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audiocraft

THE HOW-TO-DO-IT MAGAZINE OF HOME SOUND REPRODUCTION

Authors new in this issue, in order as they appear at the right:

David Hafler is probably best known in audio circles for the ultra-linear (tapped-screen) method of operating power output tubes, which he developed with Herbert Keroes and subsequently described in the technical press. He is also responsible in large measure for the present emphasis on stability in amplifier design. Formerly with Acro Products Company, he recently organized Dyna Company in Philadelphia and now manufacturers Dynaco transformers and Dynakits.

Saul White is a veteran and highly esteemed loudspeaker design engineer. He must have an understanding wife, because he seems to get away with littering the large, handsome living room of his New Rochelle home with various speakers, enclosures, and associated items with some regularity.

Brooking Tatum is a naturalist and author of some reknown, and an audiophile of some persistence. He manages to have music wherever he goes, which is just about everywhere in his combination house-office trailer. Lucky fellow — what a life!

E. B. Mullings (Ernie) isn't actually an author new with us in this issue; he started his series on test instruments in December, but we didn't have room to say anything about him then. Anyway, he's an engaging and capable fellow who is Publications Editor for Heath Company. If you've wondered who is responsible for those excellent instruction books, now you know.

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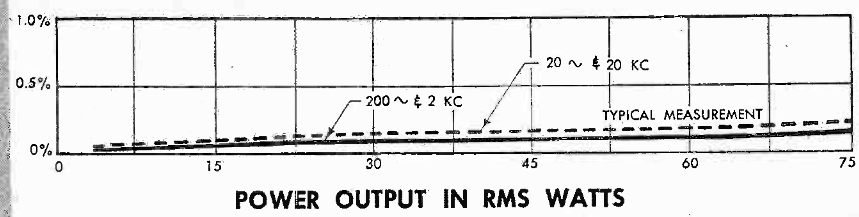
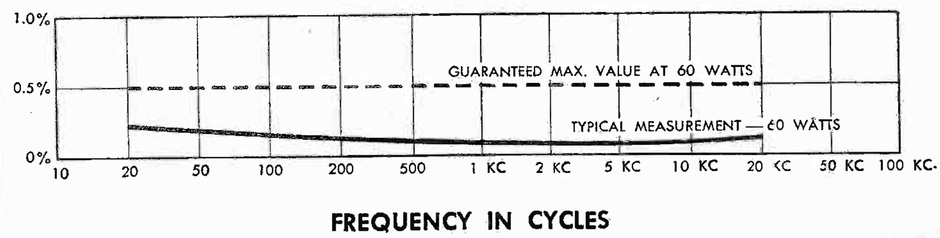
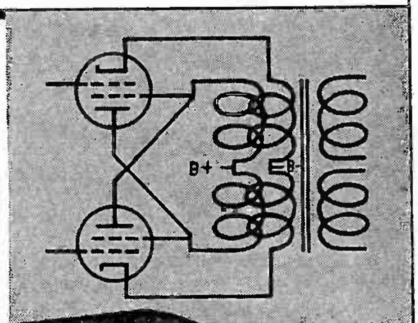
DISTORTION VS. POWER OUTPUT



SINGLE FREQUENCY HARMONIC DISTORTION





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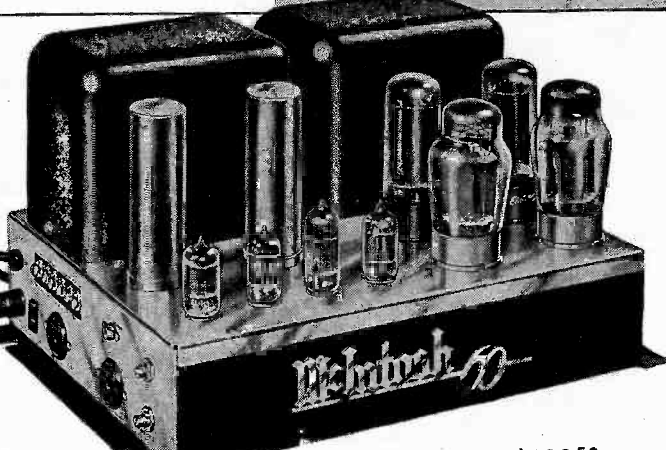

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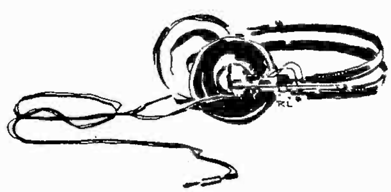
The Grounded Ear *by Joseph Marshall*

Stereo High Fidelity

It had been my intention to devote this column to a once-over-lightly of technical developments revealed at the fall audio shows. However, the introduction of the Ampex stereo system just before the show season and its demonstration at the shows comprise, in my opinion, the most important news of the season and the most significant for the future. We have talked about stereophonic high fidelity in the home for years. Now that it is here in practical form, available to anyone with a large enough bank account, the question bothering many people in the industry, as well as their customers, is whether its arrival threatens the obsolescence of single-channel high fidelity as we know it today. Having lived with an Ampex stereo system for a month and worried the problem myself, I should like to offer my opinion on this matter.

First, as to the Ampex system: it is highly successful in performance — as far as I'm concerned, the first really successful stereo system suitable for home use. Its ability to increase the illusion of presence in almost any living room, big or small, is probably beyond argument. My neighbors here in the hills of Tennessee, though highly musical, are not generally considered to be sophisticated either about music or high fidelity. Yet all, without exception, noted the spectacular realism of stereo, and its illusion of bringing the performers right into the room. They noted this, not only as it was compared with the Ampex system itself used as a single-channel system, but also in comparison with the excellent degree of presence which my own elaborate single-channel system can provide. Depending on the tape, the stereophonic or directional effect was very marked — sometimes too marked — and more independent of the position of the listener in the room than any previous improvisation I have heard or attempted myself. Again, though the amplifier-loudspeakers used in the system (excellent as they are) do not compare with the best possible combinations now on the market, the high fidelity quality is more than acceptable. In short, Ampex offers genuine stereophonic high fidelity in a very compact form which requires no special knowledge or skill to set up. Anybody who wants stereo sound in his home need only come up with the necessary $700. So far as I can see, there is practically no risk of failure in achieving the advertised "startling difference in realism".

Here are a few observations on the lessons to be learned from the Ampex system. For one thing, it seems to me that the compactness of the system is a large factor in its success. The degree to which a genuinely stereophonic effect is achieved in a given room depends largely on the positioning of the speakers. The Ampex speakers are so small and handy (in either the portable or the furniture versions) that, no matter what the size or arrangement of a room, it is relatively simple to find practical positions which yield good results. Small speakers have their inadequacies, especially in bass response. But I'm afraid that attempts to remove the deficiencies by using larger speaker systems will tend to defeat the stereo effect. I made some experiments myself using the Ampex tape player and 2 combinations of excellent (but large) speakers. Though the fidelity was improved, I could not equal the stereophonic presence of the smaller Ampex units. This was partly because it was not possible to position the bulky speakers so favorably, and partly because the better speaker systems have a wider sound source and the stereophonic effects appear to be much more dramatic with 2 rather narrow sound sources.



I have pointed out that even with 2 small speakers, by no means in the same class, the very compact Ampex system provided a more spectacular degree of presence than what, with all due modesty, I consider to be one of the finest single-channel systems extant. It seems pretty obvious, therefore, that small, compact systems will profit most from stereo on 2 counts: 1) it is easier to obtain a good stereo effect with a compact system, and, 2) when it is obtained, it equalizes the disparity between the small and the space-is-no-object system. I can even visualize (though not without misgivings) stereo systems consisting of 2 boxes the size of table-model radios, plus a simple tape player, the whole works selling for a good deal less than $200. And a lot of people would be quite happy with it.

The fact that the 2 amplifier-speakers in the Ampex system are identical is perhaps even more important than their size. "Phase" is a word which most stereo proponents would like to have banned from any conversation concerned with stereo, for the directional discrimination of the ear is based to a considerable degree on phase differences in the arriving sound. Any room can be expected to show some peculiarities in phase reversal or modification; such modification will affect the stereo characteristics for the worse. If the equipment also possesses phase individualities, the effect is usually in the direction of far worse. By using 2 systems as identical as careful production control can guarantee, Ampex minimizes and, indeed, largely eliminates phase troubles. Those who want to experiment with their own versions of stereo sound will do well to keep this in mind.

But the big question is whether, with this nicely working sample to whet the appetite, single-channel hi-fi is threatened with obsolescence. I don't mind going out on the limb and answering the question with a qualified negative — I have no doubt we will see great acceleration in the production of stereo systems, especially small ones; but I will be very much surprised if stereo systems ever take over as much as half the market, and I'm even more confident that a high proportion of present owners of single-channel hi-fi systems will be quite content with what they now have.

I base this opinion on what seems to me a fundamental consideration. High fidelity sound is a system of communication and is subject to the general laws of communication. One of these laws is that the more *relevant* and *necessary* information a system delivers, the better (more efficient) it is. Hi-fi systems are intended principally for listening to music: the relevant and necessary information for this purpose is that which provides a complete enjoyment and appreciation of music. And the basic reason for the wide acceptance of high fidelity has been the fact that it communicates the greatest amount of relevant and necessary information for the enjoyment and appreciation of music. The pertinent question here is this: does stereophonic sound increase the information relevant and necessary to the enjoyment and appreciation of music?

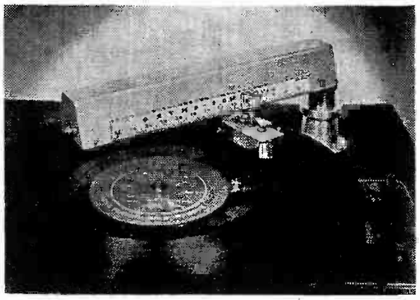
Well, what information does stereo deliver that a single-channel system does not? Two kinds of information are unique to stereo: 1) it conveys a sensation that we are present at a performance; 2) it tells us whether the performer is to the left, right, or straight

Continued on page 32

AUDIONEWS

ORTHO-SONIC V/4 TONE ARM

The Bard Record Company, Inc., has announced the introduction of a new radial tone arm. Designed to eliminate tracking error, the Ortho-Sonic V/4, the manufacturer asserts, overcomes many of the problems associated with radial playback arms.



V/4 radial tone arm.

It is stated that the cartridge carriage of the V/4 will accept most popular cartridges, and changing from one cartridge to another can be done quickly without the use of tools. The arm is easily installed and stylus pressure can be adjusted by turning a thumb screw.

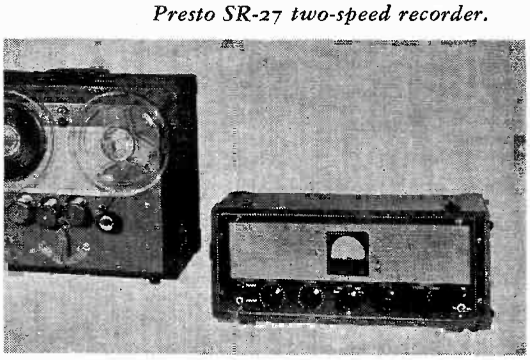
For further information about the Ortho-Sonic V/4 tone arm, write to Bard Recording Company, Inc., 66 Mechanic St., New Rochelle, N. Y.

PRESTO TAPE RECORDER

A new 2-speed tape recording unit was displayed by the Presto Recording Corporation at the Audio Fair which opened in New York on October 13th. Designated as the Presto SR-27, the unit consists of a tape transport mechanism and a 10-watt amplifier, each furnished in a separate carrying case.

The R-27 transport mechanism embodies many design features of Presto's professional models. It utilizes 3 individual magnetic heads to record, erase, and play back tape on standard 7-inch reels at 7½ or 15 ips. Three separate motors are employed for tape transport and fast-speed wind and rewind. The capstan is driven by a hysteresis synchronous motor. Supply and takeup reel motors are of the standard induction type. The brakes on the R-27 are self-adjusting and self-aligning. A single control lever sets the mechanism for record, playback, or fast-speed operation, and the desired speed is selected by moving the speed shift knob up or down.

Presto SR-27 two-speed recorder.



The A-920B amplifier is a modified version of Presto's A-920 unit. It contains microphone and playback preamplifiers, a power supply, and 2 small speakers for low-level listening or for monitoring the recorder. Microphone inputs of 50 to 250 ohms and a bridging input are provided and the maximum output power is 10 watts at 15 ohms.

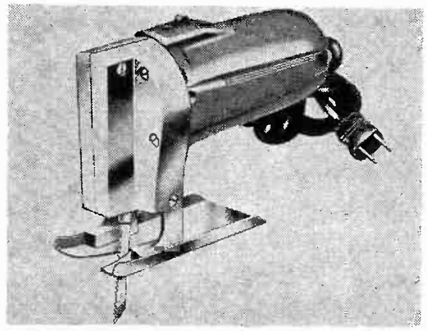
When operated at 15 ips, the SR-27 has a frequency response up to 15,000 cps, the signal-to-noise ratio is better than 50 db, and the flutter is held to 0.15% RMS, according to the manufacturer. The mechanism and amplifier combination, furnished in 2 separate carrying cases, is sold at a list price of $588.00. The address of the manufacturer is Presto Recording Corporation, P. O. Box 500, Paramus, N. J.

WEN PRODUCTS SABER-TYPE POWER SAW

Wen Products, Inc., has developed an all-purpose saber-type power saw which retails for $29.95. This tool is reported to be able to do the work of a jigsaw, rip, crosscut, bandsaw, hacksaw, coping, scroll, and keyhole saw. The unit makes its own hole for inside cuts.

The saw, known as the Model 505, will cut such materials as wood, plastics, metals, composition board, hard rubber, and leather. In preliminary tests, it is stated, the saw cut easily through a 2 by 4-inch board in 14 seconds. The motor fan blows a stream of air over the work to keep the guide line free of sawdust.

The Model 505 saw is 6¾ in. long, 5 in. high (without blade), and has a shipping weight of 4½ lb. It is powered by a 115-volt, AC/DC, 1.8 amp. motor. Fine, medium, and coarse blades are supplied with each saw. Blades have a ⅝-inch stroke and the motor delivers 2,650 strokes per minute under load. Also part



Wen portable saber saw.

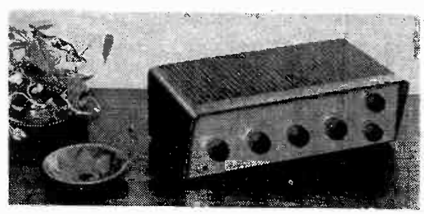
of the standard equipment are a heavy duty slide switch, a 6-foot heavy duty cord, and a molded plug — all listed by Underwriters' Laboratories.

The Model 505 saw is manufactured by Wen Products, Inc., 5808 Northwest Highway, Chicago 31, Ill.

PRINTED CIRCUIT AMPLIFIER-PREAMPLIFIER

A low-priced amplifier-preamplifier unit has been announced by Harman-Kardon. Employing printed circuits throughout, the "Prelude", Model PC-200 is rated at 10 watts.

The preamplifier section provides inputs for phono, tuner, and tape. A tape output, unaffected by the tone controls, is also featured. Full record equalization with separate roll-off and turnover controls, a 4-position Dynamic Loudness Control, bass and treble controls, and a rumble filter are standard features of the Prelude.



PC-200 10-watt compact amplifier.

The PC-200 is consumer priced at $55.00. A matte black cage and safety interlock power cord are included. Further information may be obtained from Harman-Kardon, Inc., Westbury, N. Y.

BALANCED SOUND KIT

Walco Products, Inc., recently announced a new kit to aid in obtaining better sound and longer record life through greater turntable and tone arm accuracy.

Known as the Walco Balanced Sound

Kit, it is packaged in a durable storage box and includes an accurate turntable level and a stylus pressure gauge. The turntable level is approximately 3 in. long and has a "Clear-View" glass bubble indicator for easy reading. The stylus pressure gauge, precision made of

Walco kit contains level, force gauge.

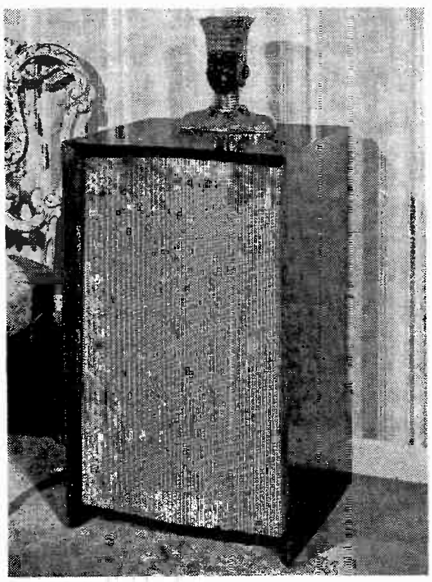
one-piece chronometer spring steel, can be checked and calibrated for accuracy by the user. Its design permits placement directly on the turntable with the tone arm in normal record playing position.

With both items packaged together, the kit lists at $1.50. Scales and levels are available individually packaged at $1.00 each. Complete information may be obtained by writing to the manufacturer, Walco Products, Inc., East Orange, N. J.

NEW HARTLEY SPEAKER ENCLOSURE

The Hartley Products Co. has announced the introduction of the Hartley 1-2 speaker enclosure. The 1-2 is a non-resonant enclosure with 7-section, 2-stage acoustic filter, for 1 or 2 Hartley 215 non-resonant speakers. The unit is

The 1-2 Boffle holds 1 or 2 speakers.



available in blond or mahogany. Dimensions are 30 in. high by 18 in. wide by 16 in. deep. With 1 speaker, the unit is priced at $160.00; with 2 speakers, $225.00.

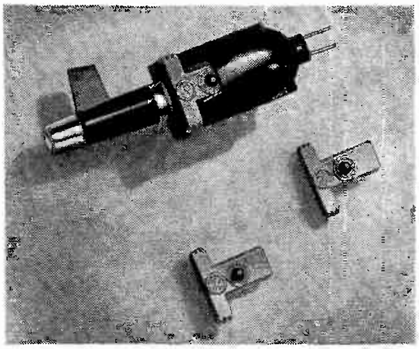
Further information is available from Hartley Products Co., 521 East 162nd St., New York 51, N. Y.

PICKERING "FLUXVALVE" MAGNETIC PICKUP

The "Fluxvalve", a new, wide-range magnetic pickup with easily replaceable styli has been introduced by Pickering & Company, Inc. According to the manufactuer, the design of the Fluxvalve meets the demands of all presently envisioned recording developments, including those utilizing less than 1-mil styli.

The Fluxvalve is a turnover design featuring easily replaceable styli. The vibratory mass has been reduced to an amount so low that pickup response is stated to be flat at 30 Kc on ordinary vinyl.

The manufacturer states that electrical characteristics of the "Fluxvalve" include a frequency response absolutely



Fluxvalve variable reluctance pickup.

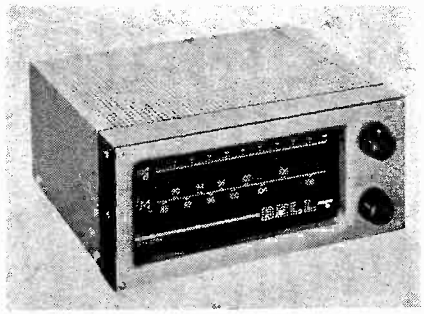
flat to well beyond 20 Kc, negligible intermodulation distortion, output of 25 millivolts at normal recording level, and medium impedance, requiring a termination of 47,000 ohms.

The entire magnetic circuit, including the magnetic gap, is encapsulated in plastic. The pickup is supplied with a mounting clip which adapts it to all standard arms and also acts as the bearing for the turnover action.

FM TUNER ADDED TO BELL HI-FI LINE

A new FM tuner has been added to the Bell line of high fidelity components as a companion to the recently introduced "Golden Twins".

The new Model 2254 FM tuner covers the FM band from 88 to 108 megacycles, and is complete with a log scale for precision tuning. The circuit design features a grounded grid input stage, a 2-stage limiter, and low distortion characteristics in the output stage. An output level control is located on the rear of the chassis. The 2254 is designed especially for use with the Golden Twin



Golden Bell FM tuner.

Model 2256 amplifier, but will perform satisfactorily with any high fidelity amplifier.

Complete information may be obtained by addressing Bell Sound Systems, Inc., 555 Marion Rd., Columbus 7, Ohio.

ELECTRO-VOICE "DO-IT-YOURSELF" KITS

A complete line of "Do-It-Yourself" K-D kits has been introduced by Electro-Voice. The kits include the Electro-Voice Patrician and Georgian interior "K" horn units, and the complete Electro-Voice Baronet, Aristocrat, Regency, and the new Empire and Centurion enclosures.

Pieces in each kit are precut and ready for assembly: exterior surfaces are of clear-grained birch. The kits include glue, screws, and nails. An illustrated "Do-It-Yourself" book giving step-by-step instructions, diagrams, and photos is included with each Electro-Voice K-D kit. These books are also available separately, at nominal cost, for those who wish to purchase their own material at local lumber yards and hardware stores.

For complete information, write for Bulletin No. 211 to Electro-Voice, Inc., Buchanan, Mich.

GRAY COMBINATION TURNTABLE AND TONE ARM ASSEMBLY

A new turntable and tone arm combination has been announced by Gray Research and Development Company, Inc. This combination features a massive design which the manufacturer claims eliminates rumble and vibration. The arm is the Gray 108C Viscous Damped Tone Arm. The manufacturer has placed a cue light in the arm rest which provides enough illumination to place the arm on the record without turning on other lights in the room. The turntable operates on all 3 standard speeds, and accommodates up to 12-inch records or 16-inch professional transcriptions. Either of 2 motors, a heavy-duty induction motor or a hysteresis synchronous motor, is available.

Additional information about the Gray Combination Turntable and Tone Arm assembly is available from Gray Research and Development Co., Inc., Hilliard St., Manchester, Conn.

Tips for the Woodcrafter

by George Bowe

Woodworking Drawings

I met Joe at lunch one day — I hadn't seen him for years — and he would not be content until I had accepted his gracious invitation to spend an evening at his new home in a neighboring town. My admission that I didn't know how to get there presented no obstacle, according to Joe. Nothing to it — he'd draw me a map.

On the appointed evening my wife and I piled into the car, anticipating a friendly dinner with friendly people in a friendly house. As we neared Joe's town, out came the map and Mary took over as navigator while I continued to pilot. Then the fun began as we tried to find the landmarks indicated on Joe's drawing. "Look for a red, white, and blue gas station," it told us — we saw 5 with that patriotic motif. "Watch for a vegetable stand that's closed for the winter . . . ." We counted 8. "Turn left at the apple orchard . . . ." There were so many orchards we thought we were in a forest. As Joe, himself, had said, we couldn't miss the house — it had a rail fence and was painted barn red. We didn't miss it. It was the *third* red house with a rail fence that we stopped at. We had a wonderful evening, though, despite the fact that we were almost an hour late for dinner.

P.S. Joe is coming to our house soon and I've already drawn a map for him. Good luck, Joe — you see, we also live in the suburbs.

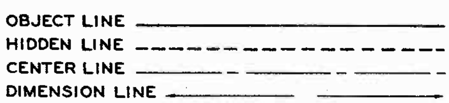
I daresay most of us have had experience in receiving and giving similar confusing masterpieces of amateur cartography. Of course, it's impossible to include more than a few identifying landmarks on such a small drawing, even if our memory permitted more.

