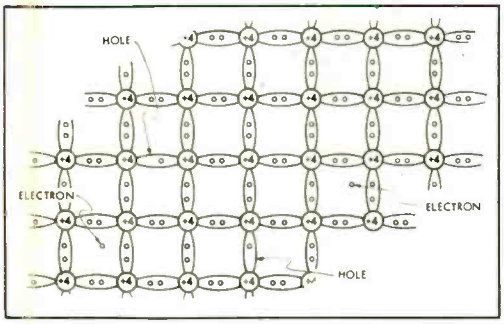
AUDIO

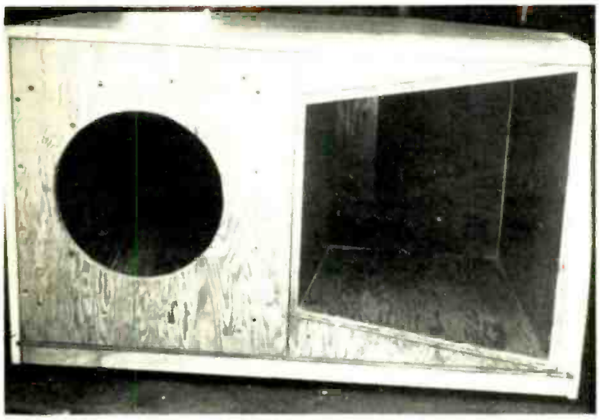
OCTOBER, 1956

50¢

ENGINEERING MUSIC SOUND REPRODUCTION



While it is possible to describe the internal workings of transistors in a way that is understandable only to the physicist, it is also possible to do it simply and clearly. See page 15.



Designs for satisfactory low-frequency horns are many, but few are suitable for installation in the home. This one, shown partly finished, is of a size and shape that results in an attractively proportioned cabinet. See page 26.

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OCTOBER, 1956 VOL. 40, No. 10
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AUDIO

ENGINEERING MUSIC SOUND REPRODUCTION

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CONTENTS

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ABOUT MUSIC

HAROLD LAWRENCE*

Short And Not So Sweet

THE TROUBLE with so many TV dramas is that they are really full-length plays in disguise, crammed into an hour's time—and not even an hour at that. For after the station breaks, commercials, and credits are added up, some forty-five minutes might be left over, which would be only enough time to build up to the climax of the first act, not to mention the entire play. No matter how skillful the adaptation, everything seems to happen too quickly: characters are developed on the run, issues are met, fought over and resolved almost in the twinkling of an eye, and before you know it, you're watching next week's trailer. The end result is a feeling of resentment over having been tricked into something like drinking a gin and tonic without the gin. Of course, there is a large number of plays written expressly for the medium by authors who are fully conscious of its limitations and potentialities. But the tendency among TV playwrights today is to adapt—whether consciously or not is beside the point—the theatre to the video screen. Such projects seldom bear fruit.

The tyranny of the clock somehow has an unsettling effect upon writers (can anyone escape it?) and throws their timing off. It takes an author with the genius of a de Maupassant and a director with the imagination of a John Huston to successfully beat the clock. Not that it's an easy task to produce a play intended for an evening's entertainment. But at least it's not like looking at things through the wrong end of a telescope.

Given all these problems, the two hour play, simmered down to less than half its length, can sometimes be justified. A shifting of accents, elimination of minor characters, and perhaps an isolation of one particular aspect of the drama, might lead to an absorbing play within a play.

The same cannot be said for music. When a Beethoven symphony is whittled down from thirty to ten minutes, the work's impact turns as soggy as a wet roll. Whole chunks of Beethoven are still there, all the principal themes dutifully make their appearance, and the orchestration has not been tampered with. Yet the total effect is repulsive to the musician and serious music lover, and strangely unsatisfying to the layman.

In digest versions of symphonic music, the peaks are there but the valleys are gone. Development sections that repeat themes over and over again are thoughtfully omitted; connective tissue leading to the introduction of a new motive is cut away to permit a more direct approach; and as for *da capo* repeats, well, those are obviously unnecessary. The streamlined piece that emerges from the operating theatre is a head without a body. High points follow each other in rapid succession; they do not grow, but instead smack up against stone walls at the end of blind alleys. Too much climax, not enough contrast; like a meal composed of éclairs, cream puffs and banana short cake.

The "Listener's Digest" is merely a more skillful counterpart of the overzealous record salesman who is demonstrating the latest release. This stylus-hopper will roam over the grooves in search of deafening tutti passages, soaring themes, tympani rolls or cymbal clashes—all this with the gain way up. The key sections of the disc are sandwiched in between short, terrifying blasts as the salesman's pickup skitters across the record.

