Recording Binaural Sound on Discs

Author viewing binaural cut in process on special recording lathe

Use of LP discs having two recorded bands offers a very compatible and practical binaural record system. Great new market potential indicated for record player manufacturers.

By EMORY COOK
Cook Laboratories
Stamford, Conn.

IF the advantages and potential wide sales appeal of binaural sound are to be exercised, the realm of disc-recording, where cost and compatibility factors with existing standards are favorable, offers great possibilities. Let us then review the several ways in which a synchronized double track in disc can be produced:

1. A binaural recording can be made on opposite sides of a disc, playing back both sides simultaneously. This method is not very practical however, because stampers cannot possibly be centered and aligned in the press in the necessary rotational accuracy, and a wholesale redesign of playback turntables would be necessary.

2. Interleaved grooves are another theoretically possible means of binaural disc recording. This method however is costly to record and to playback and further, a great deal of special equipment would be necessitated.

3. A single sideband carrier system has been proposed, but the limitations of this method are such that the frequency range of each "ear" is restricted to a low value that could not be considered acceptable from a fidelity standpoint.

4. To date then, it appears that by far the most compatible and practical system is that of placing two recorded bands on the same side of an LP disc as diagrammed in Fig. 5.

As with ordinary recording equipment, the cutting styli move on a radius,—from outside in. Therefore existing recording equipment is easily modified to perform the mastering function. The playback arms may be integrated into a single arm containing two cartridges side by side as shown in Fig. 1.

Compatibility

The confusion of multiple standards has already shaken up the record industry once or twice and another upheaval would probably be impossible. Therefore, both the binaural record and its playback means must be interchangeable with existing standards. Due to the halving of available elapsed time with two channels, the 12-in LP is a natural starting point. With a normal 12 minutes of binaural playing time and a possible maximum of 14-15 minutes, most musical requirements can be met. The method described here produces a record which can be played (one "ear" at a time) on existing equipment, and the binaural reproducing system will likewise play regular records by simply blocking one of the cartridges up off the record.

Accurate Radial Relation

In Fig. 5 is shown the schematic arrangement for playing back the record of Fig. 4. Within the limits of travel in arc of the arm across the narrow band of grooves a high degree of accuracy of radial relation of playback points is obtained. In the practical case the positive error is made to equal to the negative error in terms of wavelengths, —at 1000 cps for instance. The maximum error then measures to be of the order of magnitude of 0.01-in. along the groove longitudinally at the middle of the record corresponding to less than a wavelength at 1000 cps along the groove. The purist might say here that we cannot tolerate a phase error of 180° in the range of maximum directional sensitivity of the human ear, but this is not true, and it is not a matter of "toleration" anyway unless we confine our remarks to the use of earphones as a listening medium. As a matter of fact, earphones can be given no considera-

Reprinted from TELE-TECH • November 1952

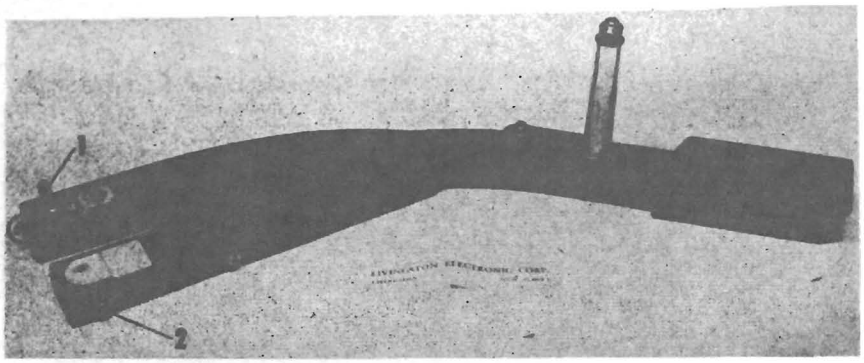


Fig. 1: Close-up of dual cartridge playback arm as manufactured by Livingston Electronic Corp., Livingston, N. J. (1) and (2) are adjustment screws

tion at all commercially. If we think in terms of spaced loudspeakers in a room then a full wavelength error at 1000 cycles can be thought of as corresponding to a motion forward or backward of one of the loudspeakers of about one foot, or a corresponding random motion of the listener in the room (such as turning the head) while the music is playing which is easily possible, in fact probable, without getting up from the chair.