Fortunately, in making a drawing for a woodworking project it's possible to include all the little details that are necessary to facilitate construction. A good working drawing or blueprint leaves no guesswork for the craftsman. In the case of the amateur woodworker, he is frequently draftsman of the plans from which he builds, since there are no drawings available for many of his projects. This is particularly true when it is desired to build hi-fi units into existing construction. For instance, a sketch or photograph may show how a closet can be used to enclose hi-fi equipment, but the details of construction for the specific closet you have in mind must be specially drawn. The drawing you make does not have to be a work of art. If it is drawn accurately to scale, it will give you a true picture of the shape, proportion, and measurements of each section of the project. It is sound practice to make a working drawing before proceeding with construction as it is much easier and cheaper to correct errors on a drawing than on a piece of wood.

Perhaps you're saying, "What do I know about drawing? I never made one and to try to read one made by a professional is strictly beyond me!" If that is the situation, I feel it can be changed in a very short time by following through to the end of this article where you'll have an opporunity to check your newly acquired knowledge. If you're ready, let's explore the subject of drawing.

Drawing is older than written language. In the days of primitive men, all recordings of their ideas and material things were made on rocks, on skins, or on the walls of caves. Even in those days they realized that anything that was to be made should first be sketched or drawn. Down through the ages the drawing became the written language of industry and, whether it is called a blueprint or a mechanical drawing, it is still a picture of the object to be constructed. Like music, mechanical drawing or blueprint reading is a universal language. Men of different nations, although unable to understand each other's tongues, find no barrier in reading each other's drawings.

But how does one go about reading a drawing? Learn the basic principles of an elementary drawing and you have the key to all drawings, simple and complex. First, let's become familiar with the 4 fundamental kinds of lines: *object, hidden, center,* and *dimension* lines.

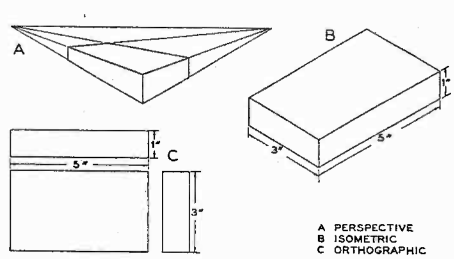


Object Lines are unbroken lines. They represent the outlines of an object.

Hidden Lines are composed of a series of short dashes representing the invisible — the edges that cannot be seen.

Center Lines are light long and short dashes indicating the center of an object.

Dimension Lines are light continuous lines broken only by numerals which give the dimension. Arrows at the ends of these lines point out where the measurement begins and terminates. Although it isn't strictly proper to do so, the arrowheads are sometimes omitted.



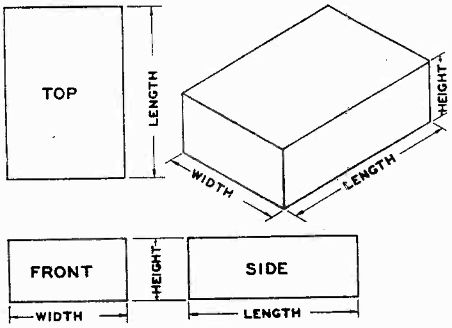
Three ways to draw a rectangular block.

A perspective drawing shows the object as you might see it from a certain distance, 3 surfaces joined in 1 view. Cartoonists, artists, and architects frequently employ the perspective in their illustrations. Parallel lines are drawn so as to converge at an artificial horizon some distance behind the object. This technique is effective and pleasing to the eye but does not show true lengths or distances. Thus a perspective drawing does not supply the information we need when we are ready for actual construction.

On the other hand, an isometric drawing represents objects as they actually are — the word "isometric" meaning "equal measurement". The fact that this type of drawing looks somewhat distorted is due to an optical illusion. There are 3 sets of lines in the isometric drawing: one set drawn vertically, one set slanting to the right, and one set slanting to the left. To produce a true isometric drawing, the slanting lines must diverge at an angle of 30° to the right and to the left.

The orthographic drawing differs greatly from the perspective and isometric, particularly in the views of the various faces of the object. This type of drawing places you in a position which allows you to see one face at a time rather than 3 faces joined as in the other types.

The orthographic and the isometric are the drawings which will be of greatest help to you when the hammering and sawing start. The orthographic gives you a plan of the individual section which permits you to carry out your work one step at a time. The isometric is generally used to provide a picture of how the individual parts look assembled or partly assembled. For example, let's examine this drawing showing an isometric view of the assembled project and orthographic sketches of the 3 faces.



Dimensions as given in typical drawings.

In the orthographic drawing notice how the rectangular block is shown in 3 views: front, top, and side. By showing it in this manner, the 3 requisite dimensions are displayed: height (or thickness), width, and length. Notice the following, for they are fundamentals found in most orthographic drawings:

1) The front view gives the height and width.

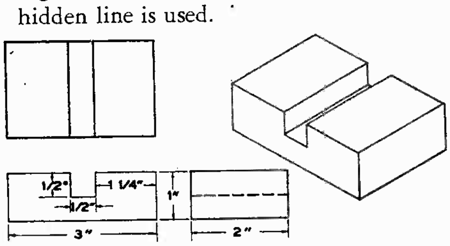
2) The side view gives the height and length.

3) The top (or *plan*) view is the same width as the front and the same length as the side.

4) The front and side views are the same height and drawn on the same level.

5) The side view is drawn directly to the right or left of the front view, and the top view directly above the front view.

So far we have used object and dimension lines to demonstrate various drawings. Now it's time to show how the hidden line is used.



The hidden line in an orthographic view.

In looking at the actual model pictured above, the bottom edge of the groove can be seen either from the front or top. Therefore, in the orthographic drawing, the bottom edge of the groove is visible in both the front and top views. Since, in actuality, this bottom edge cannot be seen from the side of the model, it is shown as a hidden edge in the drawing of the side view.

Now, if you'd like to apply your

Continued on page 35

SOUND SERVICING

by Irving M. Fried

THOUGH a lot of mysterious noises and hum can originate inside a preamplifier, it is always best to make sure, first, that the noise you think originates inside is not being fed in. Last month several methods of localizing externally caused noises and debugging your system were discussed, and it would be well to review them carefully before you proceed with the rest of this article. If, with all inputs removed, you are still obviously getting unpleasant noises from your preamplifier, the following discussion may help.

How Much Hum?

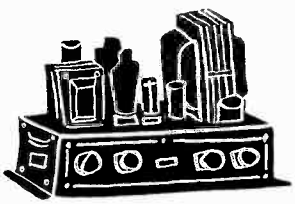
Hum of various types can plague you to distraction. While it is true that no amplifying device is completely free of hum, you should not be expected to endure very much in your high fidelity set. For instance, if you can hear hum from your loudspeaker with normal preamplifier volume and tone setting, and it is audible without poking your head into the loudspeaker, you have too much of it. But if you must wait until midnight and put your head against the speaker to hear hum you are being too demanding: in other words, you should be able to get hum levels inaudible under normal playing conditions. If not, proceed.

The most obvious source of hum is the preamplifier's power supply. If the filaments are powered by AC, you may have extra hum simply because you haven't adjusted the hum control pot for optimum performance on the phono channel. You will find, incidentally, that the adjustment point for minimum hum will vary from channel to channel — the minimum point on the tuner input may not be the same as for the minimum on phono — and vice versa. Try adjusting the hum pot; it may surprise you, particularly if your wife pulled out the line plug and reversed it since you last made the adjustment!

Then, of course, you may find enormous differences in hum produced by various tubes in the first socket. Certain preamp manufacturers carefully pass the first tubes of their preamps through demagnetizing loops before installation, for minimum hum. At least one tube manufacturer I know of does the same thing, and chances are that his tubes will be quieter — until you use a magnetized screwdriver near the preamp, or let it get into a strong magnetic field.

Another possibility is that of induced hum. Because of the enormous gain of preamplifiers, input tubes can pick up hum in their grid circuits from a power transformer or a turntable motor. As always, rotation of the preamplifier is the test — if the hum seems to die away and return, you ought to reorient your components until, in playing position, you have little of this kind of hum.

Particularly in a home-wired preamplifier you may, by observing wiring practices of the experts, kill pernicious noises. Hum levels in commercial equipment can often be lowered too. For instance, make sure that all grid returns (the lower lead of a grid resistor) touch the ground bus bar or the chassis at precisely the same point as the screen and cathode returns. Even with ¼-inch separation you may get a beautiful ground loop, with a wonderfully loud roar. Sometimes, on the other hand, you can buck out a hum condition simply by moving the grid return along the bus bar, on either side of the screen and cathode returns.



Check lead dress also. Filament connections should be as close to the chassis ground as possible; grid leads should be as far away from AC filament leads as you can get them. A probe, a power amplifier, and an old speaker you don't have to worry about are valuable aids in this kind of hum bucking.

Hiss and Sizzle

Troublesome also is the hissing kind of noise. Tubes can vary widely on this; older tubes generally tend to build up more hiss than brand new ones. Certain tube types tend to hiss more than other special-purpose designs. You might want to try the low-noise equivalent of your standard input tube (check your parts dealer on this, before you put a different tube type in), just to see whether the noise will go down below that of a quiet general-purpose type.

But, before you try tube changes, check your input circuit resistors. Some manufacturers use special deposited-carbon resistors to get the hiss level down; others use one-watt resistors where ½-watt units would carry the current; certain others try to minimize current drain by proper selection of operating conditions — all to reduce resistor noise.

If you suspect you have hiss from this quarter get an insulated probe. With the preamplifier tube in the circuit and the power on, gently wiggle first the plate lead resistor, then any other unbypassed resistors, such as the cathode and screen droppers, or even the grid resistor. A noisy one will tend to crackle when you disturb it. Remedy: replacement.

An oscillating preamplifier will tend to give out intermittent hisses, just like an oscillating power amplifier. With an oscilloscope the oscillation can be seen immediately. The hissing sound you hear is not ultrasonic, even though the oscillation that causes it is; the audible noise is a result of extra current drain through the plate and cathode resistors. In any case, if you suspect oscillations (which can be a real problem with very-high-gain preamplifiers, particularly when feedback is used), you may find that slight reorientation of signal leads, or reduction of gain by inserting tubes with less gain, may help. If you suspect oscillations, but aren't sure just what they are, or how to cure them, better get your preamp in expert hands soon.

Closely allied are the problems of motorboating, which produce low-frequency rumbles, particularly when you try to advance the bass control. Suggested cures are additional B+ decoupling, redressing leads, changing tubes, or cutting extreme low-frequency response by interstage capacitors of lower capacity.

Tied in, too, are the problems of microphonics. An efficient bass propagator, an enclosure resonance, a room resonance, and a microphonic input tube can cause all sorts of strange gurglings. If you simply can't find a tube that won't "bong" in your circuit, you should isolate that tube from shock excitation. Acoustic feedback may occur through the floor or via the air itself. If isolation won't work, you may have to consider another preamplifier circuit — for, because of reasons unknown to all concerned, certain circuits lead to microphonic problems — and certain tube types won't stay quiet, no matter how carefully you select them.

Tape News and Views by J. Gordon Holt

The Well-Integrated Recorder

It is entirely safe for me to go on record as stating that more tape recorders have been sold this year than last year, and that, barring a national economic collapse, there will be more sold next year than this year.

But to assume that every person who bought a tape recorder this year did so with the intention of using it for high fidelity recording would obviously be foolish. Probably more than half of the individuals who contributed to this year's yet-unpublished statistic spent less than $200 for a recorder, and will use it to record baseball games, light music broadcasts, and baby's first attempts to produce intelligible speech. A large percentage of the remainder would be more likely to fall into the high fidelity enthusiast category, and this includes us.

For the hi-fi user a tape recorder is required primarily to serve as an adjunct to FM and disc records, and the closer his recorder comes to equalling or surpassing the results from these other media, the better he likes it. But problems that are important to the hi-fi recordist simply never occur to the average user.

To someone whose ear is decidedly uncritical, the program's the thing, and if Mel Allen happens to come out sounding like Arthur Godfrey it's perfectly all right, as long as the words are intelligible. Such an enviable point of view can justify putting a cheap, mediocre microphone in front of a poor loudspeaker for radio or TV recording, but the results would never be tolerated by the audio perfectionist. The owner of an inexpensive packaged tape recorder purchased convenience, and to him this means the ability to use the recorder's own microphone for every source of sound, be it radio, television, or offspring. He is never faced with the problem of making electrical connections between his recorder and the rest of his system; his recorder *is* his system. All he does is plug in the AC cord, plug in the microphone, and record. To play the tape, he just rewinds it and plays it. No fuss. No complications.

The high fidelity enthusiast, though, is typically armed with enough information to suspect that he isn't getting as much out of his recorder as he might, but every circumstance seems to stand in his way. He knows that, to function at its best, a tape recorder should be connected electrically to the rest of the system for all applications except live recording. But this is where difficulties arise, because many control units, amplifiers, and tape recorders were obviously designed with a total disregard of each other's existence.

Control units and amplifiers have been made which possess but one output connection, at the tail end of the circuit as far as it goes. Fortunately, they are becoming much less common. Tape recorders have been — and still are — being made with but one output connection, usually following a somewhat inadequate power output stage, while a few have no output connection at all. It's no wonder, then, that many recordists end up passively accepting the mediocre results obtained from a microphone in front of a loudspeaker.

There are 2 reasons why the speaker-into-the-mike expedient yields such poor results. First, of course, is the quality of the microphone, which is often by far the worst piece of equipment in the entire system. It imposes its own limitations on the recording, and to these are added whatever distortion or frequency deviations exist in the loudspeaker supplying the source of sound. Then if the recording is played back through the same loudspeaker the speaker's deficiencies are added to the sound a second time, precisely doubling them. Under these circumstances, even the finest loudspeaker will show up rather poorly, while an average speaker will produce very bad sound.

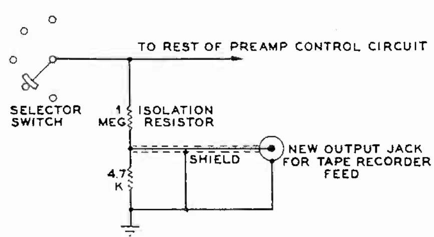


Fig. 1. Medium-impedance control output.

The same thing happens, in much milder form, when the tape recorder is fed by the output from a fairly good amplifier or control unit. It is only in the very best of these that there is not some measurable frequency response deviations well within the audible range, and while the deviations may be very slight, initially, they become quite audible when they are doubled by the playback signal passing through the same system a second time.

For these reasons the recording perfectionist prefers to take the desired signal out of the control unit as early as possible in the circuit, so that in playback the signal will not be obliged to pass through the same stages a second time. Similarly, the shortcomings of power amplifiers in most tape recorders are such that it is highly advisable to eliminate them from the playback circuit if maximum quality is to be realized.

Some tape recorders are supplied with a built-in magnetic-phono preamplifier stage, having equalization and enough gain to offer plenty of reserve volume. But the use of such an input involves sacrifice of variable equalization, so not all records will be equalized correctly when they are recorded. And after they have been recorded there is little or no way in which the response can be corrected accurately by means of conventional tone controls. So the time to get a record equalized correctly is during the record function, and the standard flexible equalizer section of a control unit is the best means of accomplishing this. Therefore at least part of an external system will be needed for best results in dubbing discs onto tape.

It would also be quite convenient to be able to record from any input source without plugging and unplugging interconnecting cables, so the output from the control unit should be at least as far along in the circuit as the input selector switch. Beyond this point there are likely to be tone and volume controls, through which the signal would have to pass in playback, so the moving arm of the input selector seems to be the ideal place from which to tap off the signal.

Very often, though, the signal appears at this point at too high an impedance to be run through any reasonable length of cable (to the recorder) without excessive high-frequency losses. Most shielded cables have about 60 $\mu\mu$fd capacity per ft. Three ft. of this connected to a source of, say, 250,000 ohms (which is not unusual at this point in the circuit) would cause high-frequency attenuation above 4,000 cycles . . . a quite audible loss. The thing to do, obviously, is to reduce the source impedance to the cable, so that the frequency at which rolloff begins will be pushed up out of the audible range. A resistor of, say, 4,700 ohms connected across the line would accomplish this, but it would severely limit the low-frequency response from the preceding stage and from the other input sources, besides dropping the volume of the input signals far below their normal figure.

To get around this, a 1-megohm resistor can be connected between the takeoff point and the interconnecting cable, effectively isolating the line from the signal takeoff point. See Fig. 1. The 2 resistors would then constitute a voltage divider network, and would reduce the output voltage enough so that it would have to be fed to the recorder's microphone input. Still, this would not be nearly as bad as feeding it through the preamp's tone and volume controls before it arrived at the recorder.

The physical installation of this Tape Out connection is simply a matter of drilling a hole in the chassis of the control unit or amplifier in which to mount the phono pin-tip receptacle, and then connecting the resistors as described. Remove all the tubes from the chassis while drilling, and make certain all metal filings are removed from inside the chassis before putting it back into service. The permissible length of the interconnecting cable to the recorder will be determined by the cable's capacity per running ft., and the total capacity should not exceed 1,500 $\mu\mu$fd. If it is desired to place the recorder as far as possible from the rest of the equipment, special low-capacity shielded cable should be used. The physical separation between the recorder and its signal source can be up to 60 ft. by using cable of 25 $\mu\mu$fd per ft. capacity.

The Tape Out connection just described will permit any channel that is plugged into the control unit or single-piece amplifier to be piped to the tape recorder as it is selected on the channel selector switch, leaving the control section's tone controls and volume control operative only as a monitor, so that the listening level while recording may be varied without affecting the signal going onto the tape. Of course, many control units and one-piece amplifiers are already equipped with a similar tape output connection.

That gets the signal onto the tape; the next thing is to get it back into the system on playback with the minimum loss in quality. This time it is the recorder's circuitry that comes under scrutiny, since the object is once again to eliminate all the unnecessary stages of amplification, leaving only the essentials.

The only really indispensable part of the recorder's playback circuitry is the preamplifier-equalizer stage. Why not use the one in the phono preamp-equalizer unit? Principally because phono preamps with 1,600-cycle bass turnover positions with flat treble aren't too common, while ones that can supply a 3,000-cycle position (for Ampex tapes) are still nonexistent. Playback heads in many recorders are of quite high impedance, too, so that short, direct connections to the playback preamplifier are

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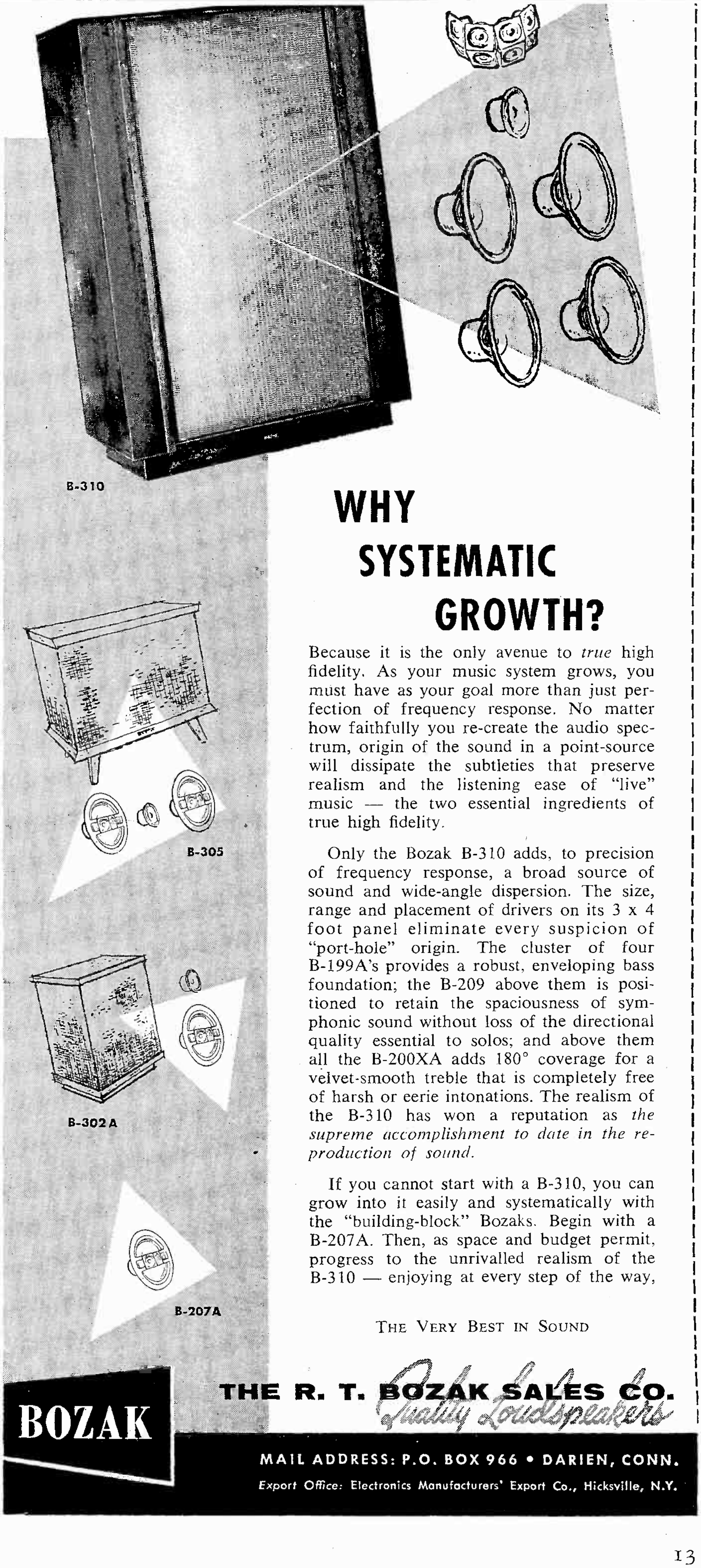

Following the phenomenal success of the industry-sponsored Philadelphia High Fidelity Music Show held in November of this year

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These industry-sponsored shows are intended to provide the place and the opportunity for new audio developments, techniques and equipment to be seen, heard and appraised by the general public. The readers of this magazine are earnestly solicited for their views on show format and practices, that these shows may better serve the growing public interest in high fidelity.

Please address all replies to: **Show Plans Committee**

INSTITUTE OF HIGH FIDELITY MANUFACTURERS, INC.

25 Broad Street, New York 4, N.Y.

READERS' FORUM

Gentlemen:
Would you care to quote me a price on a life subscription? I was born on July 12, 1906, in case that makes any difference.

Henry F. Robbins
New York, N. Y.

We've received several requests like this one, and have finally decided on a price of $60. If you expect to be around for 20 years or more, then, this might be worth looking into.

Gentlemen:
In the initial issue of AUDIOCRAFT, under the heading "The Grounded Ear", mention is made of the Mullard driver circuit. On page 40, you mention Amperex as the U. S. agent for the new EL-84 tube, and as a source of a circuit booklet by Mullard.

I have tried to find Amperex in a half-dozen magazines with no success. Will you kindly supply the full name and address.

Charles V. Thayer
Springfield, Vt.

