DESIGNING STEREO TAPE RECORDERS —SOME POINTS

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Since a stereo deck is supposed to form a part of the high-fidelity paraphernalia of a musical cognoscente, its technical specifications have to be more rigid compared to that of a mono cassette tape recorder meant for the entertainment market. Mono cassette tape recorders use small speakers, around 90mm in dia, in which low frequency response is very poor and one need not worry about hum problem. In the case of a stereo recorder using external high fidelity speakers for playback, the low frequency response has to be very good and hum level must be extremely low. Output of a stereo magnetic head is 6 to 10 dB lower than that of a mono head. To achieve a comparable signal-to-noise ratio it is essential therefore that the equivalent input hum and noise should be lower in the same proportion.

In stereo operation the defects of reproduction become more obvious, the basic operation of the deck therefore becomes more critical. Frequency response of the reproduction system has to be wider, and harmonic as well as inter-modulation distortions should be low. In the case of a tape recorder, circuitry is definitely not the limitation. The frequency response limitations arise because of the limitations of the head characteristics and the tape. The circuit response can fortunately be manipulated to make up for the head and tape deficiency. Care must, however, be taken that noise and distortion do not go up beyond tolerable limits. Even if it does not look impressive on paper, a limited frequency response is preferable to a wide but noisy response.

It used to be quite a feat to design a valve amplifier using transformers all-over and achieve a good frequency response versus gain. With transistor amplifiers, and no transformers, deviations in the characteristics desired become more important.

Fig. 1 shows the characteristics of a stereo head. It may be noted that response drops sharply at the lower frequency end, limited by the self-inductance of the head, and also at the higher frequency end, limited by the head gap width. To get a reasonably good reproduction from the equipment it is essential to see that frequency response is improved without increase in noise level from the circuitry. Of course, the noise level in the system at the higher end is affected by the tape hiss. Well, with the best of the heads available today, and the low-noise tapes used with the noise reduction circuits, it is quite possible to get a system response flat to 20,000 Hz with a cassette deck.

Normally, the low-frequency compensation is provided

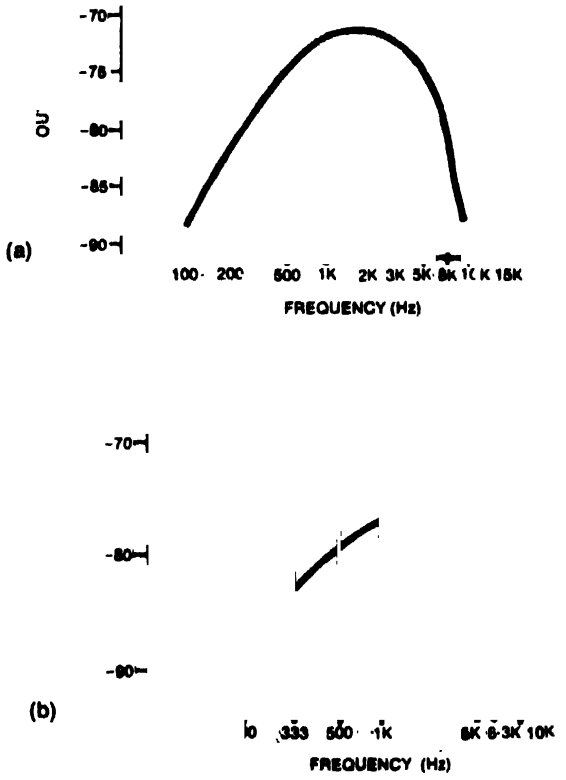

Fig. 1 (a): Record playback frequency response
(b): Playback frequency response

during playback to avoid saturation of the magnetic head by high level of the low-frequency signal due to limited self-inductance of the head during recording. For the highs, pre-emphasis is provided during recording, partly after the amplifier chain; part of the feed resistor to the head is shunted by a capacitor to increase the level of the highs at the head. During playback, the de-emphasis of the highs in the preamplifier brings down the highs to the desired level. The high frequency response also depends on the bias frequency and the bias level during recording.

Tape hiss is the limiting factor for an expanded high frequency response. Recently a number of noise eliminating circuits have been developed. The best circuit for the purpose is Dolby B system, which is now being incorporated in most of the stereo decks produced around the world. JVC Nivico's ANRS, basically developed for their

CD-4 quadraphony system, works on similar principles, and it is totally compatible with the Dolby B system. Philips did bring out Dynamic Noise Limiter (DNL), which being open ended had its limitations, but now as a licencee of Dolby, Philips also uses the Dolby B noise eliminating system.