A typical modified arm would display a dimension of 10½-in. from pivot to farthest stylus, an offset angle of 27.5° and the standard spacing of 1 11/16-in. The fractional spacing is chosen rather than decimals to facilitate the rough adjustment by using a standard inch rule, where the points will fall into the indentations at the specified dimension.

The radial error is not much affected by the length of the arm, and short 12 in. turntable arms are candidates for conversion.

In order to permit equal tracking pressure of each point of contact, at least one and preferably both of the cartridges must be individually pivoted for the vertical plane, although of course, if one is tempted to put up with the inconvenience, two separate arms may be operated.

Random Production Errors

No record is produced which is actually on center. The magnitude of the combined error in good commercial practice can hardly be reduced under .010-.015-in. The staggered method of interleaved grooves can not operate satisfactorily because of the centering problem alone, since there is a large angle subtended between the two points of pickup. However, the radial method is the least susceptible, in fact practically immune to centering errors such as normally encountered. But there is another and more insidious danger to watch against. In establishing a 1 11/16-in. dimension between points of pickup we must allow a tolerance.

Not only is it quite unthinkable to be able to align recording heads and styli on a lathe to .001-in. tolerance for each and every master, but the metal parts, especially stampers used to mold pressings are basically 0.032-in. copper as regards mechanical strength. In the modern fast cycle press and in handling they become stretched, so that 1 11/16-in. may become distorted around the circle. Furthermore, non-uniform cooling of pressings just removed will produce a small eccentric shrinkage on one side of the record and not the other. All these errors are of course capable of being cumulative to the effect of at least 0.015-in., and therefore we must have a mutual "lost motion" in the 1 11/16-in. spacing figure of ±.015-in. or thereabouts. However, since the record is started with pickups dropped in the spiralling lead-in groove, this does not mean that we shall have trouble getting into the correct grooves; it merely means instead that there is to be a "free" lateral motion of one cartridge with respect to the other. However, the business of "loose pivots," i.e., rattles, in vertically pivoted arms is well known to produce non-linear effects at some mid-frequency. The answer to the problem is the packing of the pivot points with viscous damping, so that the compliance of the cartridge needle is two or three times higher than the viscous compliance for frequencies at and below the undamped lateral resonance.

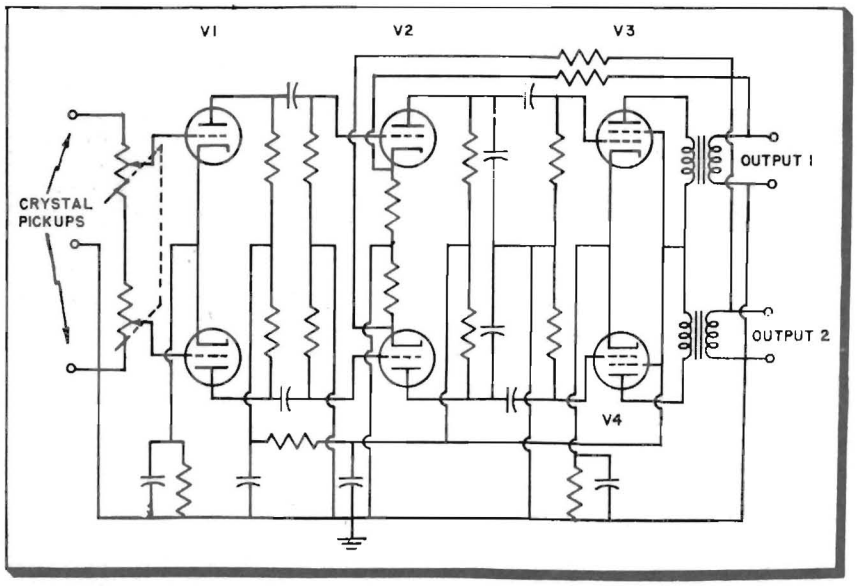
In bringing binaural into focus as a practical medium, the cost factor is particularly important. A first reaction might be that the cost would be almost doubled but this is not the case. Binaurally, power output per channel can be *less than half* that of an equivalent monaural channel for the same apparent loudness.

Using Twin Triodes

With the use of twin triodes the basic amplifier design may be doubled up (as in push-pull) without much additional cost. Since we certainly need no more than half the output power "per ear" the power supply is the same. The twin cathode, screens and plate supplies may be by-passed through common capacitors, since a moderate amount of crosstalk between channels is permissible. The only serious added cost will be that of the second output transformer, and means for reducing even that appear to be forthcoming.

