIR noise-weighting curve which may be interpreted as a plot of the human ear's sensitivity to noise vs frequency. Since noise in the 6kHz region is most objectionable and since this noise will be masked only by music information of the same frequency content, the audio BW must be adjusted dependent on only the information present in this frequency band. These considerations yield the control path response characteristics shown in Figures 3 and 4.
2. The attack time of the control path peak detector, that is, the time required to open the audio BW at the onset of a high level musical passage, must correspond to the ear's ability to respond to sudden increases in volume. Thus the 1mSec attack time.
3. The human ear also exhibits a recovery time phenomenon after the cessation of a high level musical passage, that is, the masking phenomenon will persist for some finite length of time after the musical signal has passed. The 50mSec decay time of the peak detector is based on this characteristic and prevents suppression of natural musical reverberations.

4. In any situation where dynamic frequency shaping or amplitude control is applied to a stereo signal, channel-to-channel matching of the parameter modification is necessary to prevent wandering of the stereo image. The ANP derives a single control signal from a summing of the two audio channels and guarantees excellent channel-to-channel matching due to the monolithic construction of the LM13600 as used for the two audio channel VCF's.

PITFALLS - or what to listen for in non-complementary noise reduction systems.

The result of the proper implementation of this data is a noise reduction system which is indeed practically inaudible in its effects on the musical content of the processed signal. Improper implementation or improper usage of such a system may result in one or more of the following audible effects:

1. Pumping. Incorrect selection of the control path bandwidth and attack/decay times may result in an audible "swishing" as the noise level is changed or in a "breathing" effect as the high-frequency content of the audio signal is altered.
2. Control Feedthrough. Since this type of ANP uses a voltage controlled filter to modify the audio BW, the system designer must take care to prevent the control signal from feeding through to the audio output. The LM13600 data sheet specifies a V_{OS} change of typically 0.1mV (3mV max for an LM13600A) as the control current is changed from 5μA to 500μA. For the circuit of Figure 2, this V_{OS} change will manifest itself as a 2.5mV shift in the audio output DC level.
3. Apparent h. f. Loss. On an initial evaluation of the ANP, using a source with poor S/N, most people will hear an apparent loss of high-frequency music information in an A/B comparison. This is a subjective effect in that the addition of high-frequency noise (hiss) to a music signal will seem (audibly) to add to the high-frequency content of the music. This effect can be demonstrated by playing a good quality (high S/N) source and listening for a dulling of the highs while switching the filter in and out.

4. Sensitivity Setting. An improper setting of the sensitivity control may cause or aggravate any of the above problems. For maximum noise reduction effectiveness, the control is set such that the noise of the source is on the threshold of beginning to open the audio BW. For a cassette tape this will be a biassed but signal free portion of the tape. For sources with an initially high S/N, the user may wish to sacrifice some noise reduction capability and ensure no music degradation by setting the control such that the audio BW is held more open. In no case should the sensitivity control be set such that the noise floor of the source is below the point of beginning to open the filter, for this will cause the system to have an audible effect on the music BW.

ADVANTAGES

Accepting that a non-complementary noise reduction system is a feasible solution to the ever present noise problem, one must justify its use in an audio field which is currently dominated by readily available complementary systems such as the Dolby® System. Of course, a non-complementary system is the only solution possible in the case of non-encoded source material. Secondly, the ANP does not require any trims or precision components to match a decode reference level to an encode reference level. This leads to the third consideration, that of cost. As shown, the ANP costs 1/4 to 1/3 as much to produce as does the Dolby® System in IC form. So, while the ANP will never replace the Dolby® and similar systems, it is certainly a viable and sometimes necessary alternative in many situations. Incidentially, the ANP should be particularly attractive to those consumers who prefer the more brilliant sound obtained by playing Dolby® encoded tapes without decoding. ANP processing of a Dolbyized tape will leave unaltered the boosted high frequencies yet still provide 14dB of noise reduction.

REFERENCES:

1. Burwen, Richard S., "A Dynamic Noise Filter For Mastering", Audio, page 29, June, 1972.

2. Hellyer, H.W., "Noise Reduction Techniques", Audio, page 18, October, 1972.

3. Scott, H.H., "Dynamic Noise Processor", Electronics, page 96, December, 1947.