The promoters of abbreviated music maintain that this is the only way to bring classical music to the masses, that what they have done is to skim the cream off great musical works. But, as Paul Henry Lang so astutely pointed out, there is no cream in great musical works for the simple reason that they are all "homogenized."

Learning to appreciate music is not like learning to read faster. In the latter case, the instructor urges his students to "get the thoughts fast, do not get bogged down in words, just follow the main thread and stop wasting time on details." In reading through an article, you can afford to skip words, and even whole sentences, if you are intent on merely extracting the "message" of the writer. But you can't skip notes in music. A musical composition is a continuous fabric, with a tonal logic all its own. It is as absurd to "slenderize" music as it is to reduce a great poem to prosaic terms.

No one will dispute the fact that many composers write overlong works. Take Wagner's *Parsifal*, for example. One of the most impressive moments in all of Wagner's output is the *Transformation Music* in Act I. To reach this magical point in the score, however, one must put up with things like Gurnemanz's Monologue. Taken by itself, the monologue is long and dreary. In context it is an essential part of the slow evolution of Wagnerian musical thought. It is true that Gurnemanz was longwinded, but it is equally true that there is no way of successfully circumventing him. If the digest man used his clippers on this score, he would be cutting out the heart of the opera: its dramatic continuity.

The "Listener's Digest" turned out to be indigestible, but its spirit lives on, undetected by the very critics who annihilated it two years ago. This time opera has become the victim—opera without singers, that is. You can now hear *La Bohème* and *Tosca* in digest form in the same period of time it takes to hear only one of the operas complete. In this concentrated form, Puccini, whose music has its heady quota of perfume, now smells like a gardenia-filled room.

The "Listener's Digest" has been touted as the "exciting short cut to great music." But this and other abbreviations could better be called, "the most unkindest cuts of all."

* *26 West Ninth Street, New York 11, N. Y.*

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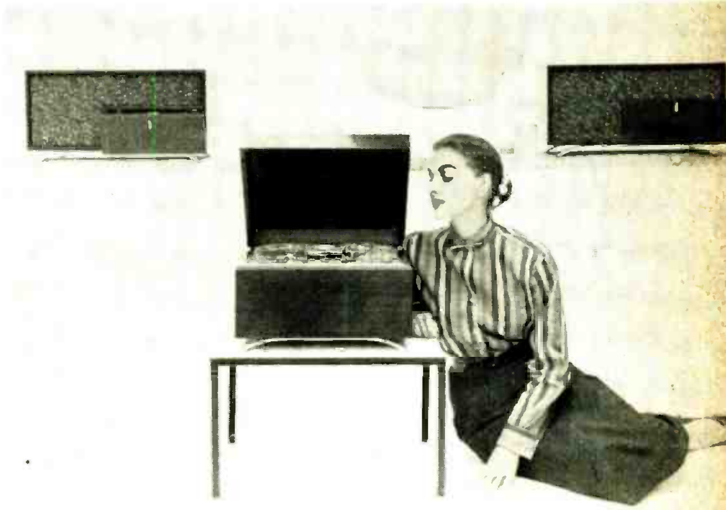

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LETTERS

Record-critic Contestant Travels

SIR:

Your last letter caught up with me here in Marrakech: "the soul of Morocco, gateway to the Sahara and the High Atlas, the sword of Al Islam . . . etc." as an Arab guide might expound. Thanks for your courtesy and for explaining some AUDIO general policy. It strikes me as quite conservative.

I came here in particular to visit the Djemaa-El-Fna (*We'd hate to run across that in a radio script.* ED.) and to hear the dancing music and snake charmers. It is well named "Place of the Dead." The entertainers have been banished and now only parked cars and parked burros are to be seen where in centuries past the well-salted heads of the conquered were displayed.

It seems, I am told sadly, that Maroc would become modern under Sultan Ben Youssef and one must search ever deeper to find the ancient sounds and sights. Not so the ancient aromas. I did find some elegant drum work and singing in the Kasba near the Bab Ksiba.

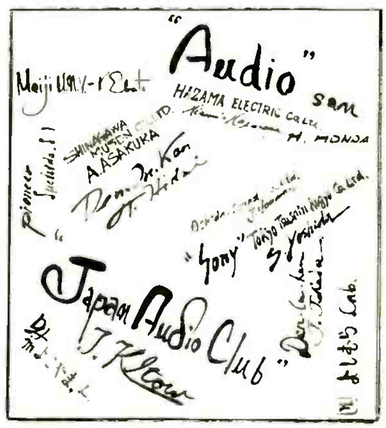
So be it, Insh'Allah, and I propose we make plans for a future Audio Show here in the Kasba. The high walls and labyrinthian alleys are ideal. We shall search out the musicians and *charmeurs de serpents* and record them in stereo. We shall set up batteries of speakers in the Djemaa. The crowds, possibly even the snakes, will appear and all will be charming and modern.