We've been flooded with similar requests. Here's the address:
Amperex Electronic Corporation
230 Duffy Ave.
Hicksville, N. Y.

Gentlemen:
In regard to your article "You Can Build a Power Amplifier": I don't think that this information is of any assistance to present readers, since anyone who is aware of your existence should also be acquainted with the fact that amplifiers are available in kit form. It would be better to shed some light on the operation of these units, since the consumer has no chance to check their performance until he has bought and assembled them, and then he is stuck with them for better or worse . . . .

I have for some time been interested in building a Theremin. The library, however, has nothing on the operation of this unusual instrument . . . . Space permitting, and reader interest warranting, I should appreciate an evaluation of existing models.

Raymond A. Donahue
Hartford, Conn.

Reader opinions are welcome on the matter of Theremin articles, too. We'll try to do better on kit construction writeups in the future.

EDITORIAL

FEW will deny that there is still room for improvement in radio and television programming. At the same time, any impartial observer will be quick to admit that there have been substantial gains during the past few years in the average quality of material from both media. The world's finest artists now appear regularly in televised performances of great plays, operas, and musical comedies; good-music radio stations are increasing in number continually, and there is at least one within listening range of just about everybody. In short, there is a wealth of material on the air that is well worth recording.

There are also many listeners and viewers who have tape recorders capable of preserving such performances indefinitely, and *their* number is growing at an unprecedented rate. An ideal situation, one might think. It is — except for one small difficulty. How can a recorder-owner get a clean audio signal from his radio or TV set to feed to his recorder?

If he has a complete hi-fi system including radio tuner he can, of course, pick off a relatively undistorted radio signal at several places in the system. And if he has a TV tuner whose sound also can be piped into and through his system, so much the better: his off-the-air recording problems are solved. But how many home recordists have such elaborate setups? Not a great number, we'd guess. Most have no hi-fi system as such, or have a system with phonograph facilities only, or one with radio and phonograph inputs. Off-the-air recordings are made in most cases directly from standard commercial television and radio sets. They are made too often simply by setting up the recorder's microphone in front of the speaker; this may produce a recording that is intelligible, but that's about all you can say for it. The quality is always dreadful. Somewhat better results can be obtained if the signal is taken directly from the speaker voice-coil leads, but even then quality degradation is easily apparent. Those more technically inclined can sometimes make circuit alterations or additions in the set that will permit signal takeoff at the volume control or some other point before the set's usually-mediocre output stage. This, however, is a tricky business, particularly with AC-DC sets; it isn't always successful and *can* be dangerous.

The ideal solution is obvious, although it will take a bit of doing to see it realized. All commercial radios and TV sets should be equipped *by the manufacturer* with a standard pin-type receptacle on the back labeled "To Tape Recorder" or a similar legend. This would be connected at some point in the circuit before the output stage, preferably before the volume control. It would be asking too much for a low-impedance output, we suppose, but at least we should be assured of minimum signal distortion and maximum safety, as well as convenience. Such an output jack would add slightly to the manufacturing cost; on the other hand, it might well be a productive sales gimmick. To anyone owning a recorder it could easily be a determining factor in his choice among competing brands.

Some action has already been taken toward bringing this to the attention of set manufacturers. At the October 1955 meeting of the Magnetic Recording Industry Association's Public Relations Committee, it was resolved to ask all segments of the radio and television industry to incorporate these receptacles in future production. Still, experience has shown that manufacturers are guided primarily by what consumers want, and if they aren't convinced of substantial demand for tape output receptacles they won't furnish them. The only way to be sure they know you want them is to write and say so. Write directly to the manufacturers, or to the Radio-Electronics-Television Manufacturers Association at 777 14th Street, N. W., Washington 5, D. C. Send a copy to Ed Altshuler, Chairman, MRIA Public Relations Committee, 4917 West Jefferson, Los Angeles, Calif.

EAGLE-EYED readers may have spotted the small boxes in the December issue announcing our offer of cash for unusual ideas or suggestions that make design, construction, operation, or maintenance of sound equipment easier, simpler, or more satisfactory. Payment for such Audio Aids we can use will be determined according to the ingenuity and practicality of the idea, and completeness of its presentation; minimum payment is $5.00 for any contribution published, and there's no maximum limit. At least 75 words are required for each idea submitted, together with clear sketches or glossy photo prints as necessary for illustration. Here is an opportunity to pass along the results of your experience to others, and make some extra folding money at the same time. Submit as many Audio Aids as you like to Audio Aids Editor, AUDIOCRAFT, The Publishing House, Great Barrington, Mass. We'll print as many as we can, but we cannot promise to return all unusable entries. — R. A.

MODERNIZE *your Williamson Amplifier*

by DAVID HAFLER

THE Williamson amplifier circuit was first publicized in England in 1947, and in this country in 1949. It has achieved wide acceptance and popularity, and has been the basis for several modifications of the original design. The most basic change was the ultra-linear version of operation, which I developed and subsequently described*. This arrangement corrected 2 of the basic deficiencies in the original design — it increased the power capability of the amplifier to 25 or 30 watts, and it improved the margin of feedback stability.

Now, as always happens, progress in amplifier design has continued: it is possible to make further improvements in the Williamson design (both triode and ultra-linear versions). These impovements again correct for limitations with respect to power output and stability.

Increasing Power Output

Present thinking on requirements for audio power is vastly different from that of a few years ago. Then, most people said, "Ten watts is enough for me." Now, however, modern program material has been increased in dynamic range many times over that of former years. This fact alone has increased the power requirements substantially for realistic, undistorted reproduction. In addition, source material frequency response has been extended, and this also introduces the need for a re-evaluation of amplifier power requirements. Increased frequency response means that the amplifier has to handle power at greater extremes of frequency. At these extremes, the impedance characteristics of the loudspeaker change from the nominal values. This means that the amplifier is *mismatched* at frequency extremes, and a mismatch decreases the maximum-power capabilities of any amplifier.

To deliver clean power into a loudspeaker load, an amplifier must be capable of at least *twice* the power required for a resistor load such as is used in measuring and rating amplifiers. Thus the extension of both dynamic range and frequency range in modern recordings, FM sources, and tape means that 25 watts are about a *minimum* if top-grade performance is required. Even this minimum will probably be increased in the years to come unless the efficiency of loudspeaker systems can be increased.

For these and related reasons, efforts have been devoted to increasing the power output of audio amplifiers. The advent of some new tube types has made this practical within the Williamson configuration without the need for completely rebuilding the amplifier. Changes required are replacement of the output tubes, substitution of an output transformer which will handle the increased power and provide suitable impedance matching, and addition of fixed bias.

New Output Tubes

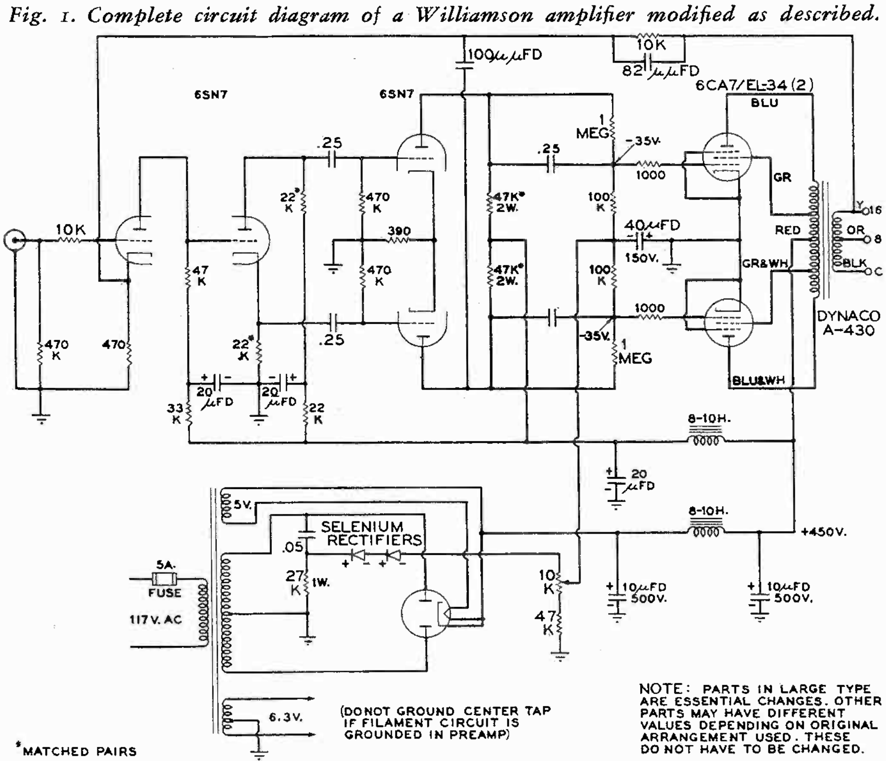
The new tube selected for modernization of the Williamson is the Amperex 6CA7, which is also imported and distributed as the Mullard EL-34. This is a compact tube with power capabilities up to 100 watts, depending on the supply voltages available. It can be plugged directly into the sockets formerly used for 5881's, KT66's, 1614's, and other tubes of this type, with the single additional requirement that the No. 1 pins must be grounded.

The 6CA7/EL-34 is a pentode tube of extreme linearity. Its preferred operating condition is as a pentode: although the manufacturer furnishes triode ratings for the tube, triode operation results in higher distortion and reduced power output. The conventional ultra-linear connection cannot provide optimum results with these tubes either, since there is no type of operation more linear than the pentode connection for which they were designed. As will be discussed later, however, a compromise form of operation fits the needs of the Williamson modernization very nicely.

To derive the potential benefits available in these tubes, proper impedance matching must be obtained in the output transformer. The Dynaco A-430 transformer has been designed specifically for this purpose. This is a 50-watt unit, the performance of which exceeds Mr. Williamson's specifications with respect to frequency response, permissible feedback, power handling ability, and so on. At present this is the only commercial transformer of correct impedance, but it is anticipated that others may be available soon.

The Dynaco A-430 has primary taps which can be used to furnish about 10% screen loading. This does not cause de-

Fig. 1. Complete circuit diagram of a Williamson amplifier modified as described.



*Hafler, D., and Keroes, H. I., "Improving the Williamson Amplifier", *Radio & Television News*, February 1953.

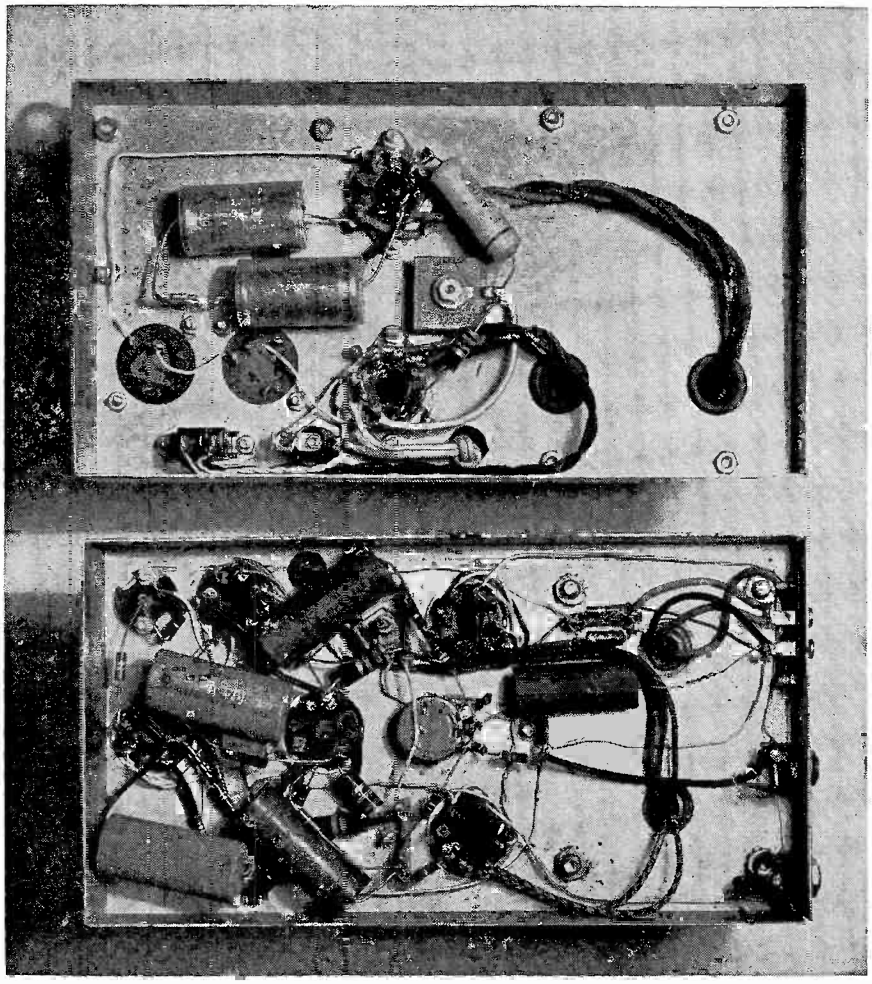


Fig. 2. Heathkit amplifier converted to deliver 50 watts with greater stability.

terioration of the extreme linearity of the tubes, and it does have the advantage of lowering the internal impedance (for better damping). Further, it improves the inherent regulation of the output stage to the point where no changes need be made in the B+ supply of the basic Williamson in order to use the new tubes.

This transformer can be interchanged directly with units formerly used in this circuit. If the original output tubes were triode connected, the 100-ohm screen suppressors connected from pin 3 to pin 4 should be removed, and the transformer leads connected as indicated in the schematic diagram (Fig. 1). The constructor should note that the circuit must be traced from the phase inverter to the output grids in order to determine which of the output tubes is the "top" one in the circuit. Transformer leads must be properly connected to the output tubes, or the feedback phasing will be incorrect. If there is a loud buzz after connecting the transformer, the plate and screen lead from one output tube should be transferred to the other, and vice versa.

Figs. 2 and 3 show the A-430 mounted on a converted Heathkit W-3M. (See Appendix for specific conversion instructions regarding this amplifier). It fits the space, despite its large size, because it has no flanges. Installation of the transformer requires no mechanical alterations in the chassis except, possibly, reaming the mounting holes to accommodate mounting studs.

Biasing the Output Tubes

The 6CA7/EL-34 requires a lower value of bias than tubes generally used in Williamson amplifiers. Value of the cathode resistor should be reduced to about 200 ohms from the conventional 250 to 300 ohms. When this has been done, after substituting tubes and output transformer, the resulting amplifier can put out 35 to 40 exceptionally clean watts. However, the capabilities of the new tubes and transformer are not fully exploited unless the constructor is willing to incorporate a fixed-bias supply to replace the original self-biasing arrangement.

Addition of a negative DC supply for fixed bias is quite simple. A capacitor of .05 μfd is taken from one side of the high-voltage secondary of the power transformer and connected in series with a 27,000-ohm, 1-watt resistor to ground. These form a dividing network which cuts the AC voltage from the power transformer to less than ⅓ its full value. Two small selenium rectifiers (20 ma or higher rating) are wired in series from this junction, with the negative rectifier terminals toward the output side. The resulting negative DC is filtered by a 10,000-ohm potentiometer and a 47,000-ohm fixed resistor, and the arm of the pot is bypassed by a 40-μfd (or greater), 150-volt capacitor. This is shown in the diagram, Fig. 1. The potentiometer can be placed conveniently in the hole that formerly held the bias-balancing pot. A bias-balance adjustment is no longer required, since the output transformer is of a design in which performance is not deteriorated by moderate current unbalance, and the tubes used do not have much variation in plate current drain.

The new potentiometer controls the bias voltage, which is fed to the bottom ends of the two 100,000-ohm output-tube grid resistors. These, of course, are no longer connected to the components formerly used in bias balancing.

The combination of changes described above has increased the power of the amplifier to about twice its ultra-linear rating and about 4 times its triode rating. This change alone makes an important improvement, but an equally important improvement can also be made by extending the stability margin of the amplifier.

Stabilizing the Amplifier

Criteria for good amplifier design have changed in recent years, and the stress is now being placed more and more on amplifier stability. Many amplifiers, while performing well under steady-state conditions, have exhibited muddy and harsh qualities when reproducing music. One reason for this is the fact that their transient performance is inferior to that under steady-state conditions. Another reason is that amplifier performance on loudspeaker loads is often not as good as it is with resistor loads. This point was touched on briefly before: its ramifications with respect to feedback instability are far-reaching. Many designers have come to the conclusion that stability has more effect on listening quality than distortion does! Consequently, increases in the margin of

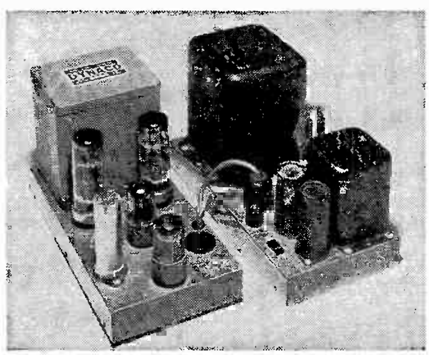


Fig. 3. New transformer goes on easily.

stability are important design problems.

By these standards, then, original Williamson amplifiers have inadequate stability at both extreme low and high frequencies. This can be demonstrated for the low end by touching the input grid momentarily with the fingertip and watching the speaker cone. The heavy low-frequency transient which is generated triggers the amplifier, and there are usually several surges before the effect is damped out. The speaker cone can be observed to move back and forth several times before coming to rest. This means that short signal impulses will also cause spurious cone movements which tend to blur the sound.

At high frequencies, the corresponding effect can be viewed on an oscilloscope with a square-wave signal input. A rippled square wave is indicative of basic instability, and indicates that there is a transient distortion of high-frequency signals.

Instability is due to the fact that the phase characteristics of the amplifier cause some of the feedback to be applied *positively* instead of *negatively* at the frequency extremes. The remedy is superficially simple — to shift the phase in the right direction at the critical frequencies. It is not always simple to do this. Fortunately, the phase characteristics of the A-430 transformer and the Williamson circuit arrangement permit complete correction of the low-frequency phase characteristic and appreciable correction of the high-frequency characteristic. These corrections are made with a few inexpensive components.

The low-frequency correction is achieved by shunting the 0.25-μfd coupling capacitors which go to the output grids with 1 megohm resistors. High-frequency correction is obtained with a 100-μμfd capacitor which is connected from the lower driver plate to the cathode of the first stage. Without going into the theory underlying these corrections, it is worth mentioning that they have a tremendous effect on performance. (It is assumed that the 10,000-ohm resistor in the input grid, change of the .05-μfd capacitors to 0.25, and the use of a small capacitor across the feedback resistor as indicated in the schematic are already included in the amplifier. If not, these should also be added in accordance with previous recommendations*.)

This completes the modernization of the Williamson. If the power supply puts out a full 450 volts with reasonable regulation, the output power will be about 50 watts at 1% IM distortion. If the power supply provides lower voltage, the output power will be reduced somewhat. Below full output, the distortion drops rapidly toward a vanishing point. The frequency response of the amplifier will be approximately the same as that of the original version except that peaks in the response (associated with instability) are eliminated. The transient response — that unmeasurable intangible — will be audibly better. It will be particularly evident in more solid, better-defined bass and smoother, cleaner treble.

*Hafler, D., "A 60 Watt Ultra-Linear Amplifier", *Radio & Television News*, February 1955.

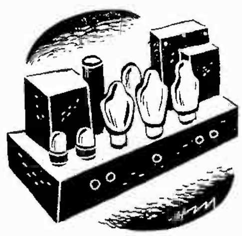
Appendix

The following specific hints will be helpful to those who are interested in modernizing the Heathkit W-3M Williamson:

The bias voltage divider and rectifier can go in the power supply chassis. Output of the selenium rectifier is connected to pin 5 of the power socket and carried through the spare wire in the connecting cable to one side of the 10,000-ohm bias-setting pot.

The 250-ohm and two 100-ohm resistors are discarded, as is the 100-ohm pot. The bias pot replaces the 100-ohm balance adjustment, and the blank tie points to which the 100-ohm resistors were fastened can then be used to connect leads which are part of the ground circuit.

In the interests of economy, the 20-μfd capacitor which formerly by-



passed the cathodes can be used for filtering the bias supply. The schematic calls for 40 μfd, but the difference in hum level is only 2 db.

Jacks formerly used for metering plate current can still be used to check equality of the output tubes. The former connection to the 250-ohm bias resistor must now be grounded in order to complete the circuit path for the cathode current. At the same time the No. 1 pins (suppressor grids of the output tubes) should be connected at the socket to the No. 8 (cathode) pins.

In order to insert the 10,000-ohm parasitic suppressor resistor directly at the input grid, the 2.2-megohm resistor should be reconnected directly from the input socket to ground. The 10,000-ohm resistor can then be inserted from the input connector to pin 1 of the first 6SN7 tube. This replaces the .05-μfd capacitor which is used as part of the bias supply in the power chassis. Make sure that the preamplifier used has an output coupling capacitor since the amplifier now has none in the input. Practically all preamplifiers are so equipped; if not, one should be added.

The .05-μfd coupling capacitors between the two 6SN7's should be increased to 0.25 μfd. Care should be exercised in order to get these to fit the space. If difficulty is encountered, it is suggested that miniature capacitors be used, such as Aerolites made by Aerovox.

The 1-megohm phase-correcting resistors across the coupling capacitors permit some positive DC to appear on the grids if the negative bias supply is inoperative. The existence of negative voltage at the grid should be checked with the rectifier removed before permitting the B+ voltage to be applied. Then the rectifier should be inserted and the bias set to 35 volts from grid to ground *after* the tubes have had time to warm up. Do not remove the second 6SN7 while the amplifier is on, because this will cause additional positive voltage to be applied to the grids of the output stage, upsetting the bias and possibly harming the tubes.

AUDIOCRAFT Test Results

The amplifier shown in Figs. 2 and 3, which was the basic Williamson converted in accordance with this article, produced 0.6% IM distortion at 50 watts output, 0.2% at 36 watts, and 0.1% at 15 watts. Below 15 watts distortion was in the residual range of the meter and could reasonably be called negligible if not unmeasurable. Test frequencies were 60 and 7,000 cps, mixed in a 4-to-1 ratio.

These readings could have been improved slightly by using parts matched more precisely, or by adding to the power supply filtering. It is doubtful that such small improvement would be apparent audibly. On the other hand, if the phase inverter balance were off, or certain other elements had drifted in value, the distortion figures might be doubled — still exceptionally good performance.

Frequency response was perfectly flat within the range of our test equipment. Calculated response, without the 100-μμfd feedback capacitor at the driver stage plate, is ±1 db from 2 to 200,000 cps; with this added, response above 80,000 cps slopes off smoothly. This capacitor causes a very slight increase in distortion at 20,000 cps, which is quite insignificant compared to the 12 db increase in the high-frequency stability margin. Stability at the low end, determined by recovery characteristics from a sharp overload pluse, was apparently perfect.

Square-wave response at low frequencies was excellent, and exceptionally good at high frequencies. Power response was completely flat from 20 to 20,000 cps at 50 watts. Total cost for all parts required to make the complete conversion: less than $40.00.

STEREO RECORDING with a Pentron

by Glen Southworth

THE many public demonstrations of multiple-channel sound reproduction recently have made most of us aware of new possibilities in listening enjoyment. Whether binaural or stereophonic techniques are used in pickup and playback, the results are a definite step forward, both technically and aesthetically.