The electronic circuitry of a stereo cassette tape recorder's deck consists of:

(a) Preamplifier, which also includes frequency response corrective networks.

(b) Amplifier to provide required signal for the output section, but may not be always there.

(c) Output amplifier to provide the signal to recording head during recording to headphones/output terminals for external amplifier, and to the metering circuit which is of particular importance during recording to keep the signal within desirable limits to avoid everloading of the amplifier circuitry or saturating the magnetic head.

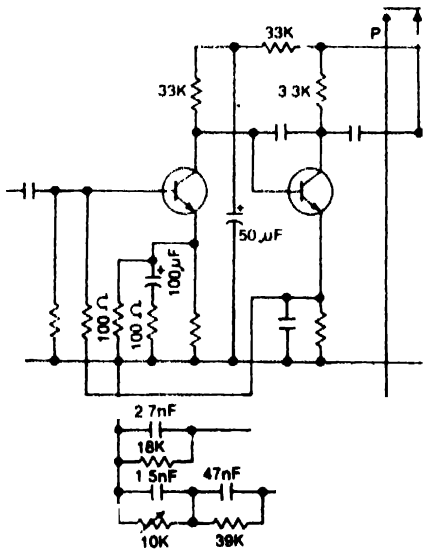

Fig. 2 (a): Preamplifier with feedback networks. National.

(d) Bias oscillator—stereo decks are invariably operated on AC bias for recording as well as erasing operations.

(e) Power supply in which an electronic filter is sometimes used to keep the hum level low; the motor may as well be electronically governed to obtain stable speed over a wide range of supply voltage.

Preamplifier

Use of a direct-coupled transistor pair is common for the preamplifier stage. Because of the heavy DC feedback from the emitter of the second transistor to the base of the first to provide biasing current, DC operating points of the two transistors are very stable. This is particularly essential as the input transistor must operate at a very low current to achieve low-noise operation essential for amplifying signal as low as 80 microvolts for each channel from the head during play. Normally, transistor noise is not the limiting factor in these circuits.

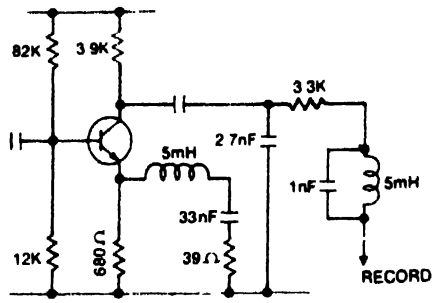

Fig. 2 (b): Output signal for recording head. Series tuned peaking LC network in emitter circuit. Parallel tuned circuit for suppression of bias signal. National.

Feedback networks have basically two functions: stabilisation of the gain at the desired level and shaping of the gain frequency curve to the required shape. Frequency corrective networks have two functions: to provide the pre-emphasis on high frequency during record and de-emphasis on highs during playback. This improves the signal-to-noise ratio, noise being mainly tape hiss. Secondly, the head characteristics must be compensated for (see Fig. 1) record/playback characteristics of the head. Networks coming into play during playback also compensate for the low frequency characteristics of the head, and final reproduction can have wider frequency range.

During recording, boosting of low frequencies in the preamplifier or, for that matter, in active stages is avoided to prevent the later stages of amplifications being pushed into saturation by the boosted signal. High-frequency pre-emphasis is provided in the path from the output to the head by an RC combination which provides the current for the record head. There is no boost of the lows during recording as low-frequency signal could easily drive the head into saturation because of the limited inductance of

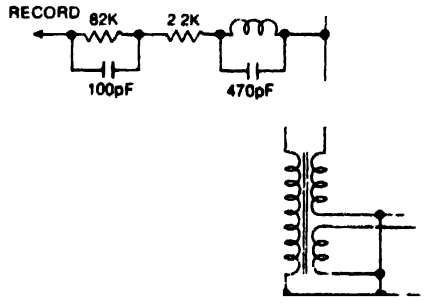

Fig. 2 (c): Output signal for recording head; note the pre-emphasis network and parallel tuned circuit for suppression of bias signal

the head. As it is, the signal normally has a higher proportion of lows compared to highs. In certain circuits high-frequency boost has been provided in the later stages by a

series peaking network used as bypass for the emitter resistance.