In the "minimum" design of Fig. 2, there are only 16 one or half-watt resistors, 4 audio condensers and 4

Fig. 2: Minimum binaural amplifier design involves only 16 one- or half-watt resistors, 4 audio capacitors, and 4 tubes not including power supply



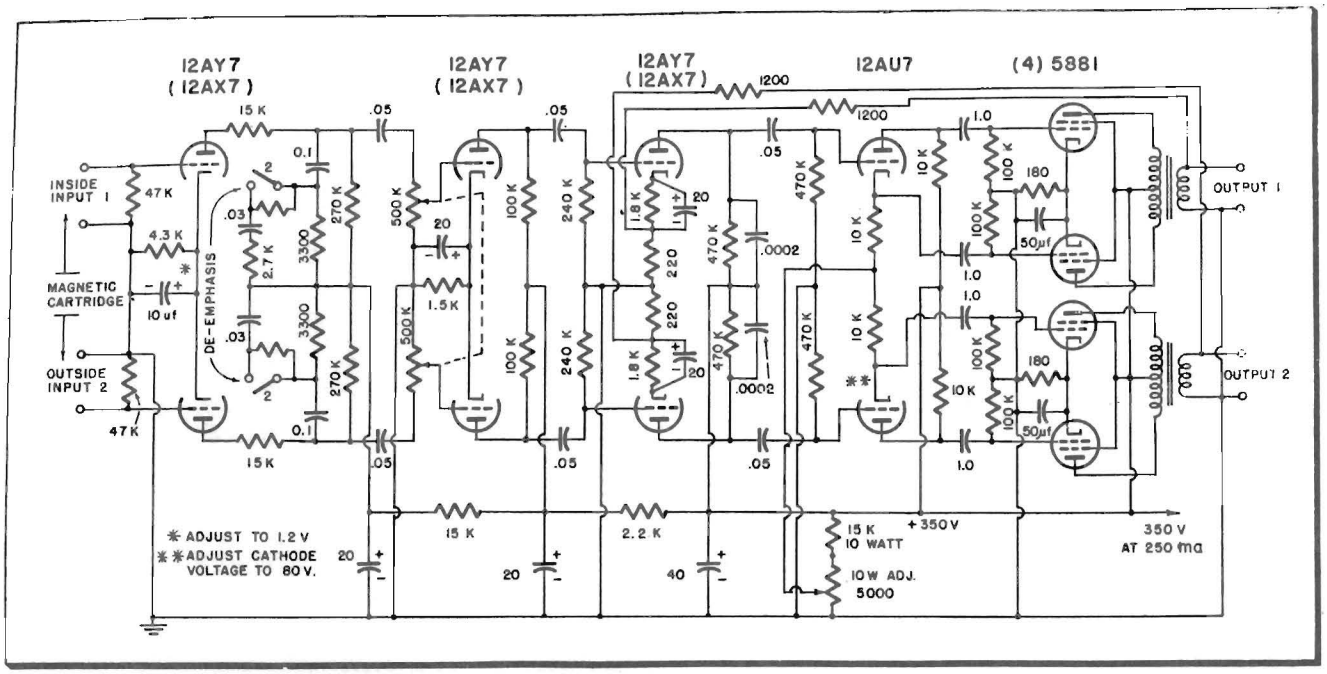


Fig. 3: Complete schematic of high quality binaural amplifying system. Power supply is separate unit

tubes, not including the power supply. No more decoupling or filtering is necessary than with a regular amplifier. The A-B comparison between binaural and monaural on such a minimum system with corresponding small speakers is perfectly astounding, probably because the cheaper monaural systems are so unsatisfactory in themselves. Yet it is hard to see where such an amplifier could cost more than a few dollars extra.