Much attention has been paid to the obvious fact that multiple-channel sound can create the illusion of spatial perspective for the listener. This is, of course, a very important feature, but only one of several that the technique has to offer. Of nearly equal or greater importance, depending upon your point of view, is the fact that clarity can be improved significantly. It is well known that distracting sounds at a live concert can be relegated to the background by the listener; he is able to tune them out, as it were, and concentrate on the music. These same sounds recorded and reproduced on a single-channel system spring into such prominence that they interfere with enjoyment of the program, and they cannot be ignored. In stereo recording and reproduction the information is retained which enables the tuning-out process to occur. Also, limitations in equipment concerning frequency range and maximum power are not nearly so apparent as they are in a single-channel system.

So — a pertinent question is how to obtain binaural recording equipment without taking out a second mortgage. There are some very nice commercial stereo recorders available, but prices begin well on the way towards $1,000. This is quite an investment for non-professional use — fine if you can afford it, but, to encourage development of the field that should result from widespread amateur activity, relatively inexpensive equipment capable of good performance should be obtainable.

The first suggestion that comes to mind is modification of one of the readily available, home-type tape machines for simultaneous recording or playback of 2 tracks. Because half-track machines are used almost universally at the present time, the only problems involved are those of mounting a second record-playback head and connecting it to a separate record-playback amplifier.

A workable combination is the Pentron line of high fidelity tape components intended for custom installations. The unitized construction makes assembly of a 2-channel system relatively easy. In fact, if you already have a Pentron tape deck and associated preamplifier, all you'll need is another record-playback head and preamplifier, such as the Pentron HFP-1: an investment of about $70.

First step in the conversion is removal of the erase head from the tape transport mechanism and its replacement with a second half-track record-playback head. The 2 heads are virtually identical in physical appearance and are mounted on the chassis with a single screw. The cover picture shows the appearance of the tape transport mechanism with the head shield removed; the original erase head was located on the right. Once the new head is mounted, the removable pole piece within the head should be taken out and re-inserted upside-down so that it will record and play back on the bottom track of the tape.

Second step is the connection of a separate record-playback preamplifier to the newly installed head. This involves

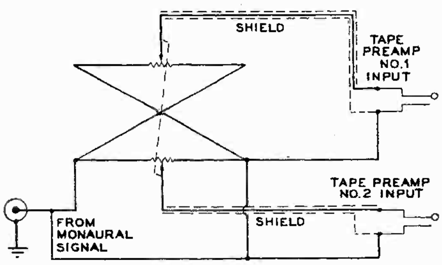


Fig. 1. Fader for pseudo-stereo effects.

only removing the 4-pin plug from the end of the preamp connecting cable, and soldering the center lead of the shielded cable to one lead from the head, and the shield to the other. The shield should also be grounded to the tape mechanism to avoid hum and noise. The other 2 leads normally supply erase current, but will not be used and should be taped up separately in order to prevent short circuits, either to each other or to the chassis. Note, too, that the solder lugs from which the erase head was disconnected will still be "hot" unless you make circuit alterations.

Since the tape deck no longer has an erase head, it will be necessary to use clean tape when making a recording. New tape may be used, or previously recorded tape may be erased on another full-width machine or with a bulk eraser. An alternative method, that may produce somewhat higher background noise, is to use a small PM erase magnet, such as the Webster-Chicago Wire Conditioner. The poles of the magnet should be mounted next to the *plastic* side of the tape. Tape can then be erased by situating the magnet before the first recording head during the recording process, or by running the tape through at high speed before recording. Be sure to remove the magnet before playing tape that you don't want erased!

As in a standard machine, the heads should be aligned before putting the equipment into operation. This is easily done by playing back a full-width alignment tape and adjusting the position of the playback heads, one at a time, for maximum output from a 7-Kc recorded tone. Loosen slightly the single large mounting screw and twist the head first one way and then the other until maximum response is obtained; the screw should then be carefully tightened down, taking care not to disturb the alignment.

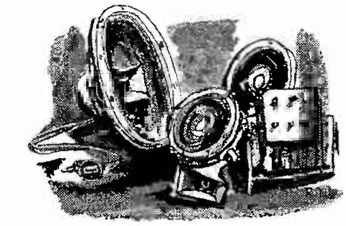
Horizontal alignment, or the distance separating the gaps of the two record-playback heads, will be of importance if you're considering the exchange of tapes or playing pre-recorded stereo tapes. The reason is that a displacement will affect the apparent location of sounds during playback. For this reason it is suggested that a reference sound such as a pop, click, or other transient noise be recorded simultaneously on both channels at the beginning of a recording. If microphones are used to pick up the reference sound, they should be the same distance from the sound source in order to provide a centrally located signal for playback alignment purposes, and gain controls on the preamplifiers should be adjusted to produce equal signal levels at each head. As an extra convenience a reference alignment tape can be made into a small endless loop by splicing the ends together. The signal will then be continually repeated, eliminating the need for hasty adjustments.

Stereo Recording

Now you're ready to start making re-

Continued on page 37

SPEAKER SYSTEM DESIGN NOTES



by Saul White

MANY people seem to think that those of us engaged in audio research enjoy unusual acoustic experiences denied to others. There is a suspicion that we may have important discoveries under wraps that will someday be suddenly released, and which will result in thrilling and dramatic super-advanced reproduction. This is not true.

There are thousands of audio systems operating in private homes today that render about as perfect reproduction as any laboratory system. Many a layman can justly glow with pride, knowing that there is little to distinguish between his home equipment and the best in professional use. In fact, the quality of sound reproduction now is limited by program sources; in the studio, in the record or pickup cartridge, in program transmission lines, and in TV sound pickup. Because high fidelity equipment often exceeds the range of broadcast equipment and techniques, we are plagued by the rumble of studio turntables, the dead quality of many live programs, low- and high-frequency losses, deterioration of remote programs because of poor transmission lines, line hum broadcast at easily audible levels, lack of uniform compensation between stations and even between programs from the same station.

Our recordings still contain far too much surface noise, although in recent months their technical quality has improved tremendously. Some record manufacturers attempt to get too much of a run from each master, so that the first hundred pressings may have substantially lower surface noise than those that follow. And the finest tape equipment, capable of amazing realism as it may be, is still quite expensive.

Yet the loudspeaker engineer is today faced with several problems. He must find answers to a variety of practical questions in order to improve his products still further and keep pace with the steady improvement in program sources. He must test his theories against actual listening tests since, obviously, blind adherence to theory without consideration of practical effects can result in unfortunate decisions.

But one trend is clear: the application of multiple speakers in 2-way, 3-way, or 4-way systems. Therefore, some of the more important questions that the industry must find answers for concern the following:

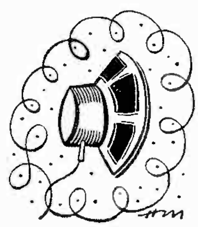
How much better is a 3-way than a 2-way (or coaxial) system, and how much superior is a 4-way system to a 3-way system? Where do we reach the point of diminishing returns?

In a 3-way system, is it preferable that the middle-range unit be a cone type (direct radiator) or a horn and driver unit type (indirect radiator)?

How important is phasing between speakers in a multi-speaker system, with each speaker operating in a different frequency band?

How important is an elaborate crossover network? Should this provide a cutoff rate of 6, 12, or 18 db per octave?

We already know the theoretical answers to these questions, but they are not enough. We have learned that they can be misleading in practical cases. The best answers cannot be found entirely in the laboratory, nor from any single expert listener. The answers should be obtained *statistically* from a large and varied group of listeners in the environment of an actual living room. This should furnish an accurate and objective evaluation.



Since little work seems to have been done in this field (or, if it has been done, the results have not been published) I attempted some simple experiments in my own living room. With the speaker components I used, and in my living room (which may not be as "average" as desirable), the results of my tests were occasionally surprising. It is up to the reader to decide for himself whether or not these results can be generalized with validity. In any case, it seems obvious that more extensive tests along similar lines might well be undertaken by some manufacturer or agency with resources adequate for a thorough job, and the results interpreted and published with profit to all.

Test Setup

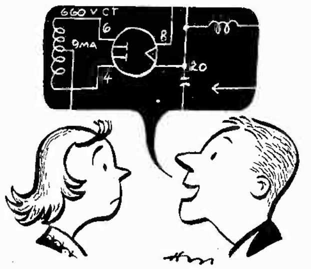
Essentially, the speaker system used was an arrangement of 7 units with an array of switches and networks to permit comparison of a variety of combinations. It was possible to convert the assembly into a 2-way, 3-way, or 4-way speaker system, with each speaker functioning over a specific band of frequencies by means of crossover networks.

The low-frequency end was covered by a 15-inch woofer in a horn-loaded enclosure having a flare rate of 40 cps. The back wave was absorbed in an airtight enclosure: only the front pressure reached the atmosphere through a 4½-foot folded air column. While a flare rate of 40 cps may not seem sufficiently low to some audiophiles, it must be remembered that for a given horn length (fixed by considerations of cost and size) a slower flare than this, giving a lower cutoff frequency, would result in a smaller mouth or terminating area. This would be a serious shortcoming in a corner horn, because an abrupt discontinuity would then exist with the flare of the adjacent walls of the room. Unless the horn flare and its mouth area blend smoothly with the diverging walls and floor, the acoustic effectiveness of a corner enclosure is largely lost.

Four 8-inch cone speakers above the woofer compartment operated in parallel in the middle range from 350 to 5,000 cps. A large double-mouth horn at the top of the cabinet could operate over the same band as the 8-inch cones or, alternatively, could be switched to operate in a frequency range adjoining and above these cones. The extreme high frequencies (above 5,000 cps) were handled by a dual tweeter, placed directly in front of the mid-range horn.

Continued on page 34

by JOSEPH MARSHALL



Practical Audio Design

Part I: Power transformers and rectifiers

ONE of the most frequent of problems faced by the amateur constructor — and one of the simplest to solve — is that of modifying a power supply design to suit some specific need (or to build a power supply using components on hand rather than those specified). These components account for an appreciable part of the cost of audio equipment; one of the easiest ways to reduce the cost is to make use of salvaged or bargain components rather than the ones called for in the circuit diagram.

The power supply performs 2 functions. It must convert the normal house-current line voltage to the higher and lower voltages required by the tubes, and it must convert high-voltage alternating current (AC) to single-direction (DC) current. Vacuum tubes used in audio equipment need a source of filament voltage ranging from 5 to 12 volts AC or DC. They also require a source of high-voltage DC ranging from 100 to 400 volts or more. But the power line voltage is, in most parts of this country, an arbitrary 115 to 125 volts AC.

Voltage conversion is easily achieved with a transformer, which consists of 2 or more coils of wire in close proximity; when AC is passed through one coil it induces voltages in the other coils. In power transformers the coils are wound on a common metal core, which increases the efficiency of coupling between them. If we have a transformer with 2 windings, and feed AC of a given voltage into one winding, the other winding will deliver a voltage proportional to the turns ratio of the 2 windings. Assume a transformer with one winding of 100 turns and the other of 10 turns: if we feed 100 volts AC into the 100-

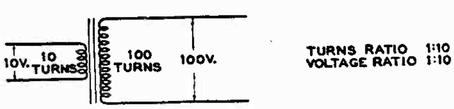


Fig. 1. Voltage ratio equals turns ratio.

turn winding we will get 10 volts out of the 10-turn winding or, conversely, if we feed the 100 volts into the 10-turn winding, the 100-turn winding will deliver 1,000 volts. See Fig. 1. We can use several windings with different turns ratios to obtain a variety of voltages. For example, we can have one winding of 115 turns, one of 5 turns, one of 6 turns, and one of 400 turns. If we feed 115 volts to the 115-turn winding, which we can call the primary, we will get 5 volts from the 5-turn winding, 6 volts from the 6-turn winding, and 400 volts from the 400-turn winding; this would give us the proper voltages for the rectifier tube filament, the filaments of the other tubes, and for the plate supplies of the amplifying stages.

There are various considerations such as efficiency, power factor, and regulation which determine the physical size of the coils, core material, diameter of wire, and so on. These are things nobody but engineers working for transformer companies need worry about. As

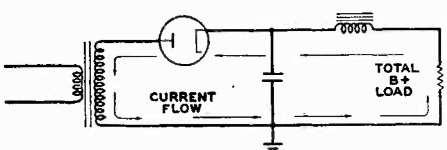


Fig. 2. A diode permits one-way current.

a user you need only know what transformer to use for a given application or how to make a given transformer serve in a particular application.

Choosing a Transformer

Most commercial transformers suitable for audio use have a single primary and 3 secondaries — one supplying 5 volts for a rectifier, another supplying 6.3 volts for the other tubes, and a high-voltage secondary which can supply voltages between 100 and 500 or more. The only worry about the filament secondaries is whether they can supply enough current to meet the needs of all the tubes used. A tube data book (such as the RCA Tube Manual) will help answer this question. Each table of characteristics begins with the filament voltage and current. Large power tubes of the 6L6 - KT66 class draw between 1 and 1.25 amps each at 6.3 volts. The typical voltage amplifier tubes used in audio circuits each require from 0.15 to 0.6 amps. It is only necessary to add the currents drawn by the tubes of the projected circuit and compare this with the specifications of the transformer. Catalogue listings of transformers always show the maximum current that may be taken from each winding. A typical transformer for an audio amplifier may have a 6.3-volt winding capable of supplying either 3.5 or 4.5 amps, and a rectifier filament winding capable of supplying either 2 or 3 amps.

Some small transformers suitable for control units, preamplifiers, and other small units have a single 6.3-volt filament winding and no separate rectifier filament winding. In such cases a rectifier must be used which has a 6.3-volt filament and a separate cathode (like the 6AX5, 6X5, or 6W4). The filament of the rectifier is connected in parallel with the other tube filaments, and the power supply filter is connected to the cathode.

Determining the suitability of a high-voltage winding is more complicated because both the voltage and current delivered depend to a considerable degree on the rectifier employed and the type of filter used. The purpose of the rectifier is to convert AC voltage into DC, and the purpose of the filter is to smooth the DC and reduce the residual AC ripple which would produce hum. Conversion to DC can be accomplished by connecting a diode rectifier in series with the load and the AC source, as indicated in Fig. 2. A diode conducts only when its plate is positive with respect to the cathode, and this condition occurs during every other half-cycle of an alternating current. The diode passes this half-cycle and, in effect, clips off the negative half-cycle. The result is indicated in Fig. 3. A is the waveform of a normal AC current and B is the waveform after it has been rectified by a diode. This is not yet a

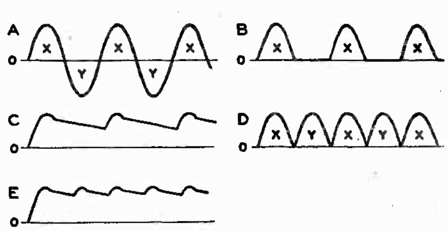


Fig. 3. Power-supply circuit waveforms.

suitable DC voltage. It can be turned into a pretty good facsimile of a direct current by passing it through a filter network consisting of a choke (or resistance) and a capacitor. Empty spaces between the peaks are filled in because the capacitor charges during the peaks and discharges during the nulls. The result is C, a current which is almost, but not quite, constant in amplitude. A smoother job can be done by full-wave rectification, achieved by connecting 2 diodes to a center-tapped transformer secondary winding, as in Fig. 4. The outputs of the 2 diodes will intermesh as indicated in D, Fig. 3. This produces

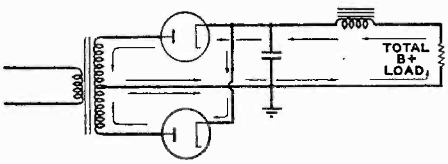


Fig. 4. A full-wave rectifier circuit.

a much smoother approximation of a direct current, and makes the filter's job easier. Fig. 3E shows the output of a simple filter following a full-wave rectifier.

With few exceptions, most power transformers suitable for audio use have center-tapped high-voltage windings designed for full-wave rectification. Catalogue information on such transformers gives the AC voltage available across the *entire* winding. When 2 rectifiers (or 2 halves of a dual rectifier) are used in full-wave rectification, the DC voltage output of the supply will be a little higher or lower than one half of this — a little more or a little less than 350 volts in the case of a 700 vct (volts, center-tapped) winding, depending on the type of power-supply filter used.

There are 2 basic types of power-supply filters. In a choke-input filter, Fig. 5A, a choke coil is the first filter element after the rectifiers; in a capacitor-input filter, Fig. 5B, the first filter element is a capacitor. In general, with a choke-input filter the DC voltage will be *lower* than the AC voltage applied to the plates of the rectifier. With a capacitor-input filter it can be considerably higher. A rectifier working into a series inductance produces a DC voltage which is slightly less than the RMS (root-mean-square, or effective) value of the AC voltage; but a rectifier working into a capacitor input produces a DC voltage somewhat less than the *peak* value of the AC voltage, which is about 1.4 times higher than the RMS value. Unless specified otherwise, sine-wave AC voltages are understood to be RMS values. On each side of the center tap of a 700 vct transformer winding, the unrectified voltage would be 350 volts RMS, and 495 volts peak.

There is a further complication. Rectifier tubes have internal resistance; therefore, the internal voltage drop is higher with high currents than with low currents. Accordingly the DC voltage available from a rectifier connected to a given transformer is determined not only by the transformer specifications, but also by the type of filter used and the current drawn. Fortunately the tube manuals provide charts, curves, and tables which reduce these apparently complicated interrelating factors to simple form. You can find what DC voltage can be expected for various AC voltage inputs, given load currents, and either choke- or capacitor-input filters. Fig. 6 is a curve from the RCA Receiving Tube Manual* for the 5V4. The curve shows, for example, that with 300 volts AC per plate, the 5V4 will deliver a little over 250 volts DC at 50 ma and a little under 250 volts at 150 ma, with a choke-input filter; but it will deliver about 375 volts at 50 ma and about 325 volts at 150 ma with a capacitor-input filter. It will be noted that while the capacitor-input filter produces a higher output voltage, the choke-input filter provides better regulation — that is, the difference in voltage between low and high current loads is much smaller.

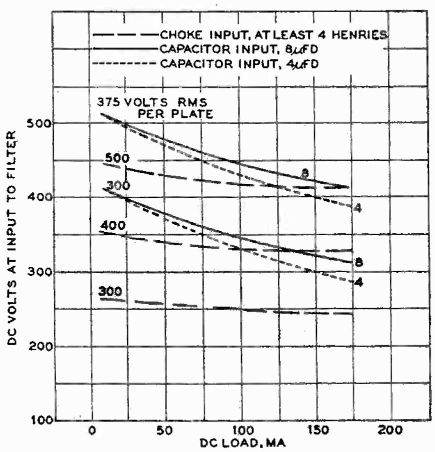


Fig. 6. Tube manual rectifier data chart.

Capacitor input, obviously, is preferable when a high voltage under a relatively constant load is required: choke input is preferable when the load varies widely but the voltage must be kept reasonably stable. High fidelity amplifiers using triode output tubes, or pentodes in an ultra-linear tapped-screen circuit present a fairly constant current load. For such amplifiers a capacitor-input filter is preferred because it permits the use of a less expensive power transformer for the same output voltage. On the other hand, amplifiers using pentodes in Class AB (for example) may have a current swing of 50% or more: it is then preferable to employ a choke-input filter so that the voltage may be kept fairly constant. If the voltage drops as the current rises, the maximum power output cannot be obtained and the advantages of using AB-type operation would be nullified to some extent.

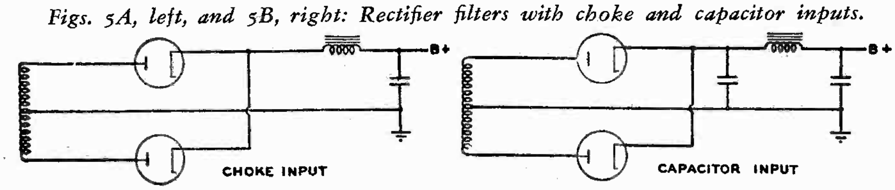
*Available from most parts distributors at 60 cents.

With this in mind, let us go through the steps of choosing a power transformer for a given job. Again a tube manual is an essential tool. First, we must establish the DC voltage and current needed. The RCA Manual rather falls down here, for it does not show operating conditions for the most frequently used hi-fi output tubes. However, tubes of the 6L6, 807, 1614, KT66, and 5881 family require between 400 and 450 volts on the plate for triode or ultra-linear operation, and, with normal bias, pass about 100 ma steady, possibly 125 ma at full output peaks. Voltage amplifying stages, inverters, and drivers need 300 volts or less. An acceptable rule of thumb for estimating their current requirements is to allow 10 ma for each low-gain triode (or half-section of a twin triode) and 2 ma for each high-gain triode (or half-section of a twin triode). This leaves a large safety factor. The current requirements of the filament strings are easily totaled from the tube manuals.

Let us take an example. Assume that we are designing an amplifier using KT66's in an ultra-linear output circuit. We shall need 400 volts or a little more for the output stage, which will draw 100 ma at normal levels and possibly 125 ma on peaks. We will use 2 twin triodes (12AU7's, 12AX7's, or 6SN7's). By our rule of thumb, they will draw 40 ma. Between 140 and 165 ma DC at 400 volts will be adequate. The KT66's will need 2.5 amps at 6.3 volts AC for the filaments. The filaments of 6SN7's draw 0.6 amps apiece, while filaments of 6SL7's, 12AU7's, or 12AX7's draw 0.3 amp apiece. So we will need somewhere between 3.1 and 3.7 amps at 6.3 volts for the tube filaments.

We will use a capacitor-input filter. A check of the rectifier tubes indicates that a 5Y3 will be rather hard pressed to deliver more than 125 ma and, at 125 ma, it would need at least 400 volts AC per plate to deliver 400 volts DC. On the other hand, a 5V4 is not only capable of delivering more than 150 ma, but it can deliver 400 volts at 125 ma with only 375 volts AC per plate, and needs no more filament current (2.0 amps at 5 volts) than the 5Y3. The 5U4 can supply about the same voltage and even more current, but needs 3 amps filament current. In any case, we can set our minimum and maxi-

Figs. 5A, left, and 5B, right: Rectifier filters with choke and capacitor inputs.



mum specs for the transformer. Minimum: 375 volts AC per plate (or 750 vct) and 150 ma; 6.3 volts AC at 3.0 or 3.5 amps; and 5 volts at 2 amps. Maximum: 400 volts AC per plate (800 vct) at 150 to 200 ma; 5 volts at 2 or 3 amps; 6.3 volts at 3.5 amps.

If we now consult the catalogues we find, for example, that the Stancor 8411 and Thordarson 22R33 each meet the minimum standard. The Stancor 8412 and Triad R-21A meet the maximum specs, while the Chicago PCC-200 (770 vct at 200 ma), UTC S-39 (800 vct at 175 ma), and Thordarson 22R34 (770 vct at 225 ma) fit in between minimum and maximum. The minimum transformers are a little smaller and lighter, require less space, and will probably heat up more: the maximum and intermediate units provide a higher safety factor, will probably run cooler, but take more space and cost more. However, any of them can do the job. The specific choice can be made on the basis of secondary requirements. For intermittent home use where the amplifier operates at low levels, the minimal transformer and even the minimal rectifier can be used. On the other hand, when the amplifier is used at high levels and/or for long continuous periods, it would be wiser to employ a maximal transformer.