Normally, AC bias is applied directly at the recording head and a parallel LC tuned circuit is used in series with the pre-emphasis network to prevent breakthrough of the bias signal into the audio, section. This can be a major problem in high fidelity equipment with extended frequency response. Today, power amplifiers with frequency response much beyond the bias oscillator frequency of 40k Hz or 60 kHz are fairly common. Sony, for instance, has been using a frequency of 100 kHz to overcome this problem and to extend the frequency response of the tape unit itself. Heads are designed to operate with a specific bias oscillator frequency, and hence this frequency cannot be chosen arbitrarily by the circuit designer. Well, it is natural that the manufacturers who make their own components can use the custom-made components for obtaining the best performance from the circuit. In fact, the equipment design starts with the components design.

Low frequency is compensated for during playback only by feedback network in the preamplifier. 3dB points of overall amplitude response of a home cassette tape recorder should be at 80 Hz and 6300 Hz. To achieve this, 13 dB increase in treble is provided during record and 17 dB boost in bass during play. Considering the large amount of boost at low frequency, it is essential that hum level at the input is controlled to minimise hum at the output.

With wide availability of pre-recorded cassettes, it becomes essential that replay characteristics follow standard practice so that the pre-recorded cassettes sound the

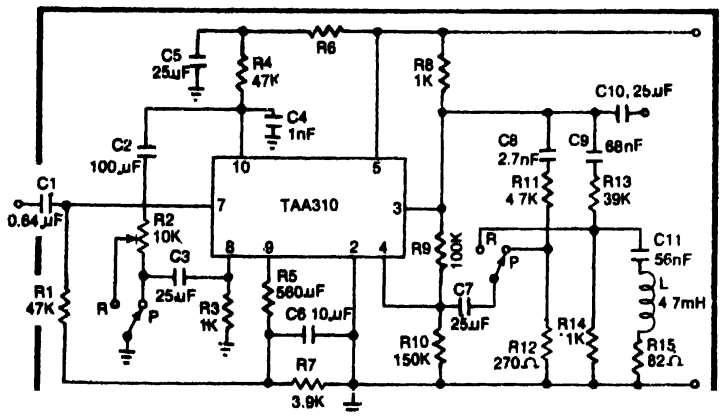

Fig. 3 (a): Circuit diagram of recording and playback amplifier using TAA310 IC, switch in play position

same on all equipment. With availability of chromium oxide and other better quality tapes, with improved high frequency response and low noise, de-emphasis networks are provided with 70μS for the normal tapes and 120μS for special tapes. Extended frequency response up to 20 kHz can now be achieved on better quality decks.

Fig. 2(a) shows a typical circuit (National) using direct coupled transistor doublet. Fig. 3(a) shows a preamplifier circuit using TAA 310 Philips IC. Fig. 3(b) shows the no-load voltage of playback head as a function of frequency and Fig.3(c) shows the frequency response characteristics of record and playback amplifiers. 10kHz peak for record-

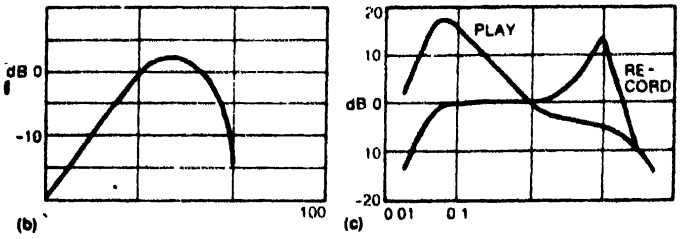

Fig. 3 (b): No-load voltage of playback head as a function of frequency

Fig. 3 (c): Frequency response characteristics of record and playback amplifiers

ing is obtained by LC circuit. Fig. 2(b) shows an output stage with series tuned peaking LC circuit as emitter resistor bypass, 3.3k resistor in series with output decides recording current level. Parallel tuned circuit, LC—5mH and 1 nF, reflects the bias signal.

Amplifier

With the output signal from head about −82 dB and the dynamic microphone signal output about the same, overall gain required of the equipment is about 90 dB. Part of this gain is provided by the preamplifier and part by the amplifier—gain contribution of the final stage may often be nominal. If the output is emitter follower, the gain is unity. Even otherwise, the gain is low with low collector impedance.

Amplifier stage may consist of single or two transistors. Quite often the output section may provide the additional gain and the frequency compensation, if necessary.

Output stage

Emitter follower configuration is common at the output in stereo decks; this provides the signal for recording. High impedance headphones may load the emitter follower directly; provision for low impedance headphones is through a matching transformer. Fig 2(b) shows the output stage for recording signal. The peaking coil bypasses the emitter resistance. Parallel tuned filter to block the bias signal is in series with the output. Fig. 2(c) shows the section of the output for recording signal; it also shows the pre-emphasis network and blocking filter for the bias signal. Circuit shown in Fig. 2(b) is that of National deck and that shown in Fig. 2(c) is of Nivico stereo tape recorder. Nivico's circuit is complete with audio output stage. It is probably an earlier model. The output stage is transformerless and uses a complementary transistor pair, yet transformer has been used at the output to match the loads. The use of transformer could have been avoided. Use of matching transformers for headphones is quite common. Metering circuit

would also normally come across the output.