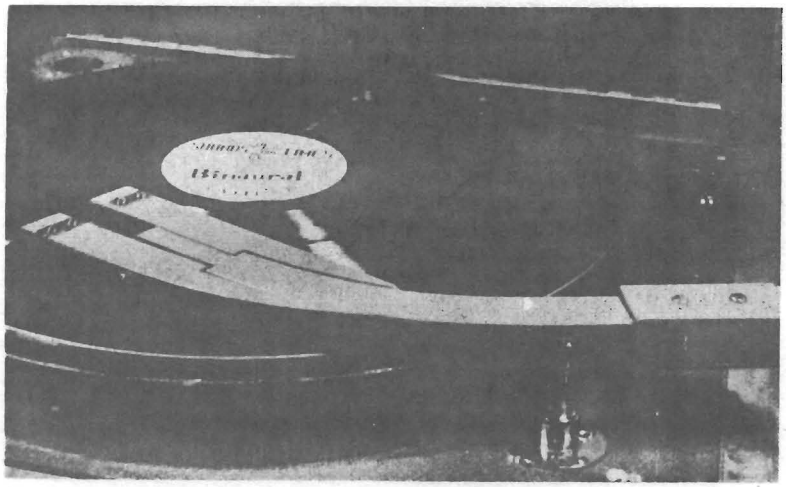
The opposite extreme would be something along the line of Fig. 3, where provision for magnetic cartridges is made, together with phase-splitting so that each output is balanced. Again the increased cost over that of a straight "push-pull" design is very nominal, if one is to compare it with a regular amplifier using four output tubes as a cost reference.

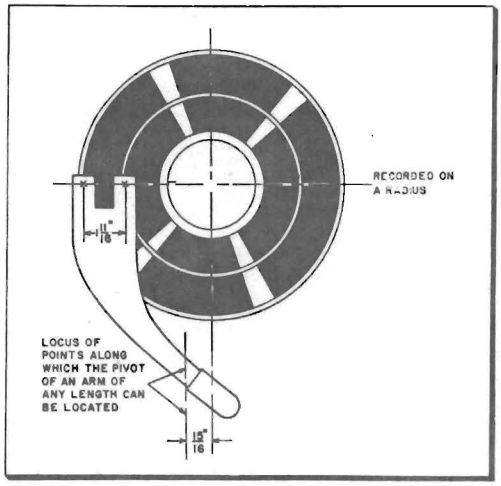
For equalizing the effective high frequency response of the channels in the room a condenser may be introduced across one or the other of the 220 ohm feedback re-introduction points in the 3rd stage of Fig. 3.

Test & Alignment

In addition to the necessity for an adjustment to permit re-setting the $1^{11}/_{16}$-in. dimension should cartridges be changed, there must also be a "fore and aft" adjustment provided so that there is no time delay error between channels,—so that they operate on the same radius. A means for locating to the required accuracy of 0.01-in. this longitudinal adjustment can be supplied through use of a test record signal. The Cook Series 30 test record is intended as a temporary standard, and in order to be palatable to non-technical users employs a slowly ticking clock as the source. The clock is fed into both channels in parallel simultaneously, in order to provide a synthetic binaural signal. When played on a binaural arm into a binaural reproducing system which has been adjusted for equal gain per "ear," the cartridges in the arm may be adjusted until the clock sound in the room appears to be neither to the right nor to the left, but dead-center. In order to prevent insofar as possible inadvertent errors, the record is made not in the 12-in. size, but

Fig. 4: (Left) Photo of binaural tone arm playing back binaural disc. Fig. 5: (Right) Diagram showing how binaural arm is pivoted





Binaural Sound

(*Continued from page 50*)

as a 10-in. disc, where the diameter of start of the test grooves corresponds closely to a zero point in the radial error cycle.

No better method than cut-and-try has been discovered yet for cutter alignment on the recording lathe, and such alignment then has to be done in conjunction with a playback turntable whose adjustment has been made on the basis of the Series 30 record as a standard.

The difference in frequency response between inner and outer diameters of pressings is a subject which is well explored and about which much has been written. Additional pre-emphasis is often and may here be applied at inner diameters to compensate somewhat in advance for translation loss. Unfortunately, there is an engineering proclivity toward making hard and fast rules for "shop practice," to cover all such points as diameter equalization and reference pre-emphasis. The trouble is that rules do not take into account the varying character of program material. The method which is satisfactory for a piano — velocity microphone pickup is not applicable to a bright orchestral picked up with a wide-range condenser. With material which is originally bright there is a severe limit on the amount of effective pre-equalization. Fortunately in a binaural system the two channels are not necessarily matched for frequency response, and in Fig. 3 it will be found that in the de-emphasis circuit (plate) of the first stage of the "inside" channel a 2.7K resistor is used to leave pre-emphasis in effect above about 3300 cps.