Making an Old Unit Do

A saving can often be made by using a transformer salvaged from an old amplifier or radio. Several problems may arise. The first problem may be that of determining the specifications of the transformer. This is easily solved with the help of any meter capable of reading AC volts in the range between 2.5 and 1,000 volts. But before measurement is possible it may be necessary to identify the windings. If the transformer has colored-wire leads, the windings may be identifiable by the color code:

Primary (115 volts AC) ...... Black
(If the primary is tapped, the black lead is the bottom of the winding, the black and yellow is the tap, and the black and red is the top.)
High-voltage winding .... Red
Center tap .... Yellow and Red
Rectifier filament winding .... Yellow
Center tap .... Blue and Yellow
Filament winding No. 1 .... Green
Center tap .... Yellow and Green
Filament winding No. 2 .... Brown
Center tap .... Yellow and Brown
Filament winding No. 3 .... Slate
Center tap .... Yellow and Slate

But suppose the transformer has an unmarked terminal strip? An ohmmeter will help arrive at the truth here. First, by continuity tests identify the terminals for each winding. Now measure the DC resistance for each winding. The high-voltage winding invariably has an appreciable resistance — 50 ohms or more. The next highest resistance is that of the primary. The filament windings have very low resistances — 1 to 5 ohms or so.

Now get an AC cord with a regular plug at one end and stripped wire at the other end. Connect the stripped wire to the terminals you have decided represent the primary. Cautiously insert the plug into the power line receptacle, being ready to pull it out at the first sign of smoking or overheating. (Exercise caution to avoid any personal contact with the terminals.) If all looks well, measure the AC voltages across the other windings with an AC voltmeter. You can get a quick check of whether or not you really have the primary by noting the reading on the filament windings. If it is correct, the voltage will be quite close to one or more of the following: 1.25, 3.1 (½ of a 6.3-volt winding), 5, 2.5, 6.3, 7.5, 10, or 12 volts — possibly also 24 volts. If the AC isn't connected to the primary, you will get various odd

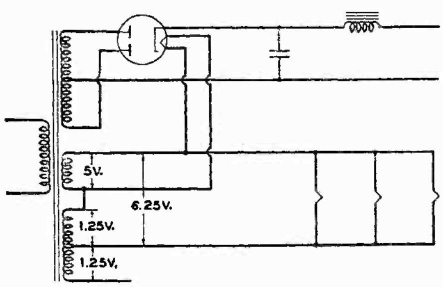


Fig. 7. Old transformer filament wiring.

values. Assuming you are correct, measure the voltage across the high-voltage winding or each half of the high-voltage winding. Tabulate the voltages and there you are. If you have reason to suspect you have the incorrect winding for the primary, try shifting the AC to the next most likely winding and try again.

There is no simple way to determine exactly the current ratings of the various windings. If the transformer came from an old piece of equipment a pretty good idea of its capacity can be derived from a study of the equipment. The type of output stage will give a clue to the capacity of the high-voltage winding; the type and number of other tubes should give some idea of the capacity of the filament windings. If no such information is available, the size and weight of the transformer may be helpful. A large, heavy transformer can be expected to yield at least 150 ma of high-voltage DC and from 3 to 5 amps of filament current without overload.

There is one thing to watch out for. Some transformers used in Army-Navy equipment, especially aircraft, are designed for 400- or 800-cps rather than 60-cps AC; they will *not* operate on 60-cps house current. These are relatively easy to spot. They may be la.ge, but they are light for their size because they have small cores (the main reason for using 400-cps power sources).

Modifying Transformers

Unless you live on a desert island and components are just about impossible to obtain, there is no sense whatever in trying to rewind a transformer to produce desired voltages. It is simply too difficult a job. Sometimes, however, you can adapt a transformer to do a job which at first glance it might seem unable to do. For example, many old radios have husky power transformers capable of delivering 250 or 300 volts at 125 or 150 ma, but they often have 2.5-volt filament windings. It is quite possible to make shift with one of these for modern 6.3-volt tubes if the 2.5-volt winding is center tapped. This can be done by wiring the transformer as shown in Fig. 7. Half of a 2.5-volt winding is wired in series with the 5-volt rectifier winding to produce 6.25 volts. If the first connection doesn't give the 6.25 volts, reverse the leads from one of the windings: if the phase is incorrect, the voltages subtract instead of adding.

There are 2 disadvantages in this procedure which must be taken into account. First, the current drawn through the 2 windings in series should not exceed (at least not by much) that permissible for the winding with the lower capacity. Usually, the rectifier filament winding has the lower current capacity — 2 or 3 amps. There are several ways of holding down the total current drain. For one thing, you can use a rectifier with a lower filament current drain. The 6AX5 will draw only 1.2 amps compared to the 2 amps of the 5Y3, but will deliver 125 ma of high-voltage DC. Its use would permit the employment of 3 12AX7's or 12AU7's or some combination with a total drain of 2.1 amps, well within the capacity of a 2-amp winding. In fact, 4 of these tubes and a total drain of 2.5 amps would not be a serious overload. If the high-voltage current doesn't exceed 50 or 60 ma, you can provide for an even greater number of tubes by using the 6X4 rectifier whose filament draws only 0.6 amps. This would be all right for a control unit in which even 5 or 6 twin triodes would not require over 50 ma plate supply current.

The other consideration is this: because the rectifier will operate from the same source of filament voltage as the other tubes, *it must have an independent cathode.* The 5V4, for example, cannot be used. With a filament-type rectifier the filaments of all the tubes would be at a DC potential above ground equal to the high voltage. Accidentally grounding one side or the other of the filament loop would burn all out immediately. In any case, the tubes could not tolerate the high filament-cathode bias very long.

Continued on page 34

How They Did It

CARNEGIE HALL ON WHEELS

by Brooking Tatum

SO you don't have a 40-foot listening room? Well, don't hang your head; maybe you can do very well in your (very) small quarters. Equipment has now been brought to such a level of excellence that those who have learned what they should about its selection and operation can now achieve their next quality advance in the successful adaptation of system and habitation to each other on an acoustic basis. Study your abode with care: it may contain hidden adaptabilities that do not reveal themselves to a first glance. I found this to be so. My problem was to get high fidelity sound reproduction, from radio and records, in a mobile home 17 ft. long, 7 ft. in diameter (sic), and of 500 cubic ft. total volume.

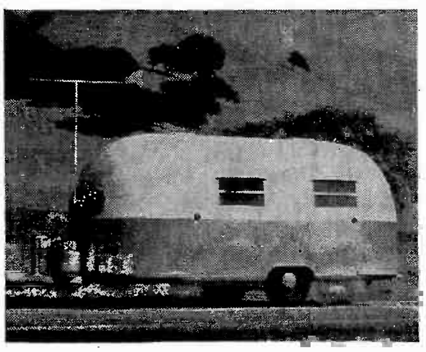


Fig. 1. Mr. Tatum's Carnegie Hall.

Since all living functions as well as the professional work of an artist and a naturalist are carried on in this small space, it is obvious that bulky sound equipment is out. All domestic fixtures and equipment are built in, for the simple reason that there is no room to walk around them. Therefore, audio equipment must not take up any new floor space. This stricture slowed the evolution of a high fidelity installation to a snail's pace and resulted in much reading and dreaming before the current, successful solution was conceived. The study and thought were worth while, however, for in time they bore real fruit. Results are of such a high order of excellence as to satisfy myself and professional acquaintances, including both engineers and musicians.

Despite the space limitations, there was achieved a 25 cubic-foot infinite baffle, sound output satisfactorily flat from below 30 cps to above 15,000 cps, and placement of all necessary equipment without *any* encroachment on living space. The key to achievement of all this was the principle of multiple use. Existing fixtures were made to do double duty. The trailer is built like an airliner: an outer and an inner shell of aluminum, with glass fiber insulation between. This seems to provide good acoustic qualities, being both somewhat reflectant and somewhat absorbent. One quarter of the floor area is taken up by a double bed: various bookcases, cabinets, nooks and crannies (and human bodies) provide further terminal absorption of sound. The result is good propagation of sound throughout the trailer, and quick die-away so that the echoes and reverberation built into a record or other program source are not compounded — and confounded — by undue re-echo and re-reverberation in the listening room. No wall is more than 12 ft. from any speaker, so echo time cannot be longer than 24/1,130 or 1/50 second, and room volume and absorption are such that audible (handclap) reverberation time is in the neighborhood of 1/5 second. Since ideal reverberation time *in performance* is considered to be in the range of from 1 to 2 seconds, it is apparent that reverberation *in reproduction* in this little listening room offers a minimum of competition to that recorded in the music. This is borne out in practice: reproduction is notably clean and fresh-sounding, and the lovely reverberations of the original performance are heard clearly and normally. I have listened to a number of home installations made in large rooms by competent acquaintances, and, while all sounded good, too many sounded like phonographs lost in large rooms to which they were not integrated acoustically. This trailer installation, on the other hand, to others as well as to the owners, when fed a near-perfect program signal produces a sriking illusion that the instrument or the voice is right in the room. Score one for the little listening room, when acoustically well-treated.

Other attributes of the trailer contribute to good listening. The curving walls and overhead, with the band-shell ends, produce no outstanding resonances, standing waves, or eigentones. There are no parallel flat walls. Fig. 1 is an overall view of the trailer. Almost complete sound integration is achieved because the number of resonances is almost infinite and, therefore, smooth in distribution, rather than finite and peaky in distribution. About the only audible resonances the room provides are those related to its volume: these are seldom noticeable and are easily ignored.

Advantage was taken of the curving overhead to provide good sound diffusion throughout the trailer, Figs. 2 and 3. Facing up on the flat top of a wardrobe is a Wharfedale Super 12-CS/AL. Its mid-range and treble are nicely reflected and propagated out, over, and down, by the continuous curve of the walls, to all parts of the trailer. A V-shaped aluminum reflector was found necessary to get the extreme highs to both ends of the trailer where the listening is done. This was a cut-and-try job, quite successful.

The 25 cubic-foot wardrobe provided the needed baffle for the speakers. As it is full of clothes anyway, no further provision had to be made to absorb the back radiation. Theory is borne out in practice: one can hardly hear the backwave even when the door is open. However, it was deemed desirable to stiffen the ¼-inch wardrobe walls and add mass by gluing and screwing ½-inch plywood to the inner surfaces, doors included. Weldwood adhesive was used together with ¾-inch Phillips-head screws driven through the ¼-inch and into the ½-inch wood. Neat spacing, and the neat cross-slots in the screw heads, make a pattern on the outside which is not objectionable to the owners. Because this is not a bass-reflex cabinet nor a *small* infinite baffle, and because speaker loading at all frequencies is externally provided, more rigid bracing and airtight construction were found not to be necessary.

Jones Apparatus Company 10.2-mh air-core coils and 80-μfd capacitors, which divide the amplifier output at 175 cps, are mounted inside the wardrobe. One coil is on a side panel and the other at right angles to it on the under surface of the top. Care was taken to

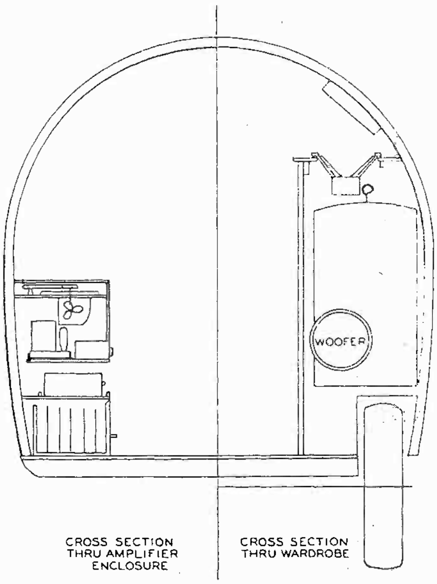


Fig. 3. Speaker and equipment locations.

place the coils where their magnetic fields would least interfere with each other and with the speakers. Fig. 4 is a diagram of the crossover network wiring.

The Wharfedale Super 12 weighs over 18 lb., so it is held by its own weight on a sponge-rubber ring (weather-stripping) which is self-adhesive to the top of the wardrobe. This makes a nice acoustic seal and cushions the speaker in transit. Instead of thickening the ½-inch plywood top of the wardrobe, as was done on the panels, the greater stiffness necessary was provided effectively by gluing and screwing ¾ by 1¾-inch wood ribs on edge to the underside, coming as close as possible to the speaker hole and extending, in the long dimension, to the ends of the board. The speaker is adequately loaded by its infinite baffle in the range above 175 cps, in which it works. A tweeter, in a 3-way system, had originally been intended — and may yet be added — but the highs put out by the large magnet, light aluminum coil, and bakelized cone apex of the Wharfedale are so satisfactory that the additional work and expense can comfortably be deferred until quite convenient.

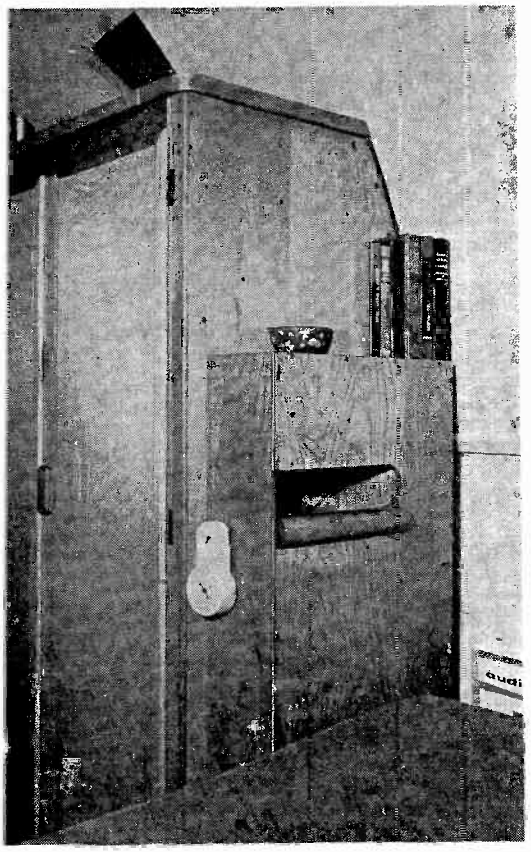


Fig. 2. Wardrobe used to baffle speakers.

Bass (below 175 cps) is smoothly and fully produced by a Junior Air Coupler driven by a 12-inch Stephens 120 LX woofer. The Coupler is screwed to the side of the wardrobe (which is fastened to both wall and floor) next to the bed, with its foot on the floor, filling a space not useful for much else. Its top makes a much-needed bookshelf. As it is the natural resting place of the gaze of anyone reclining on the bed listening, great care was taken in its construction to make it beautiful visually as well as aurally. It is made of ½-inch birch-veneer plywood and hand-finished with linseed oil. Weldwood adhesive and Phillips screws are used to fasten it to the wardrobe. To obtain maximum efficiency all the inside corners were blocked and faired with galvanized iron; continuous taper of the air columns was provided by shaping the long partition of 2 by 6-inch stock. Since the Coupler is firmly secured to the structure of the trailer, its full effectiveness is apparent to ear *and* body — organ pedal tones fairly earthquake us. (Plans and a description of this Junior Air Coupler were published in HIGH FIDELITY for May-June 1953.) Bass reproduction is smooth and distinct down to 30 cps, and falls off gradually to a clean 24 cps which is bottom on my test record.

The power and attack of this reproducing system are a source of continuing amazement. Its ability to encompass the entire tonal range of the symphony orchestra without effort or default is unexpected and extremely gratifying. Output seems to be essentially smooth: if there are any bass resonances they do not obtrude, so that listening is not marred by distractions. Of course, as has often been pointed out, familiarity, in audio, breeds acceptance. Still, there have been no complaints from the well-qualified listeners who have audited the rig, although a symphony conductor once thought he heard some slight intermodulation in a violin concerto passage.

It was found that the Wharfedale and the Stephens s~eakers balance naturally without controls, so the potentiometer normally included in the dividing network was removed. Speakers and the dividing network are connected to the power amplifier by waxed, cotton-covered, twisted No. 12 flex wire, run under the floor and behind the galley.

The power amplifier is a Heathkit W-4M, an ultra-linear Williamson type, on a single chassis for easier mounting in a mobile installation. Construction was carried out by the author with great care — result: no noise. The power amplifier is housed, along with the typewriter, office file, natural history reference library, Webster International Dictionary, record library, magazine rack, turntable, FM tuner, preamplifier, cooling fan, and assorted duffle, in a light but strong cabinet on the other side of the trailer from the speaker system. Thus, despite the general intimacy of accommodations, acoustic feedback is held to non-troublesome levels. Figs. 3 and 5 show this arrangement. The power amplifier has a plywood bottom board which rests on a ¼-inch mat of sponge rubber. Tall (1-inch), springy angle pieces of aluminum abutting the amplifier allow vertical movement (and removal) but prevent lateral shifting from road vibration. In a year of use and 10,000 miles of travel no microphonics have developed and only one tube has been replaced.

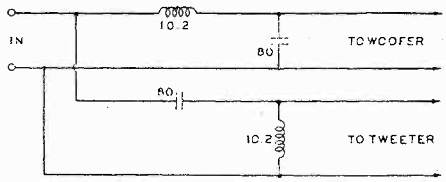


Fig. 4. The 175-cps crossover network.

The general-purpose cabinet just described takes up no new floor space: it merely formalizes and greatly improves a former collation of apple boxes, orange crates, and loose pieces of equipment in the same location. Despite its inventory of contents this cabinet is only 48 in. long, 35 in. high, and 19 in. deep at its wider end. It continues the lines of the stainless-steel galley to the front of the trailer. Construction is of ½-inch birch-veneer plywood, secured with 1¼-inch No. 8 wood screws, glue blocks, and screw blocks. Fastenings are mostly concealed. The finish is hand-rubbed linseed oil, giving a lustrous but quiet surface, which is not vulnerable either to mechanical or liquid damage. The top, comprising 5 separate pieces, was cut from one piece of plywood and reassembled in construction so that the original continuity of grain is preserved. A piano hinge is used in the folding lid of the turntable compartment. A spring-loaded, hinged trap door was cut from the front panel to accommodate the Heathkit WA-P2 preamplifier, which can also be used remote, at bedside. For reasons not yet

Continued on page 36

by E. B. Mullings

Using Test Instruments

Vacuum-Tube Voltmeters, Part II

SECOND OF A SERIES OF ARTICLES ON TEST INSTRUMENTS AND HOW TO USE THEM.

PART 1 of this article was concerned with the operating principles of vacuum-tube voltmeters, on the assumption that such instruments could be utilized more efficiently with a clear mental picture of how they work. Using basic circuits as examples, it was determined that a VTVM functions very much like an amplifier, in that an unknown voltage is applied to the control grid of a vacuum tube so that the resulting change in plate current can register on a meter. It was also explained how the usual multipurpose VTVM can measure AC or DC voltage, and resistance. The objective now is to discuss some of the specific tests that can be made on audio equipment with a VTVM, and to outline the procedures.

It is desirable to be able to make measurements on your own audio equipment for several reasons. If your sound system should stop functioning properly or collapse entirely, it is worth dollars to you to be able to trouble-shoot the equipment and remedy the situation. Even if you have the dollars to spare, service agencies able and willing to repair hi-fi equipment aren't common except in cities of appreciable size. Also, having the facilities and the knowledge required for testing will enable you to experiment with your equipment, learning more about it and about electronics in general.

Many experimenters measure the voltages present at various test points in their equipment to establish a "normal" set of readings, which is kept on file for comparison purposes. Then, should trouble occur, it is a simple matter to repeat the same tests and compare the results with those obtained under normal conditions. This will often show up the defective section of the circuit quickly, and in many cases reveal specifically the defective component.

Power Supply Measurements

Fig. 1 is a schematic diagram of a half-wave power supply circuit. Refer to Fig. 2 if any of the schematic symbols are unfamiliar to you. Most high fidelity equipment requires a full-wave power supply, but the half-wave circuit is simpler to understand and will make a better example, at least for this discussion of basic measurements. Both AC and DC measurements can be made in a typical power supply. AC measurements should be considered first.

The VTVM (a typical one was shown in Part 1) is set up for AC voltage

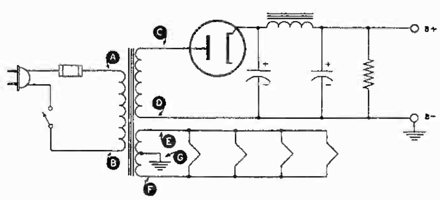


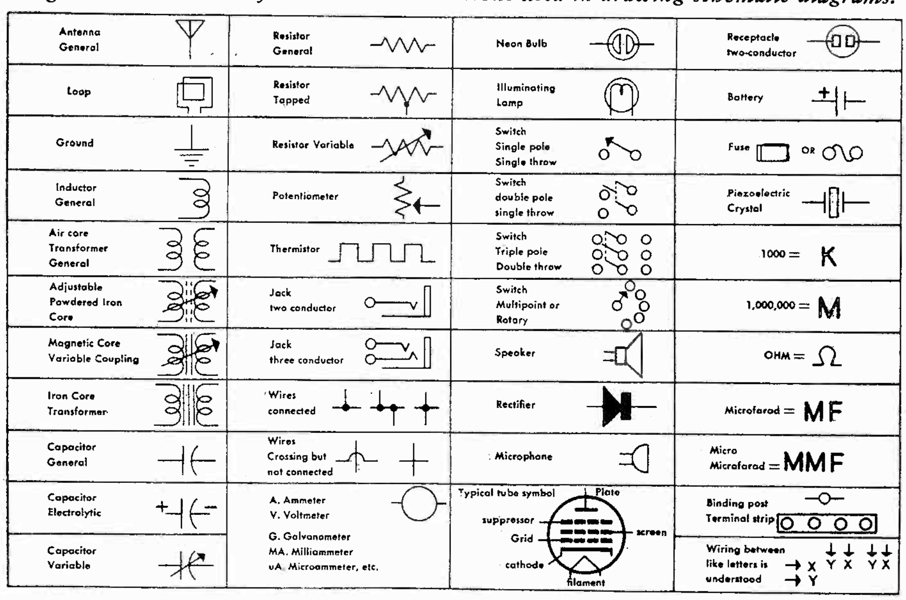
Fig. 1. Half-wave rectifier power supply.

measurements by first switching the function selector to AC. The range selector is set to the highest AC voltage range, regardless of the level of the voltage to be tested. This will eliminate the possibility of overloading the instrument. After the test leads have been connected to make the measurement, the range switch can be turned down to an appropriate position that gives a reading within the normal range of the meter movement. AC measurements are made with the black lead inserted in the COMMON jack, and the red lead inserted in the jack marked AC-OHMS. Some VTVM's have a separate test lead that is used with the common lead for AC measurements only.

The first step in making the measurement is to be sure the power is removed from the device being tested before the common test lead is connected, since it usually has a clip-on termination. To be doubly sure about this, pull out the line cord plug! Connect only one test lead at a time, leaving your other hand in your pocket. Then there will be no danger of putting yourself across a high voltage by connecting the 2 test leads at the same time. Also, always grasp the test probe by the insulated portion of the probe body, without touching the metal tip.