Bias oscillators

Because of the higher frequency band and critical requirements of tape-deck, the bias oscillator requirements become critical. It is more common therefore to use a pushpull oscillator as the waveform from it would be less distorted compared to that from a single transistor circuit. Lower distortion means lower harmonic content, which is an advantage when the deck has to be used with a tuner or a radio receiver. The harmonics can interfere with reception and create disturbance. Besides, preset pots are invariably used in case of tape-decks to set the recording bias, to achieve the best possible high frequency response.

It should be noted that in case of cassettes, the first and the second channel form the stereo pair and not the first and third as in case of reel-to-reel tape recorders. As such, the erase head for mono and stereo systems are the same.

Fig. 4(a) shows a single transistor oscillator circuit providing the erase voltage and the record bias for two channels. Figs. 4(b) and 4(c) show oscillator circuits using trans-

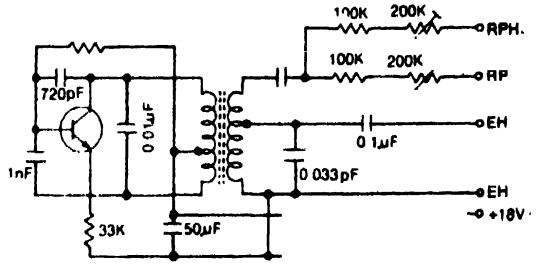

Fig. 4 (a): Single transistor bias oscillator

istors in pushpull operation. Fig. 4(c) shows a coilless circuit using a complementary pair of transistors. Effectively, it uses erase head itself as a part of the oscillator circuit, the frequency of oscillation of which is therefore decided by the inductance of the erase head. This would, of course, make the replacement of the erase head difficult, as a near equivalent could change the frequency of oscillation.

To get the best high frequency reproduction, record bias should be adjusted properly. The normal procedure followed is to insert a low value resistor in series with record head on the earth side and monitor the voltage drop across the resistor. The preset potentiometer is adjusted to get the rated bias current for the head, as indicated by the voltage drop across the calibrating resistor.

Power supply

Except for those meant for car operation, all stereo decks operate off AC mains. As indicated earlier, it is essential to control hum level in case of stereo cassette decks because of lower output from the magnetic head and smaller track width. Apart from the use of electronic stabilisation to reduce hum in the supply for low level signal stages, care in the design of the printed circuit board and component layout is essential. Undesirable earth loops can be more of a problem, introducing instability and hum into the circuit.

Automatic level control (ALC) is now more or less stan-

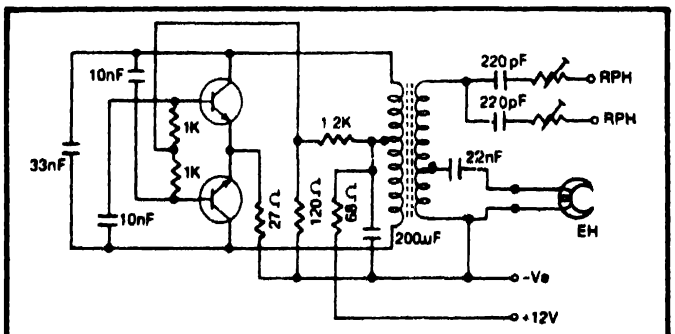

Fig. 4 (b): Push-pull bias oscillator

dard in case of mono tape recorders. In case of stereo decks, ALC is sometimes provided with the facility to switch over to manual control of the recording level. Use of independent ALC for the two channels would affect the stereo character of the recording. Hence the ALC voltage is combined and both channels are controlled by the predominating voltage so that the stereo character is maintained.

Tape hiss has been a major problem affecting the quality of the recording and its dynamic range. Most of the stereo decks now have Dolby facility for use, if desired. As the facility can be incorporated under licence from Dolby Laboratories Inc. only, the circuitary used by most of the manufacturers is nearly identical. ICs for Dolby B system have become available now.