A general development probably not too far away is the "half-mil" point which can only be associated with cartridges having extremely low motional impedance. When such cartridges become available in manufacture, the inside-outside range and distortion of LP's in general will be vastly improved, and the binaural translation loss factor will be negligible. As for present practice, it has been found generally acceptable to maintain approximately a 50 μs (3300 cps turnover) differential between inner and outer binaural bands in the original recording. Depending upon the program material the outside band might be 50 or 100 μs pre-emphasis, and the inner band 100 μs or 100 μs + 50 μs, correspondingly.

Assuming that binaural recordings are pressed in high grade plastic, the most serious surface noise will be that of ticks and pops. Such noise here, however, will take on a random left-right character and as such is distinctly objectionable because of the directional effect. Hence the recorded level must not be lowered in an attempt to permit full "curve" equalization of bright original material.

When experimental recordings were made using 6-in. microphone spacing and earphone playback, phasing was of course necessary. But contrary to what might at first be expected, phasing of playback *speakers* is unnecessary for material recorded indoors (rather than outdoors.) With any spacing of microphones in excess of ear spacing, phase becomes random in view of the acoustics of both the original room and the playback room. However, in playing back material which was recorded in the open, with no confining walls, phasing may well become desirable, especially if the acoustical environment of the playback speakers is on the "dead" side.

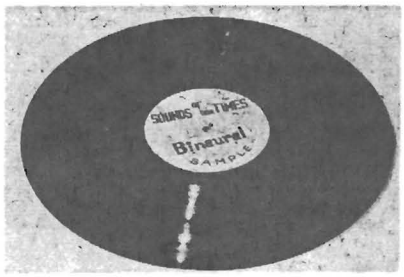


Fig. 6: Close-up of binaural recording shows the two bands of grooves

By now, most of us are well aware of the fact that a real distinction exists between standard monaural and binaural systems. Any comparison is unfair at the start because the two media are not comparable on any real basis. The extension of the aural medium by addition of dimension, direction and perspective is important not only for vitalizing the musical catalogs we are building but also for extending useful repertoire into fields such as plays and other documents, where the third dimension communicates enough additional information to make the difference between failure and success.

Of commercial necessity we have had to rule out earphones as the playback mechanism, albeit their rigorous binaural nature. We thus descend into a morass of conjecture relating to position of loud speakers, acoustical reflection characteristics of side and back walls, shape of room, etc., all applied to the room in which playback occurs. Here none but the broadest rules may be drawn, since even mass-produced living rooms are decorated and carpeted differently.

In the case of standardization of recording characteristic curves a basic truth was finally recognized, wherein it is obviously both ineffectual and impossible to standardize the *recording curve*. What we try to standardize is the *playback curve* only. Thus in developing techniques for binaural recording insofar as microphone placement is concerned, the basic truth must always be kept in mind—that playback (on the average) will take place using 2 speakers separated perhaps 12-15 ft. against a wall in a room of corresponding size and fairly random acoustics.

As binaural disc as a medium develops, there will no doubt be a great deal of expert activity in the realm of "where to put the microphone" and "studio acoustics," and there will be many interim pet theories expounded. Without a conclusive amount of experience at this point, we can only suggest a few directions in which *not* to go. For instance, the business of about-facing the band on stage and playing into microphones in opposite corners of the stage wings is extraordinarily unnatural in effect. Wall reflections abuse the reality, and treatment of the walls to inhibit reflections pulls the teeth out of the binaural head. The bright synthetic modern studio acoustic appears definitely out from the binaural standpoint. In general, any studio or hall which has been treated with the idea in mind of creating an "even" frequency distribution of energy per square foot,—the "mix 'em up" philosophy,—is lowest on the binaural scale.

And the one unhappy malpractice which has been in vogue for 20 years of broadcast and recording,—that of the small and odd-shaped, acoustically odd and unnatural control room is absolutely fatal for producing binaural. Note is taken of various broadcast and recording company executives who, for very good reasons, insist on listening to their records in an audition room about the size and shape of an "average" living room with similar acoustics. Yet the records are produced and balanced in a studio control room which is about as far away as one could get from the living room prototype, both in size, shape, proportion, acoustics, and relative position in the room of loudspeaker and listener.

For binaural records, it would be better in these control rooms that earphones be used, for making binaural productions will probably become much more of an *art* than the regular monaural ever was.