AC line voltage is probably the simplest test that could be made in the power supply section of the circuit. This should be measured at points A and B, Fig. 1. Remove the power plug from the wall socket. Connect the common test clip to either side of the power trans-

Fig. 2. Some common symbols and abbreviations used in drawing schematic diagrams.



former primary (either at the transformer itself or at the switch), remove your hand from the common test clip, insert the power cord, turn the switch on, and, with one hand behind your back, use the other hand to apply the red test probe to the other side of the power transformer primary. This places the VTVM directly across the power line (in parallel) and when you switch down to the appropriate AC range, the line voltage should read in the vicinity of 117 volts. Remove the power by removing the line plug before grasping the common test probe to disconnect it from the circuit.

This business of unplugging the equipment and handling the test clip and probe only when they are "cold" applies with *all* voltage tests. The procedure should become habit for your own safety.

If no AC voltage can be measured across the transformer primary winding with the plug inserted and the switch turned on, then either the fuse is blown or the switch is defective. In that event the line voltage will be measured when the test leads are placed across the terminals of the defective component.

Following the same procedure as outlined for measuring the power line voltage, the filament voltage of your equipment can be tested at points E and F. Physically, this may be done directly at the filament winding of the power transformer, or it may be made across the 2 filament terminals of one of the tube sockets. The final reading will be obtained on a lower AC range of the voltmeter, but to protect the instrument you should still start with the highest range and switch down until you get your reading. Notice, also, that if filament voltage were measured between points G and E, or G and F, only half the voltage would be measured. In almost all audio equipment the ground is at the center-tap of the filament winding, not at one side.

Another AC voltage test in the power supply circuit is that across the high-voltage secondary winding of the power transformer. This is measured at points

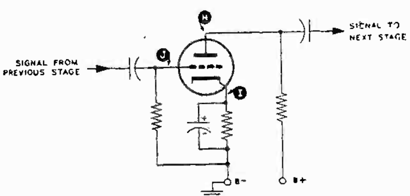


Fig. 3. Test points in voltage amplifier.

C and D. In the case of a full-wave rectifier, the voltage test would be made between one side of the high-voltage secondary winding and the center tap, or, to check the entire transformer winding, 2 measurements should be made; one from each side of the high-voltage winding to the center tap. The voltage present at these points is extremely high and you should be doubly sure to observe the safety precautions regarding power-off conditions when touching the probes or the terminals. An open in the high-voltage secondary winding of a power transformer is not an uncommon trouble, especially after an overload of some kind has occurred. Therefore, a lack of voltage across the winding could very well be a decisive test, and one that could lead you to the source of an irritating problem. In these, or any other AC voltage measurements, no polarity factor is involved. Either test lead may be used for either side of the voltage to be tested. It should be noted, however, that the case of the VTVM can be lifted above ground potential in such tests and become hot with respect to the chassis of the audio equipment being checked. This is because the common test lead is grounded, or connected to the VTVM case. Do not touch the VTVM case or panel and the chassis of the equipment being tested at the same time, unless the particular measurement you're making calls for connecting the common test lead to the chassis of the audio equipment, thereby making the cabinet and the chassis the same potential. Even though there is no polarity as such for AC measurements, it is good practice to connect the common lead to the lower-potential side of the voltage being tested.

One function of the power supply is to take AC voltage from your power line, increase it by means of the transformer, change it to single-direction current with the rectifier, and then filter it to obtain relatively pure DC voltage which can be applied to the tubes in various stages of the equipment for proper operation. Therefore, another of the tests that can be made in the power supply is a measurement of its DC output, or B+ as it is commonly called. To measure DC potentials, the following procedure should be used. The function switch of the VTVM should be set to the DC PLUS position and the selector switch set to the highest voltage range. DC tests are made with the common test lead and the test probe connected to the lead inserted in the jack marked DC. Polarity must be observed in DC measurements, and the common lead is *negative,* while the lead in the DC jack should be connected to the *positive* side of the DC source. As with AC measurements, the negative test probe should be connected to one side of the voltage to be tested *with the power off*; then, after the power is turned on, the positive probe should be applied to the hot terminal, taking care to touch only the insulated portion of the test probe. The B+ output from the power supply is high enough to be extremely dangerous, and all normal precautions should be observed as outlined previously. DC output from the power supply should be measured between points B— and B+, Fig. 1.

Measuring normal line, filament, high-voltage secondary, and B+ voltage can give you an excellent set of data for evaluating power supply operation. Most power supply troubles can be recognized by a change in one of these voltages.

Circuit Measurements

In addition to making measurements in the power supply, a VTVM can be used to measure operating potentials at the tube sockets of various stages in a piece

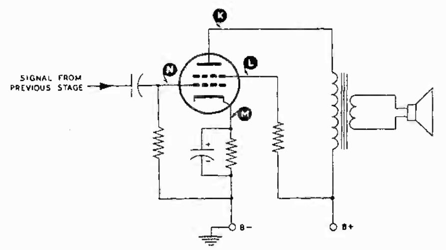


Fig. 4. Measurements in a power stage.

of audio equipment. A typical voltage amplifier stage is shown in Fig. 3. Apart from filament voltage, the operating potentials supplied to an amplifier stage are always DC. The negative side of the DC voltage (B—) is usually the chassis of the equipment in question. Therefore, the common test lead can be connected to the chassis for all the DC tests, and the positive test probe can be moved around to the various points where measurements are to be taken.

Referring to Fig. 3, the plate voltage of an amplifier stage is measured between point H and the chassis (B—). The plate is positive and the chassis negative, so the test leads should be used accordingly. If the tube is conducting there is a voltage drop in the plate resistor, so the plate voltage will, normally, be less than B+. Bias voltage for this simple stage is measured between point I and B—, with point I being positive and B— negative. This bias potential also appears on the grid of the tube; it can be measured by testing between point I and point J. In this case the common lead would be connected to point J, and the positive lead to point I.

Measurements at the tube sockets require a knowledge of the connections between the tube elements and the socket terminals. A tube manual, available free from some wholesalers and distributors, or available at a very small charge from others, will enable you to look up the particular tube type and determine from the base diagram how the tube elements are connected to the socket.

In addition to a voltage amplifier, your high fidelity system will undoubtedly contain a power amplifier as well. A simplified circuit of a power amplifier

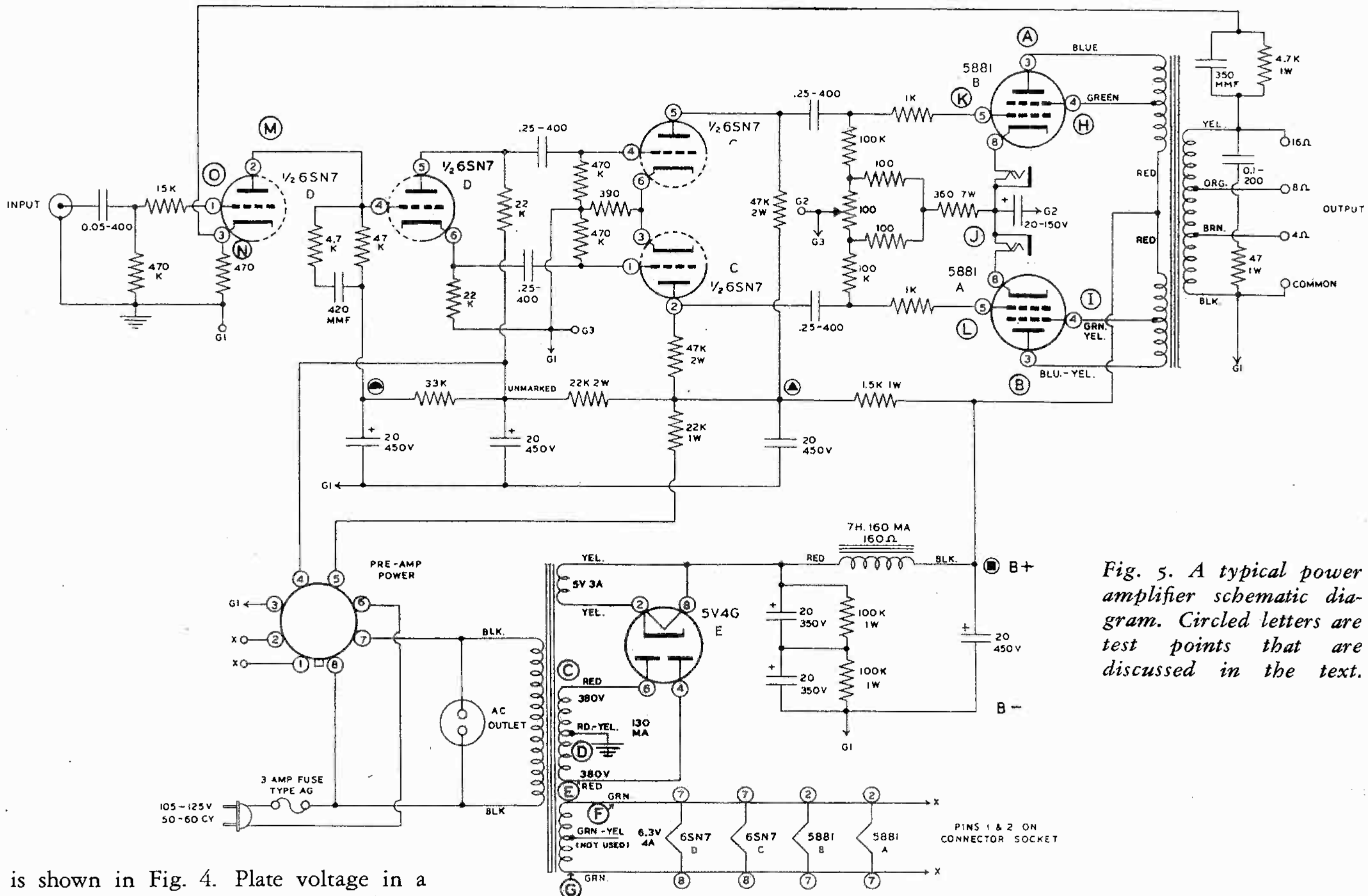


Fig. 5. A typical power amplifier schematic diagram. Circled letters are test points that are discussed in the text.

is shown in Fig. 4. Plate voltage in a power amplifier stage is measured exactly as it is in a voltage amplifier stage. In Fig. 4 this is from point K to B—, with point K being positive. Screen grid voltage is measured from point L to B—, with point L being positive. Bias voltage is measured between point M and B—, or between points M and N, with point M being positive. All these are DC measurements. The only AC measurement to be taken would be the filament voltage. Most troubles in an amplifier stage will reveal themselves through some change in the operating voltages. Should you find one of the voltages higher or lower than normal, it would immediately point to trouble in that particular section of the circuit.

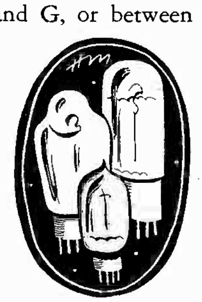
Although it may not be encountered often in audio equipment, there are some occasions when the DC voltage to be measured is negative with respect to the chassis, not positive as has been true for all the DC readings described so far. When this happens, it is usually necessary to reverse the test leads and connect the positive lead to the test chassis, using the common lead for the "hot" measurement. However, some VTVM's are provided with a DC— position on the function switch, which automatically reverses polarity within the instrument itself. The test leads are then connected as for positive measurements.

Typical Measurements

Fig. 5 is a complete schematic diagram of a modern amplifier. This schematic shows the power supply, the voltage amplifier stages, and the push-pull power amplifier stage. Inspection of this diagram will reveal its similarity to the simplified circuits used to illustrate the test points thus far. This schematic is probably similar to that of your high fidelity amplifier, and it may be helpful to look it over and try to locate some of the test points for various measurements.

The power supply section of this schematic shows a full-wave rectifier circuit. Therefore the AC voltage across the high-voltage secondary is measured beween point C and the chassis (point D), and between point E and the chassis. Both will be AC voltage measurements.

Filament voltage is measured between points F and G, or between the appro-



priate pins of one of the tube sockets. The parallel filament string is shown as part of the power supply. This particular amplifier uses AC filament voltage entirely.

The high-voltage *DC* output from the power supply is measured between the points marked B+ and B—. The common test lead connects to B— (chassis). Plate voltage for the push-pull output tubes is measured between the chassis and point A or B. Output tube plate voltage readings should be equal in magnitude. Screen grid voltage is measured from the chassis to point H or I for each tube. The chassis is negative in each instance, and the test leads should be connected accordingly. Bias voltage for both output tubes is measured between point J and the chassis, or between point J and point L, with point L being negative.

Plate voltage for a voltage amplifier stage is measured between point M and the chassis, with bias voltage being measured between point N and the chassis or between points N and O, with point O being negative. This particular schematic shows pin numbers on the diagram for the various tube elements, and saves the extra step of referring to a tube manual for identification.

Fig. 6 shows a useful voltage chart that can be prepared for your particular amplifier. AC and DC measurements can be made when the equipment is known to be in good operating condition, and the values can be marked on the chart for reference when trouble is indicated.

In addition to the AC and DC voltage measurements described, the VTVM can be used for other tests. For example, it can indicate DC potentials across individual components, such as resistors. To make such tests the leads are connected directly to the terminals of the part to be tested, with the negative test lead applied to the terminal known to be more negative. Extreme caution should be observed here, because the case of the vacuum-tube voltmeter itself is at whatever potential the common test lead is connected to. Therefore, if you're checking the voltage across a part in the plate circuit of a stage, and you connect the common test lead into the plate circuit, the cabinet and panel of the VTVM are at plate potential with respect to the chassis of the piece of equipment under test. Extreme caution should be observed not to touch the chassis of the equipment and the case of the VTVM at the same time. Aside from this, however, the instrument is used and read much the same as when measuring operating potentials for the tubes. An alternative method — longer, but safer — is to measure the voltage at both terminals with respect to the chassis, and then subtract the readings to obtain the voltage across the circuit element.

Other Measurements

A VTVM may also be used to determine the AC or DC current flowing in a circuit. Many cannot measure current directly, but, by applying Ohm's Law, the current value can be found quickly. In order to determine the current, you must know the voltage drop across a resistor and the value of the resistor. Resistor value may be determined by reading the color code, or by actually measuring it (resistance measurements will be covered later.) The voltage drop across the resistor can be checked with the VTVM as described previously. When resistance (R) and voltage (E) are known, the current (I) flowing through the part can be found by using Ohm's Law. In Fig. 7 is shown a circle containing the letters E, I, and R. By holding your finger over the unknown value, the formula for finding that value is revealed. For example, if you want to find current, cover up the I, and you will see that current is equal to voltage divided by resistance. By the same token, if E were to be determined, cover up the E and it is evident that current times resistance equals voltage. Finally, if R were unknown, covering up the R would reveal that it is equal to voltage divided by the current. This little symbol is easy to visualize and handy to work with in remembering the 3 different forms of Ohm's Law. You can use this principle to determine current with your VTVM.

Power supply ripple voltage can be measured also. This is the amount of AC voltage remaining at the output of your power supply (between points B+ and B—) after the choke and capacitors have performed their filtering action. All you need do to make such a test is to set up the VTVM for ordinary AC measurements and then connect the 2 test leads across points B— and B+ to see how much AC voltage is present. Use the common lead on B— to keep the VTVM case "cold". The value should be very small, less than 1 volt. Excessive AC ripple usually indicates a defective electrolytic condenser in the power supply.

A VTVM may be used also to measure signal voltages at the control grids of the tubes in the amplifier, such as that shown in Fig. 5. The test procedure for ordinary AC measurements is followed. It should be found that the signal voltage becomes progressively larger as you test through the various stages of amplification toward the output of the amplifier, except in the case of a cathode-follower stage or a split-load phase inverter (the second tube section, Fig. 5). If the signal value is large enough, the VTVM can be used to measure it at almost any point in your sound system. The lowest voltage range on the VTVM used as an example is 0 to 1.5 volts, which gives sensitivity sufficient for many low-level measurements.

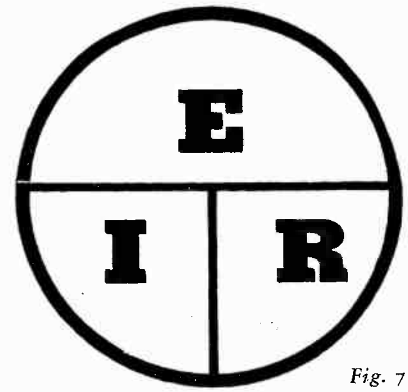


Fig. 7

With a test record or signal generator the frequency response of your entire amplifying system can be measured by connecting the VTVM across the speaker terminals on the power amplifier.

Resistance Readings

Most VTVM's can measure resistance in several ranges. Ohmmeter tests are extremely valuable in investigating circuit paths, tracing wires through the circuit, and determining the condition of individual components in the circuit. However, it must be emphasized that resistance measurements should *never* be made in a circuit until *all power is removed*. Not only is there danger of shock when making resistance measurements with the power on, but the ohmmeter portion of the VTVM circuit may well be damaged if voltage is applied to it.

To measure resistance, set the function selector switch to OHMS and the range selector to a range that seems appropriate for the test you're going to make. Use the common lead and the lead marked AC-OHMS or OHMS for the test. The meter will indicate the total amount of resistance connected between the 2 test probes. (It should be noted that a resistor connected in a circuit may have another path between its terminals that will lower the reading. For higher accuracy disconnect one of the resistor leads and then make the measurement.) The scale of the meter marked OHMS is the one you read for resistance measurements. This scale is non-linear, in that the divisions are closer together at one end of the scale than they are at the other. A range should be selected that brings the meter reading into the spread-out central portion of the scale. The multiplier given at the range switch position used will indicate how many zeros to add to the reading on the meter.

An ohmmeter also proves valuable in checking to see if tube filaments are open. If no indication of resistance can be obtained when checking between the 2 filament pins of a tube (while the tube is removed from its socket) the tube filament is open and the tube should be replaced. The ohmmeter will allow you to check between tube elements to see if there are any undesirable shorts between elements. With experience you can tell with ohmmeter tests the condition of other circuit elements such as large capacitors, transformers, and so on. Always remember, though, that the ohmmeter section of the VTVM cannot be used in energized circuits.

The VTVM is one of the most versatile of test instruments. It can go a long way in itself toward providing test facilities for construction, repair, and maintenance of sound equipment, and is the basic tool of the hobbyist.

TUBE TYPE	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
First 6SN7	0	50	1	50	200	60	3 VAC	3 VAC
Second 6SN7	0	140	3.5	0	140	3.5	3 VAC	3 VAC
Either 5881	0	3 VAC	430	430	0 to 10	0	3 VAC	36
5V4G		450		350 VAC		350 VAC		450

Fig. 6. Normal-voltage chart you can set up while amplifier is working properly.

BASIC ELECTRONICS

III: Resistance

by Roy F. Allison

AMONG the more important points that have been made so far in this series are the following:

1) Electricity is the flow of electric charge, either as electrons or, in chemical reactions, as ionized particles. This flow is caused by the existence of excess electrons at one point relative to another, and the fact that like charges repel one another while unlike charges attract one another. The practical unit of electric charge (Q) is the coulomb, equal to 3 billion esu or 6.25 billion billion electrons.

2) Current is the rate of flow of electric charge; the basic unit of current (I) is the ampere. One amp is a current of 1 coulomb per second, and amps are the number of coulombs per second:

$$I = \frac{Q}{t}.$$

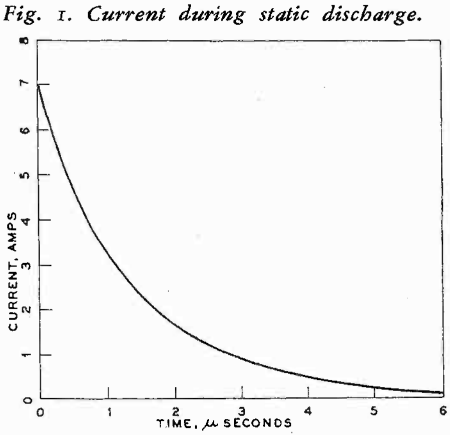
3) Electric charge will flow between points for which there is a potential difference, if permitted to do so, and will do work in the process. Conversely, work must be expended to raise a charge from one potential (V) to a higher one. The value of potential difference, emf, or voltage (E) is 1 volt if 1 joule of work (W) is done when a charge of 1 coulomb moves from one point to another. Accordingly, volts equal joules per coulomb:

$$E = \frac{W}{Q}.$$

Resistance

In a previous discussion on electrostatic charges it was pointed out that when 2 bodies having opposite and equal charges were left suspended in air, the excess electrons on one would very slowly leak off and make their way through the air to the other. Connecting the bodies with a material such as glass had relatively little effect on the charges, while connecting them with a copper wire resulted in quick and virtually complete charge neutralization. Evidently some materials permit the flow of electric charge more readily than others. Those substances which permit charge to flow with ease from one point to another are called generically conductors; those that restrict the rate of flow severely, insulators; those which fall in neither class, semi-conductors. These divisions are not clearly defined since, if common materials are listed in order according to the facility with which they conduct electric charge, it will be seen that there is a fairly gradual change from very high conductance to very low conductance.

Fig. 1. Current during static discharge.



Let us examine that process of charge neutralization more closely. Before a conductor is bridged between the charged bodies a certain difference in potential exists between them. As soon as contact is made with the conductor the charge begins to flow; as it flows from one body to the other, the voltage between them is continually being reduced, with the result that the charge flow gradually becomes less intense. Since the time rate of charge flow is defined as current, we can say that the current begins at a certain value in amperes and decays in a non-linear manner as the discharge is completed. If a chart of current is made on a basis of time from the beginning of the discharge, it would look very much like that in Fig. 1. Current in amperes is plotted on the vertical scale, and time from the beginning of the discharge on the horizontal scale. Units of time are μseconds (microseconds, or millionths of seconds). At the moment of conductor contact the current assumes a value of 7 amps. This decreases rapidly at first, because the heavy current reduces the voltage quickly; the reduced voltage makes the current smaller, which in turn reduces the voltage more slowly, and so on. In about 5 μseconds the discharge is practically complete, although theoretically it is never entirely completed. This is known as an *exponential* decay curve.

Assuming the same charged bodies and the same conductor between them, it is self-evident that a higher initial charge — a greater voltage between the bodies — would produce current that was higher initially and during the entire time of discharge. The curve in Fig. 1 would simply be raised vertically upward. If the initial voltage were doubled

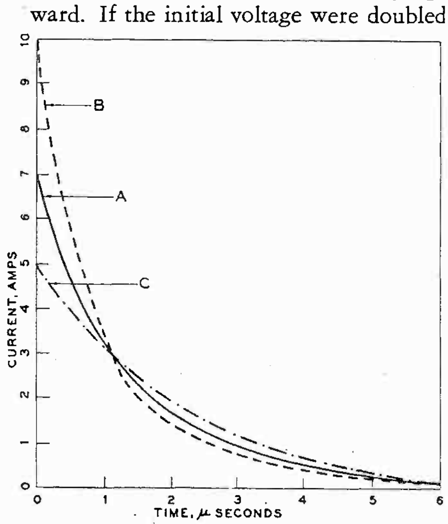


Fig. 2. Effect of changing conductance.

the current value at any time from the beginning of discharge would be doubled; by the same token, half the initial voltage would produce current values exactly halved. The curve *shape* would not be affected.