Operation of JVC Nivico's ANRS is very similar to operation of Dolby system, and they are compatible. Both provide high frequency boost during recording and reduction on playback to obtain the original level of the highs in

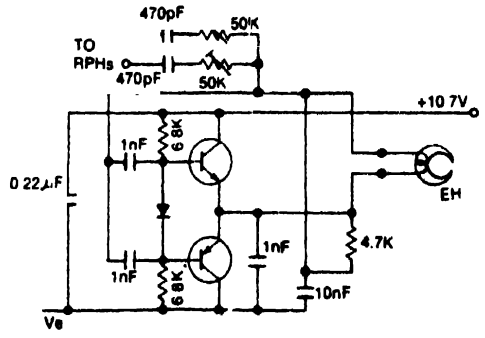

Fig. 4 (c): Bias oscillator using complementary pair of transistors. Erase head is part of the tuned load

relation to low frequency signal. In operation it appears to be very similar to the normal pre-emphasis and de-emphasis used in tape recorder circuitry. However, in case of Dolby B, the pre-emphasis during recording and the turnover points of the frequency curve of pre-emphasis are made dependent on the high frequency content of the input

signal. In case of adequate highs there may not be any processing of the signal. Weaker the signal, greater the enhancement during recording and over a larger band. When the highs content goes below 40 dB with respect to the reference, the pre-emphasis starts from 500 Hz and as much as 10 dB improvement in signal-to-noise ratio can be obtained (Fig 5).

Play-only unit

Play-only stereo units have become very popular, particularly for the car market. Most of these can be used indoors with external power supply. These operate normally on 12V supply. The power output is quite adequate for average urban rooms. With tape cassette decks available in the country, and production of pre-recorded cassette tapes picking up, it may be worthwhile for a hobbyist to assemble his own play-only unit. It would be easier to assemble as the electronic assembly can be kept away from the deck,apart from wiring to the head and of course the motor circuit.

We would need dual power supply—6 volt for the motor and around 12 volt for the circuit to obtain an adequate output. It would be preferable to operate the motor at around 7.5V to maintain good quality operation with wide variation of supply from mains. In India, the available mains voltage is normally substantially lower. If motor supply is taken as 6V nominal for 230 volt supply, a variation in speed would be experienced with the voltage going below 4.5V. Separate transformers may be used for motor supply and the circuit; easily available 6V transformers for main operation of cassette tape recorder can be used for both. These are normally available with a centre-tapped secondary. A full wave circuit can be used to get 6V supply for the motor and a bridge circuit to get 12V supply from a similar transformer.

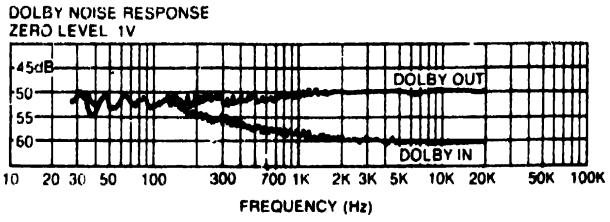

Fig. 5: Noise spectrum with and without the use of Dolby B system

The circuit may consist of a preamplifier with frequency corrective feedback network, followed by a volume control and power output circuit. A transformerless four-transistor output circuit using BC158, BC148 and AC187/AC188 matched pair would be adequate. If desired, a Baxandal type tone control can be inserted before the power amplifier. As the nominal gain at 1 kHz for the tone control is unity, its insertion in the circuit would not change operating conditions otherwise.

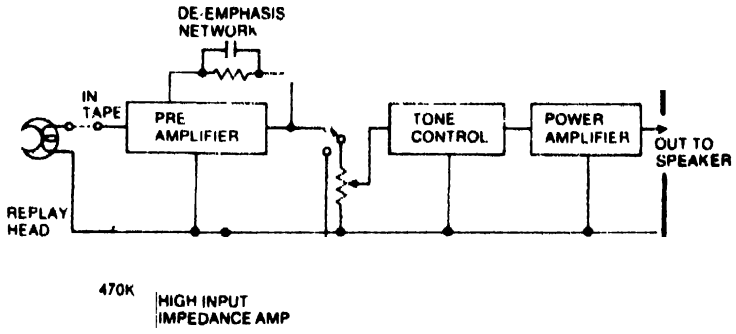

Fig. 6: Play-only stereo unit—only one channel shown

If desired, one can add a bootstrapped circuit through a switch before the volume control to use the equipment as a record player amplifier. The circuit can be used as a tape recorder amplifier with the signal from the head being fed to the preamplifier, volume control and power amplifier. As a player amplifier, output from the pick-up would be fed to the bootstrapped amplifier, output of which is fed to the top of the volume control—the preamplifier being switched out of the circuit. 12-volt operation for the power amplifier would provide an output of over 1 watt RMS each channel. Used with 15cm speakers or 15cm by 10cm speakers common in TV receivers, adequate output would be available. □