It should also be apparent that the discharge will be affected by the material of the conductor, since this determines (primarily) its conductance. The curve in Fig. 1 is reproduced in Fig. 2 as curve A. Suppose the charge is the same, but the conductor is replaced by one having greater conductance. The initial surge of current is higher than before, but it decreases more rapidly than before; the discharge is "finished" sooner, as shown by curve B. If the conductance of a third conductor were less than that of the original, it would permit less initial current — but the current would not decay so fast; see Fig. 2C.

What may not be so obvious, but is of equal importance, is that current is affected also by the dimensions of the conductor. If the cross-section area of a conductor is doubled it presents half the hindrance to the flow of electric charge, because it will contain twice the number of free electrons at any given longitudinal location. For a given voltage, therefore, the current will be doubled. Reducing the cross-section area reduces the number of free electrons, so that for a given voltage the current is reduced. In the same way, if the length of a conductor is doubled it represents twice the obstacle to the flow of electric charge; the rate of flow (current) is accordingly

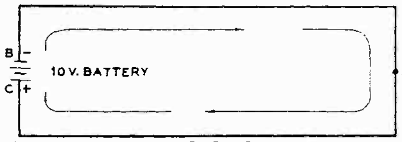


Fig. 3. Circuit with high-resistance wire.

halved for a given voltage. Reducing its length increases the current caused by a certain voltage.

We have been working toward the point at which it would seem more convenient to think in terms of how much a conductor *restricts* the rate of electric flow, rather than to what degree it passes charge freely. "Rate" is the key word here. Any material, of any conceivable dimensions, will discharge a static charge eventually, since the material will have a finite (even if very low) conductance, and a static charge consists of a limited number of electrons. This is not a dynamic phenomenon. A battery or an electronic power supply however, furnishes a relatively constant potential difference or voltage, no matter for how long or at what rate electric charge is circulated (within limits, of course!). Thus current may be continuous and unchanging, and with a constant voltage it is determined by how much the conducting elements in a circuit restrict or resist it. *Resistance* of a circuit is simply the inverse of conductance; it is designated formulatically by R The unit of resistance is the ohm, after Georg Ohm, who established the relations among current, voltage, and resistance known as Ohm's Law. Ohm or ohms is often represented by the Greek letter Omega (Ω).

We have already seen that current in a circuit is directly proportional to voltage. It was reasoned as well that current is directly proportional to conductance; it is accordingly inversely proportional to resistance. The same relations hold in steady-state circuits as in static circuits. They are stated in Ohm's Law as follows:

$$I = \frac{E}{R}\,.$$

This formula also serves to define the ohm: An ohm is that resistance which will permit a current of 1 amp in a circuit when the emf in the circuit is 1 volt. The formula is a powerful tool, since it can be used in any part of a circuit as well as in the complete circuit. It can be used to find the third quantity when the others are known, simply by restating the formula in different ways:

$$I = \frac{E}{R}\,,\; R = \frac{E}{I}\,,\; E = IR.$$

That is, current in any element of a circuit can be found by dividing the voltage across that element by its resistance; if E is in volts and R in ohms, I will be in amps. The value of a resistance can be found by dividing the voltage appearing across it by the current through it. Voltage drop across a resistance can be determined by multiplying the resistance value in ohms by the current in amps. The application of Ohm's Law to typical circuits will be covered in more detail later.

Resistance of any circuit element is related to its dimensions by *resistivity*, a function of the material. Quite simply, resistivity of a material is the resistance of a section 1 cm square and 1 cm long. The symbol for resistivity is the Greek letter rho, and it is expressed in ohm-cm. As the resistivity of materials increases, of course, the resistance becomes greater for samples of the same size. Following is a partial list of resistivities for common substances:

Table of Resistivity

Substance	Resistivity, ohm-cm.
Aluminum	3×10^{-6}
Brass	6.5×10^{-6}
Carbon	$5{,}000 \times 10^{-6}$
Copper	1.7×10^{-6}
Glass	8×10^{14}
Gold	2.4×10^{-6}
Iron	12×10^{-6}
Lead	21×10^{-6}
Mercury	96×10^{-6}
Mica	2×10^{16}
Nichrome	115×10^{-6}
Nylon	9×10^{12}
Platinum	11×10^{-6}
Polystyrene	1×10^{17}
Porcelain	5×10^{8}
Rubber	1×10^{14}
Silver	1.6×10^{-6}
Steel	17×10^{-6}
Tin	12×10^{-6}
Tungsten	5.6×10^{-6}
Wax	1×10^{13}
Zinc	6×10^{-6}

The multipliers indicated for these figures are concise means for expressing decimal places. Superscripts for the figure 10 indicate the direction and distance to move the decimal. The number of the superscript indicates the number of places the decimal should be moved; a positive number indicates movement to the right, and a negative number, to the left. For instance: the resistivity of glass is given as 8×10^{14} ohm-cm. This is the figure 8 followed by 14 zero's, 800,000,000,000,000, or 800 trillion ohm-cm. For copper the resistivity is given a 1.7×10^{-6} ohm-cm; this is 0.0000017 ohm-cm, or 1.7 microhm-cm. Glass, then, is about 500 billion billion times as resistive as copper.

Let's look at another circuit now. In Fig. 3 a long wire of moderately high resistance is connected to the terminals of a battery (the schematic symbol for a battery is alternate long and short lines, with the negative terminal represented by the final short line). For purposes of discussion, we'll assume that the battery produces 10 volts, that it has negligible internal resistance, that the total wire resistance is 10 ohms, and that the total battery can deliver the 1 amp current that will result. The wire itself must account for the entire 10-volt drop around the circuit; since wire is ordinarily of uniform cross-section and of the same material throughout, it can be seen that the voltage drop will be uniformly distributed along the wire's length. At the mid-point of the wire, point A, the voltage should have dropped by half; point A will be 5 volts positive with respect to point B, and 5 volts negative with respect to point C. This checks with Ohm's Law: 1 amp through 5 ohms (half the total resistance) produces a drop in voltage of 5 volts. The main consideration here, though, is that there is a voltage drop in the wire; therefore work is done, and power is dissipated in the wire in the form of heat. This is certainly desirable *if* the objective is to generate heat, such as in an electric toaster or oven. In most applications, however, line heating is not desired — it is considered wasteful. Lines that are used to connect a source of voltage to a separate load are, therefore, fabricated from materials of low resistivity such as copper, aluminum, or brass; low-resistance contacts are made of brass, silver, or gold. Materials such as nichrome are employed when line heating is desired.

To see how this works, suppose that we want to power a light bulb from a 10-volt battery, and that we simply connect it to the battery with the line we used in Fig. 3. The new circuit is given in Fig. 4. To make calculations easy we assume that the bulb has a resistance of 10 ohms, the same as that of the line,

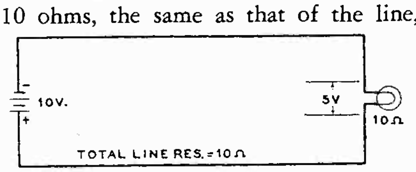


Fig. 4. Load added to circuit of Fig. 3.

and that it requires 10 volts to light with full brilliance. The total resistance in the circuit is 20 ohms; the 10-volt battery then produces a current of 0.5 amp. Across each 10-ohm resistance — the line and the bulb — there will be only 5 volts. The work done on the line, which is half the work done in the entire circuit, is wasted and the lamp does not light to full brilliance. Let us assume that we replace the line with one having a resistance of only 0.1 ohm; see Fig. 5. The total resistance is now 10.1 ohms, which will permit a current of 0.99 amp in the circuit. The voltage drop in the line is then 0.99 × 0.1, or only 0.099 volt; that across the bulb is 0.99 × 10, or 9.9 volts — very nearly that of the battery. This line is obviously much more efficient than that in Fig. 4.

In more complex electrical circuits, lumped resistances of various values, called *resistors,* are used extensively as circuit elements. Most are made of carbon, either compressed with a binder or deposited as a film on a forming cylinder. When special characteristics are required, such as high power-handling ability or greater precision, they are often made of high-resistivity wire wound on a former.

It should be interesting to check our familiar hydraulic analogy, and to find out whether or not it still holds water. You'll recall that we considered a closed hydraulic system — a long pipe connected from the outlet to the inlet fittings of a pump, and the whole filled with water. Voltage between the terminals of a battery was compared to the pump pressure, the total quantity of water in the system to circulating electric charge, and the flow rate in gallons

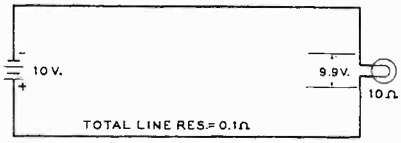


Fig. 5. Low-resistance line with a load.

per second to current. Such a system is similar to the circuit in Fig. 3. Where does resistance fit into this analogy? Well, what can limit the rate of water flow? Aside from turbulence, only the fluid friction of the water in the pipe. Reason tells us that with a given pump pressure (voltage), there will be a certain definite rate of water flow (current) determined by the total friction (resistance). If the length of pipe is decreased, friction is reduced and the flow rate increases; if the pipe is lengthened, the total friction is increased and the flow rate curtailed. If we use pipe of greater diameter the friction is reduced, so the flow rate increases; if we economize and use smaller pipe we must pay the price in fewer gallons per second. When the pipe is uniform over its entire length there is a gradual decrease in pressure from the pump outlet to its inlet, just as there is a uniform voltage drop along the wire in Fig. 3. Finally, if we use fairly large pipe except for a drastic constriction at one place, most of the pump's pressure will be developed across the constriction and most of its work will be done there. This corresponds to the circuit in Fig. 5. The analogy fits quite well, and it may be easier (although not precisely correct) to visualize the interrelations of voltage, resistance, and current with its help.

GROUNDED EAR

Continued from page 4

ahead of the listener. Is this information either necessary or especially relevant to the enjoyment and appreciation of music?

Obviously personal preference, taste, and previous conditioning will play a large part in deciding whether the answer for any given person is positive or negative. It would be foolish of me to present my own reactions as representative, and dangerous to base my conclusions as to stereo's future on my reactions alone. But I think I can pertinently make some points based not only on my own reactions and prejudices, but also on more general and basic considerations.

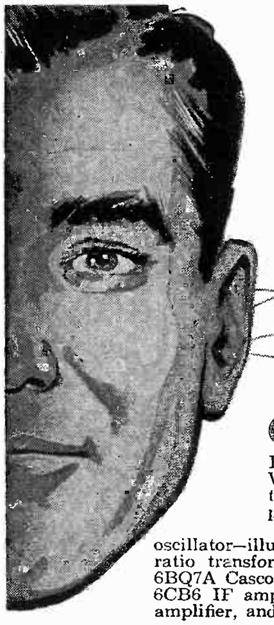
My answer was negative, and I suspect that many, if not most, people who listen purely for the music will answer also in the negative. Indeed, I will say that anyone who has become conditioned to listening to music from either a single-channel source or from a seat 50 ft. or more from an orchestra, will find the stereophonic effect of *present* tapes distracting, at least in the beginning. To be sure, part of this is due to the fact that our knowledge of stereophonic recording is elementary and the tendency in the first few tapes was to exaggerate the directionality, since this provides the most spectacular demonstration of stereophonic projection. No doubt these exaggerations will be minimized eventually. You will recall that many music lovers found the prominent high-highs and bass of hi-fi systems distracting at first. For that matter, some still find them so, even in recordings in which no attempt to exaggerate them is made. These are background music lovers.

No doubt the distracting effect of stereo sound is partly the result of novelty and unfamiliarity, and the chances are that, as one becomes accustomed to it, the distraction will disappear. But that raises a pertinent question, to wit: if the directional effects are minimized by better miking or disregarded by the ear (which in effect is what "becoming accustomed to" means), isn't that pretty good evidence that they are not necessary or relevant to an enjoyment of music? Personally, when I listen to live music I am never conscious of any directionality: my ear seems to focus, as it were, on the music itself, and to disregard the information on directionality.

Furthermore, the realism of present stereo tapes does not seem very real to me. The trouble is one of perspective. To achieve the directional effect on which the spectacular presence of stereo is based, the recording microphones have to be quite close to the orchestra and widely separated. The speakers tend to duplicate the placement of the mikes in playback, and the perspective depends on the position of the listener in respect to them. If I could take a position 30 to 50 ft. from the speakers it is possible that the perspective would be the same as exists for me in the concert hall. Unfortunately, few living rooms will permit such a listening position. In even a large living room, the perspective is that of a listener in the first 2 or 3 rows of seats, a few feet from the orchestra: in a small room, it is that of the conductor on the podium — or even of a musician within the orchestra. This may seem real to a conductor or musician, but even they would admit that neither the podium nor a seat in the orchestra is the best place to *listen* to music.

We could effect a change in perspective by positioning the mikes at a greater distance and reducing their separation, but as we do that we also reduce the directional effect and approach the projection pattern and perspective of a good wide-source, single-channel system. Stereo thus seems to be faced with a dilemma: the greater the directional effect, the greater the illusion of being in the same room with the orchestra, and the more spectacular the sound; but also, unfortunately, the more distracting to an enjoyment of the music and the more unusual is the perspective to the ear that listens primarily for the music. In other words, stereo faces the same hard fact of life — a living room is not a concert hall. For stereo it is just as difficult, though in other ways, to reproduce the realism of a concert hall faithfully as it is for single-channel systems. Stereo does produce a *different* perspective, but whether that perspective is more real will depend a good deal on the customary listening position and preferences of the listener.

I concede readily that these comments may be only reflections on the current elementary state of stereo recording techniques, and no doubt the point of the criticism will be duller as recordings improve. In any case, it is clear that there is plenty of room for argument, and that differences of opinion will assure markets for both stereo and single-channel sound. Hence, though I offer Ampex bouquets for their accomplishment in providing us with the first really practical and successful stereo sound system, I am not ordering any wreaths for single-channel hi-fi systems.



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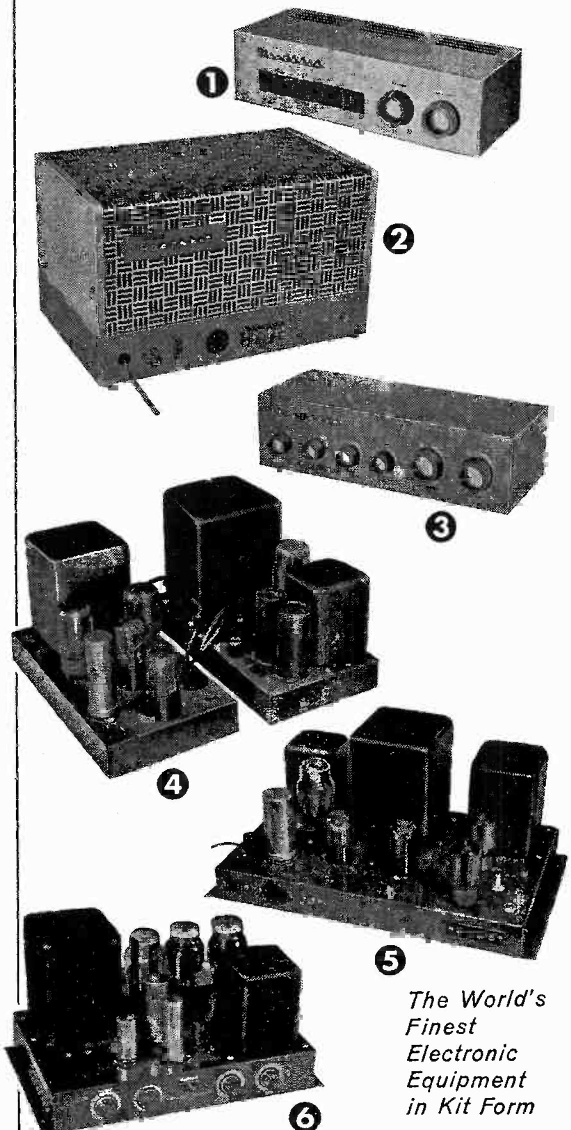

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DESIGN NOTES

Continued from page 20

In addition to the combinations possible with the speaker units, LC crossover network components could be adjusted by instantaneous switching for cutoff rates of 6, 12, or 18 db per octave.

This speaker system was in operation in my living room for several months, and some 70 visitors had opportunity to listen to the various arrangements and to express their preferences. These were noted after each listener had heard 3 standard recordings, chosen for a variety of tonal changes, complexity, and frequency range, and some special effects of interest to the technically advanced hi-fi fan.

As a basis for comparison, a "reference standard" in the form of a 12-inch coaxial speaker (in a well-designed bass-reflex enclosure) was located in an opposite corner. Listeners were exposed first to this reference speaker for an ear-conditioning period before switching to the experimental setup.

Test Results

No matter what type of system or arrangement was used, there were consistently favorable reactions as the listeners became adjusted to that system, without being furnished a basis for reference or comparison. In other words, any reproducing system evoked a favorable reaction so long as it continued by itself. When a change was made, however, there was an instantaneous recognition of a change in the program quality, and it was possible then to evaluate the 2 systems relatively.

The listener was first submitted to the reference speaker for an ear-conditioning period, and the reaction to this was favorable and frequently enthusiastic. The thought seemed to be in some listener's minds, "This is perfect: I would ask for nothing more." Yet, when the experimental speaker was switched on, the improvement was immediately obvious. The listener was amazed at all the shortcomings that showed up then in the reference speaker, previously considered excellent.

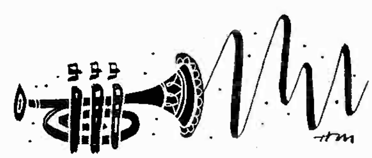
With the experimental 3-way system operating for several minutes the typical listener concluded again that perfection had been reached — until the 4-way system was activated, when further improvement became apparent (but not quite so much improvement as that noticed with the change from the coaxial or 2-way setup to the 3-way system).

Generally, the 3-way system was considered superior to the reference standard or to a 2-way system by a large and worthwhile amount: the 4-way system was thought to make only a minor improvement relative to the 3-way system, and that only during certain passages, indicating that the point of diminishing returns had been reached.

One conspicuous change as the system became more elaborate was an increase in conversion efficiency. A 3-way system gave substantially more average acoustic output than the 2-way or coaxial speakers, and the 4-way setup delivered still more acoustic power for the same input signals.

Regarding preferences for cone or horn-type reproduction of the middle range: the majority of listeners preferred the horn because of 1) increased output, and/or 2) a certain added "presence" or perspective effect. The presence feeling was, no doubt, the result of a higher acoustic output over a limited range of the middle frequencies because of the horn's greater sensitivity in that region. This gave the effect of moving an ever-present frequency band forward into the room. However, several engineer listeners recognized the effect for what it was; a peaked area in the mid-range horn, not attributable to a more linear or more perfect system. Nevertheless, the preference for the horn-type mid-range unit would appear to be logical (in my opinion), although a volume control should be provided with such a unit so that the output can be adjusted to suit individual tastes.

Results of tests on electrical phasing of speakers surprised some of my wiser and more technical visitors for, despite theoretical considerations, phasing appeared to be of little practical importance. By listening acutely, some were aware of a very subtle change at the instant of switching, but none could express a preference for one condition of phasing or another. When one thought he detected a significant change, a movement of the head, or a new listening position, reversed or cancelled the effect.



Further experimentation has convinced me that, except for speakers operating at low frequencies, program quality and its enjoyment are equivalent whether speakers operating over adjoining frequency bands are in or out of phase.

While checking various crossover networks, it was conclusively determined that the complicated network was futile. It was impossible for any listener to detect a change between a 6- and 12-db-per-octave crossover slope. In fact, on many occasions when the networks were eliminated completely and all speakers operated in parallel (with condensers remaining in the tweeter circuit), a very negligible shift was evident, not necessarily injurious to the reproduction. One could conclude that the design of a network should be based on a desire to protect the high-frequency units from distortion and burn-out, and to assure that the transmission range fed to each horn-type unit begins above the cutoff point of that particular horn. So-called quarter-section filter elements are satisfactory, giving a theoretical cutoff rate of 6 db per octave.

Literature published on the design of crossover networks is based on constant-load impedances: such data are evolved mathematically, sometimes giving values of inductance and capacitance to 2 decimal places. Such precision is completely unrealistic and unwarranted in construction of networks. Voice coils cannot be considered as loads of constant impedance because of their reactive nature. The manufacturer's rating for impedance may be off by 10 or 20% at the specified frequency; more than this if the selected crossover frequency is far from that for which the nominal impedance is given. Anticipated distortion or ringing in the 18-db-per-octave networks could not be detected. In fact, at no time could any discernible distortion be attributed to a network.

PRACTICAL AUDIO DESIGN

Continued from page 23

By these expedients one of the old 2.5-volt transformers can be made to serve the needs of a control unit, tape recorder amplifier, or something similar. Tubes in a power amplifier, however, would draw too much current for this makeshift. For such heavier jobs you might use an old transformer's high-voltage windings and buy a separate filament transformer: that would probably save some money.

There is one other filament situation that may be troublesome. For lowest hum it is often advisable to apply DC to the filaments of phono preamplifiers. This requires the use of selenium rectifiers because the current is too high to be handled by normal tube rectifiers. To hold down the size of the selenium rectifiers and to allow for various circuit losses, it is preferable to have a voltage higher than 6 volts available. The various miniature tubes suitable for preamplifiers (12AU7, 12AX7, 12AT7) can be operated at 12 volts as well as at 6 volts, and they draw only half the current at 12 volts. There are also several small, inexpensive, bridge-type rectifiers which can deliver 12 volts DC at from 150 to 600 ma. Strangely enough, however, transformers with 12-volt windings are almost unobtainable as stock items, and when obtainable are high in price. The ordinary small transformer with 5- and 6.3-volt filament windings is easily adaptable to the need and will still permit the use of the filament windings for normal AC filaments. How this can be done is shown in Fig. 8: the 5- and 6.3-volt windings are connected in series (if the first connection doesn't yield about 11 volts, reverse the

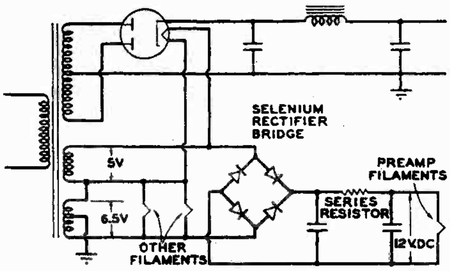


Fig. 8. Filament windings in series for the DC preamplifier filament supply.

leads from one of the windings). With a capacitor-input filter the output voltage will exceed 12 volts easily and can be set to the right value by adjustment of the series resistor. If a tube rectifier is used for the high-voltage DC, it must be a cathode-type tube, as indicated.

Adjusting High Voltage

If a power supply delivers a higher voltage than is required, it can be reduced easily. It can be dropped 25% or so by using choke input rather than capacitor input. Using a 6X4 rectifier in a small supply for a conrol unit, a 750 vct transformer winding would yield over 400 volts DC at 50 or 60 ma. We should ordinarily need less than 300 volts. Removing the input capacitor and connecting it beyond the choke will drop the voltage to about 300 volts. It may be preferable, however, to obtain the voltage drop in the hum and decoupling filters. The more excess voltage there is at the output of a rectifier, the better the filtering and decoupling possible with a given set of capacitors. An excess may permit dispensing with a choke in favor of a more compact and cheaper resistor. We will consider this in a subsequent article.

It is more difficult to obtain an increase of voltage. To be sure, if the power supply now uses a choke-input filter, a considerable increase may be obtained by changing to capacitor input. Some improvement can be achieved by a careful choice of rectifier tubes. The bigger, huskier rectifiers, capable of handling higher currents, have lower internal resistance and will deliver a higher voltage at low current loads. For example, if a 6X4 with 300 volts AC per plate delivers about 300 volts at 50 ma, a 5Y3 would produce 340 volts at 50 ma, and a 5U4 over 350. These differences in voltages would not be significant unless a power output stage were involved: even then a change of 10 or 15% in voltage would probably produce little more than 1 db difference in output power. But it is something to keep in mind, and occasionally it is useful.

Transformer Ratings

Power ratings of commercial transformers are usually conservative. They can be exceeded by as much as 50%, at the price of severe overheating. A transformer rated at 150 ma can deliver 200 ma on peaks: a filament winding rated at 2 amps will not usually burn out with 3 amps. When operation is intermittent and the equipment is operated at low levels, the overload may not be serious at all. In fact, in the compulsion to produce more compact equipment, some commercial high fidelity manufacturers operate transformers far beyond their normal ratings, despite the fact that the compact and totally enclosed pancake designs lead to even more severe overheating than the transformer designer ever considered. Personally, I prefer to stay within the conservative ratings and I recommend this strongly to others. An overloaded power transformer is not likely to burn out, but its overheating is likely to produce early failures in other components by operating them in an environment of excessive heat. Still, if it is a matter of tolerating an overload or doing without a gadget at all, it may be comforting to know that transformers not only can be overloaded, but that they often are.

The AC Load

It is desirable to know how much current a power supply will draw from the 115-volt power line in order to deter-

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WOODCRAFTER

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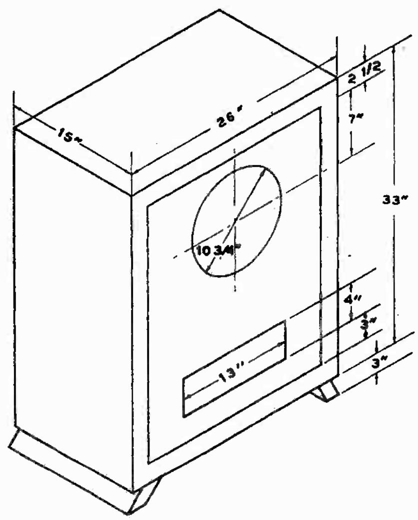
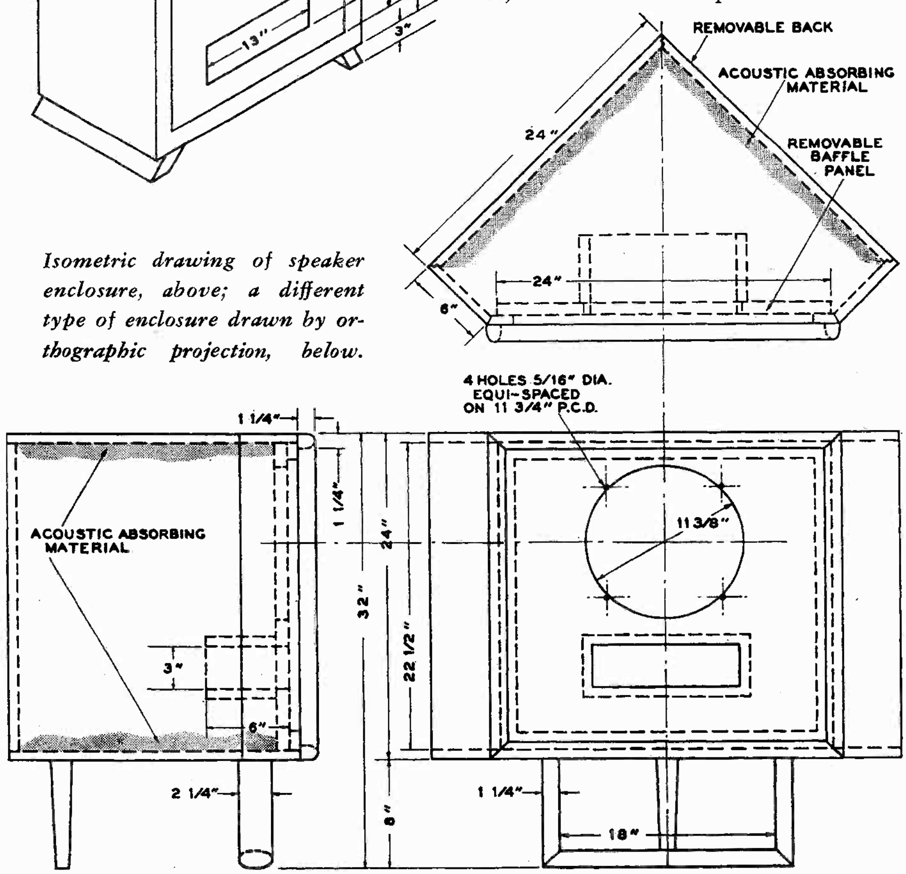


Isometric drawing of speaker enclosure, above; a different type of enclosure drawn by orthographic projection, below.

newly acquired knowledge of drawings, have a look at the plans showing the construction of 2 enclosures. One is an isometric drawing; the other a more detailed orthographic projection. Can you identify the various kinds of lines? Are the layouts of these drawings similar to the example we looked at earlier? Do the front, top, and side views present a clearer picture to you now? As you examine the details, you'll find all the fundamental ingredients you just read about — only more of them — for the principles we have discussed and shown are the same in any drawings you might see, no matter how complex.



PRACTICAL AUDIO DESIGN

Continued from preceding page

mine the size of fuse needed to protect it. This is quite simple to calculate. The total power drawn at the primary will be equal to the total power delivered by the secondaries plus the losses within the transformer. Consider the hypothetical amplifier mentioned earlier: the high voltage power will be 400 volts at 150 ma, 400 × 0.15, or 60 watts. The rectifier filament takes 5 volts at 3 amps, or 15 watts; and the other filaments 6.3 volts at 3.5 amps, or about 22 watts. The total is just under 100 watts. The power transformer can be considered to be 85 to 90% efficient, so we add 10 or 15% for the transformer losses. That gives us a total of 115 watts taken from the power line. The current drawn from the line is equal to watts divided by volts, since the load is essentially non-reactive. In this case, 115 watts divided by 115 volts gives us 1 amp. To minimize fuse blowing on momentary small overloads we can specify a 2-amp fuse.

CARNEGIE HALL

Continued from page 25

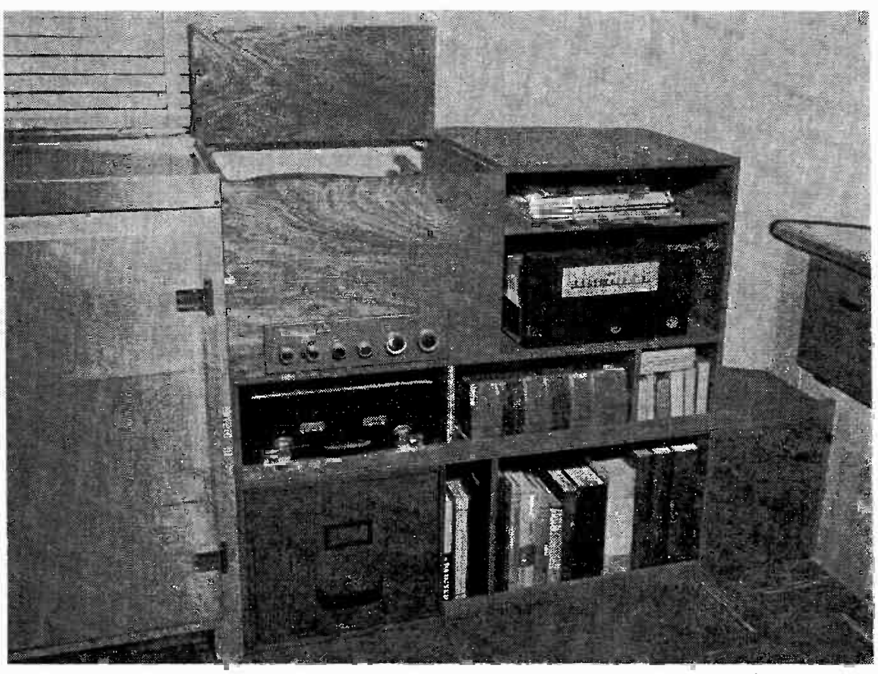
determined, the sound is cleaner with the preamp removed than it is with the preamp in the cabinet, so it spends its working time at bedside. This is where it is most wanted anyway, the bed being the only couch. Shielded cables from the power amplifier to the preamp are concealed behind the galley.

I built the preamp-control unit also, with even more care than the amplifier, in keeping with its great sensitivity and low-level signal position. Result: again, no noise (that is, none in excess of design). In constructing this kit I substituted a Compentrol Cl-70 (which has no insertion loss) for the volume control supplied, since I prefer a loudness-type control. It works very well: loudness can be turned down to a whisper with full bass audibility.

Because wide-range, high fidelity music is my sole audio interest the Craftsmen tuner is for FM only. The C-900 has excellent audio quality and extreme sensitivity. A simple twin-lead folded dipole on an 8- to 12-foot demountable aluminum mast at the front of the trailer brings in every major FM station for 125 miles around loud and clear, even over mountains. In traveling, to prevent development of microphonic tubes, both the tuner and the preamp are uncoupled and laid on the foam-rubber bed. In a year of daily use only 3 tubes have been replaced, one in the tuner and one in the preamp (twice), with no microphonics. The tuner, for operation, sits on a shelf in the general-purpose cabinet where it is handy to the desk/table. Its power, output, and antenna connections are so arranged that all pull off when the tuner is withdrawn straight out. This makes getting under way easier. A small (2½-inch) tube-cooling fan pulls air up over the power amplifier and blows it out over the tuner. This is quiet, and has been shielded to minimize hum pick-up in the magnetic cartridge.

The phonograph had to be capable of clean, wide-range reproduction, without audible rumble, flutter, or wow. It also had to be as inexpensive as possible because, for economic reasons, greatest dependence had to be on radio, with the author's few LP records reserved for non-FM areas and social occasions. A satisfactory ensemble was found in the GE single-stylus cartridge with 1-mil diamond, on a Lenco record player. By careful measurement, calculation, and mechanical work the cartridge was made parallel to the record surface, and the ideal overhang and tracking angle were established. The GE stylus was straightened and spaced precisely in the magnet gap. Rigid mounting of the turntable to the cabinet was found to be necessary to control rumble. Provision was made for leveling by means of friction contact with the sides of the cabinet, and compressable foam-rubber cushions below which take the weight of the motor board. Leveling is done dynamically. The stylus is lowered onto a rotating blank disc, without any grooves. The motor board is tilted until the arm moves neither right nor left but holds any position in which it is placed. An annoying bump was eliminated from the stop mechanism on the arm by cushioning with rubber the trip lever where it pushes a steel slide. The finished installation, at 2.25 grams stylus force, will trace band 16 on the Dubbings D-100 test record without groove-skating. At 6 grams stylus force (normal for the GE cartridge) it will trace bands 16, 17, 18, *and* 19, which provide increasing stylus velocities at 3 db increments. Bands 16 through 18 are par for record players: band 20 is traced only by professional arms, according to Dubbings. For travel, the turntable is lifted off its spindle and placed on the foam-rubber bed. This prevents possible damage by the heavy turntable to the precision bearing of its spindle under conditions of road shock. In setting up the trailer for habitation the trailer itself is always leveled both ways before jacks are set, so the turntable, when replaced, is never far from level, and minor adjustments are sufficient.

Fig. 5. Cabinet next to galley holds tuner, amplifier, preamp-control, and turntable.



Returning to the listening values of the small room, it is well to note one fundamental advantage inherent in the small room dimensions: for the desired sound pressure levels in the room the equipment is operated at lower output levels (in watts) than would be used in a large room. Lower output means lower distortion. This can cut distortion to the vanishing point in good equipment. And if the equipment has the capacity to do an acceptable job in a large room, it will perform with consummate ease and grace in the small room. In effect, you get better gear than you have paid for if you operate it at normal levels in a very small room. In the matter of tone generation, it is regarded as desirable to have one room dimension at least as long as half the wavelength of the lowest tone put out by the sound system. Thus, a 17-foot room, corner to corner, could capably handle a 35-cps tone. That's low, but it's not an absolute limit: the 17-foot trailer handles 30 cps quite rewardingly.

STEREO RECORDING

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cordings, and you're probably wondering about the microphone techniques. There are 2 basic methods: binaural, for which 2 identical microphones are spaced 6 to 8 in. apart; and stereophonic, in which the microphones are spaced fairly widely and need not necessarily be identical. The binaural technique gives most realistic results but requires headphone listening during playback. Binuaral microphone placement is much the same as you would use for a single-mike pickup, except for a much greater tolerance in permissible locations; you don't have to be quite so careful. In fact, a more distant pickup may be preferable from the standpoint of improved acoustic perspective. Recording perfectionists often put the microphones on opposite sides of a spherical object that represents a dummy head, so that phase relations of the sound normally heard by the ears will be retained in the recording.

Stereophonic pickup offers all sorts of opportunities for experimentation. The simplest standard technique is to place the microphones (separated from 10 to 20 ft.) in front of the performers. If you like to listen dangerously, however, you can use the microphones to pick up individual instruments or sections, placing the reproduced sound of the triangle, piccolo, bass drum, or what have you on one side of the room, and the rest of the orchestra on the other. You won't make a "natural" recording this way, but you'll have a lot of fun and become familiar with the effects of microphone placement. Uniformly successful recording is the result of such knowledge, which can be gained only by practice and experimentation. You might like to try out a form of vertical perspective in which you use one microphone to accentuate soloists, and the other placed at a distance for overall pickup, playback being over speakers in line away from you, or with the solo channel fed over a centrally located speaker and the other channel fed to 2 speakers, one on either side.

Because most of us are interested primarily in music, it's too bad that we don't have personal aquaintance with the major symphony orchestra conductors and have immunity from union restrictions too. There is a great deal of enjoyment, though, to be found through multiple-channel recording in other fields. I have the strong impression that nonprofessional performances are very greatly enhanced, in a musical sense, by stereophonic recording and reproduction. Similarly, the introduction of spaciousness to dramatic performances offers a whole new realm of opportunities.

Of course, those fortunate enough to be in an area where binaural broadcasts are transmitted can preserve many of them on tape; this is a veritable gold mine of material.

There is still another possibility: that of simulated stereophonic reproduction from discs or other single-channel sources. This technique is relatively simple, but will probably take some practice on your part, as well as familiarity with the music. Briefly, it consists of re-recording the original material by paralleling the 2 radio inputs of the binaural tape machine and controlling the recording level of each channel according to whether the reproduced sound should seem to come mostly from the right, the left, or from both reproducers simultaneously. When recording from disc, radio, or another tape it is usually quite practical to monitor the recording input to the stereo tape machine via power amplifiers and speaker systems, and this will give you the opportunity to hear how well you are achieving pseudo-stereophonic effects. If smooth, simultaneous manipulation of the 2 volume controls is difficult a simple right-left-middle fader can be made, Fig. 1, which simplifies the operation considerably.

The 2 potentiometers may be conventional ganged units, but be sure that they are of *linear* taper rather than the commonly used, semi-logarithmic taper. If a low-impedance source is available to feed the fader, then the potentiometers may be of fairly low resistance, such as 10,000 ohms each, and reasonably long, shielded leads can be run to the equipment. If a high-impedance source is used, however, such as from some preamplifiers, the potentiometers should be 500,000 ohms each and only short, shielded leads may be employed in order to prevent loss of high frequencies.

Some experimenters use frequency discrimination as a means of converting a single monaural signal to 2 pseudo-stereophonic ones. A simple way to accomplish this is to feed the monaural signal simultaneously to 2 preamp-control units, turning bass and treble tone controls up on one and down on the other, the amount depending on your particular equipment. The outputs are fed to the 2 stereo recorder inputs and, for simultaneous monitoring, to the power amplifiers and speakers used in your playback system.

You may not have much success in playing back commercial pre-recorded stereo tapes, because the horizontal distance separating the gaps of the pole pieces is likely to be considerably different from standard. This disadvantage is more than offset, however, by some of the other uses to which the recorder is adaptable. For example, the fact that

Continued on next page

STEREO RECORDING

Continued from preceding page

separate heads, preamplifiers, and bias oscillators are used makes it possible to record on one channel while playing back the other. As a consequence, additional material such as voice announcements may be added, at the right time, to tapes already recorded. Best results are obtained if the initial recording is half-track with the other track left blank. Not only is this technique useful for dubbing with a single tape machine for monaural playback, but it may be used also to synthesize stereophonic sounds.

An additional advantage of the Pentron recorder is the fact that the record-playback heads, as well as the erase head (if used), have replaceable pole pieces. This provides not only for simple and inexpensive replacement when wear becomes noticeable, but also permits easy conversion of the recorder for special purposes. Simultaneous recording and playback of the same signal can be achieved by using full-width pole pieces, or by placing the half-track pole pieces in line with each other. It is then possible to monitor directly from the tape a recording while it is being made, as in professional machines. You can also create artificial echo effects by feeding a portion of the playback signal into the recording amplifier. Be sure that the playback head you are using is the one closest to the capstan in either case, and, if you are using half-track heads, it is wise to record on the half of the tape proper for playback on most half-track machines. Also note that after changing pole pieces it may be desirable to check head alignment again.

Remember that tape recording requires the use of ultrasonic bias, a high-frequency signal that can cause distortion if it gets into circuits where it isn't supposed to be. The tape preamplifiers each have a bias oscillator; if they are out of tune with one another a slight whistle may be noticeable in reproduction. This can be minimized by adjusting the slug in one or both of the oscillator coils for zero beat. Also, be careful of your shielding if you're planning to make further modifications in the equipment. Sometimes the use of small bypass capacitors, 100 $\mu\mu$fd or so, will keep unwanted ultrasonic energy away from critical circuits. One good indication of stray bias in the circuit is audio output *dropping* when the gain control is advanced.

The rest of the recorder's playback circuit consists of voltage amplifier stages, assorted volume and tone controls, and ordinarily a minimum-type power output amplifier to drive the speaker. And the circuitry is all at high impedance, so running a signal takeoff cable from interim stages presents the same problems as encountered before in taking it from the control unit.

A tape recorder almost invariably has at least one stage of straight voltage amplification following the volume control, and since the playback equalization customarily takes place in the preamplifier stage, the tube following the volume control may be considered dispensable in playback. But it can't be thrown out altogether or modified drastically, since it is needed for recording. Also, there isn't likely to be a microphone input on the phono control unit (a few do have it, but they're not too common), so the low-voltage output takeoff that was used *from* the control unit won't do here. The control unit will require a good half volt of signal to drive it at the same level as the other inputs.

The only thing to do, on recorders that do not have a hi-fi output already, is introduce some modification that can be switched from the circuit when a recording is being made. For this, another voltage-divider-type network can be used across the output of the tube following the recorder's volume control, and a double-pole single-throw toggle switch mounted on the recorder unit will provide the switching facilities.

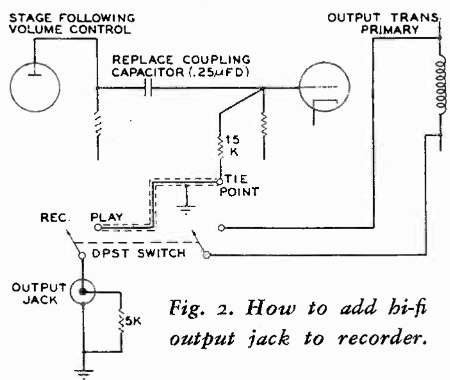

Fig. 2. How to add hi-fi output jack to recorder.

The installation (Fig. 2) can be made as follows: connect a 15,000-ohm resistor to the grid of the second tube following the volume control, and anchor the other end of the resistor to an insulated tie point. Mount a phono receptacle or standard phone jack wherever convenient, and put the toggle switch next to it. Connect 1 to 1½ ft. of shielded cable from the resistor's tie point to one contact of the switch, and ground the shield. Wire the other terminal on the same *side* of the switch to the center contact of the receptacle, and bridge a 5,000-ohm resistor from the

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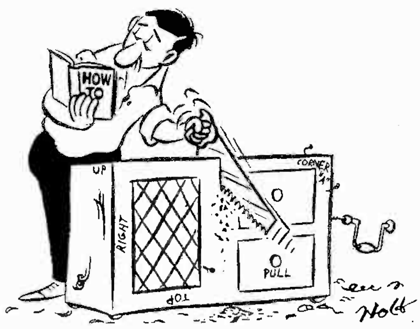
TAPE NEWS

Continued from page 13

best. Like it or not, then, it is usually necessary to employ at least that much of the tape recorder circuitry.

Audiophile's Bookshelf



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TAPE NEWS

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center contact of the receptacle to ground. Then replace the coupling capacitor with one of 0.25 μfd, 600 volts. Next, run 2 leads from the other switch terminals to the plate of the output tube and to the B+ side of the output transformer (or from plate to plate in the case of a push-pull output), so that the recorder's speaker will be cut out when playing back through the main system.

The switch will then, in the RECORD position, permit the recorder to function normally, but when turned to PLAY, it will bridge the voltage divider network across the takeoff point and will simultaneously short-circuit the output from the recorder's own monitor. This will be a "short" for the signal only, and will not damage the unit.

To record, then, the control unit's selector is set to receive the desired channel, and the recorder is set with all its switches (including the new one) turned to RECORD.

To play back a tape, the recorder's switches are flipped the other way, the control unit's selector is turned to whatever position the recorder is plugged into, and there it is.

It's really much simpler, come to think of it, to purchase compatible equipment.

Fen-Tone B&O 50

I will go on record also as stating that I have no intention of starting a *Tested in the Home* department, but when something looks good in the advertising literature I'll try to find out about it. This was one of those cases; Fen-Tone answered our request by sending a couple of their mikes.

The B&O 50 looks like a miniature compressed gas cylinder with wings. It's a ribbon unit, with a bi-directional polar pattern, and a small selector switch to turn it off or select voice or music characteristics.

So far, I must confess I haven't tested this as thoroughly as I'd like to, but indications to date are that it is far better than its $49 price would suggest. On close-miked speech it gives very smooth, clean sound with no evidence of high-frequency peaks or high-level distortion. At greater distances it produces extraordinarily velvety sound, which led me at first to suspect it just didn't have any high-frequency response. Listening tests conducted with a high-quality electrostatic tweeter (and cone woofers) indicate that it does, indeed, have all the highs it is claimed to have. It just doesn't seem to color the sound. On pickup of pipe organ the B&O 50 gave indications of having an equally good low end.

I still want to test this mike with large musical groups, so at present the only thing I'm willing to say is that it is definitely worth more than $49 on a comparative basis. Just how it compares with the $100 mikes still remains to be seen, but I'm beginning to think that it will be favorably indeed.

ADVERTISING INDEX