Please give my regards to Mr. Canby. I am disappointed that he chose so decadent a place as Europe to visit. Here there is always the possibility of hearing percussion and possibly sudden death. I look forward to resuming the fun of his contest at some future time. By the way, I heard a blind beggar singing in a dark alley near the Mellah and it brought to mind "The Three Ravens." Other than that, this place is ecstatically quiet—all is fidelity, neither high nor low.

DON SASMAN,
Marrakech, Maroc

(*Mr. Sasman will be remembered as one of the winners in the "Be Your Own Record Critic" Contest for March, as reported in the May, 1956, issue.* ED.)

Greetings from Nippon



SIR:

I am very glad to send you this letter. I have visited the United States to attend the Second International Congress on Acoustics held at Cambridge, Massachusetts, in June. After the Congress I visited New York, and intended to visit you during my stay there, but I was not able to find the time.

My occupation is that of researcher on acoustics, especially on audio engineering. I am enclosing a message from the Japan Audio Club, which consists of audio engineers. I am sorry I was unable to deliver that message from my hand to your hand.

I wish both you and AUDIO good luck.

TAKESHI ITOW,
Electrical Communication Department,
Waseda University,
Tokyo, Japan

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ALDOUS HUXLEY AND IGOR STRAVINSKY at the Gesualdo madrigals recording session.

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Both Sides at Once

SIR:

The Stereo Sound Society, which recently celebrated its first anniversary, has functioned quietly for the past eighteen months, and has gained many prominent representatives in the fields of equipment manufacture, broadcast stations, and other audio facilities.

The purposes of the Society are: (1) To promote the general use of stereophonic sound; (2) to encourage research and development in stereophonic sound; (3) to promote truthful advertising of stereophonic sound; (4) to provide lectures and demonstrations of stereophonic sound; (5) to recommend standards for the manufacture, performance, and use of stereo equipment; and (6) to encourage the affiliation of groups with similar purposes.

Further information regarding the activities of the Stereo Sound Society may be had by communicating directly with the writer.

J. JERRY LASH,
Stereo Sound Society,
c/o Audio Associates,
6026 W. 76th St.,
Los Angeles 45, Calif.

Villchur to Briggs:

SIR:

I would like to thank Mr. Briggs for his friendly, albeit critical comments, (LETTERS, August, 1956) on one of my recent articles. I am pleased that Mr. Briggs, a man who knows how to design and build speakers as fine as are the Wharfdale's, has read the article, evidently quite carefully.

I am quoted as follows:

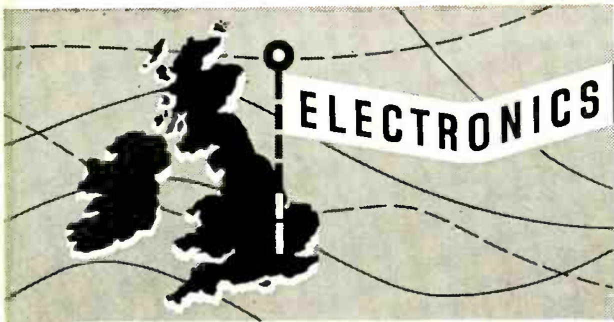
> "The great advantage of the push-pull electrostatic speaker is that the diaphragm is driven uniformly over its surface, and must, therefore, move without flexing or 'breaking up'."

—and Mr. Briggs asks how a clamped diaphragm can be freed from the laws of nature, which (I agree) allow only theoretical existence for a totally non-resonant system.

The sentence as it stands is misleading, particularly due to the word "therefore." It is true that the force on an electrostatic speaker diaphragm is applied over the whole area, and that the diaphragm can move without flexing (not counting the necessary flexure at the clamped ends) or breaking up—to any significant extent, anyway. But the application of force over the whole area is only a necessary, not a sufficient condition for such behavior. With coupling between the electrostatic field and the diaphragm as loose as it is, the diaphragm could still, from a purely electro-mechanical point of view, exhibit its natural modes of vibration.

The thing that makes virtual piston action possible is, paradoxically, the extremely low mass of the moving diaphragm. The predominant and controlling impedance is actually that of the air load, and the air load resistance damps out and swamps any tendency to resonant modes of behavior in the diaphragm within the range of excursions involved. If we think of a light diaphragm immersed in a heavy medium (water, for example), such that most of the work required for movement consists of overcoming the load imposed by the medium—and then conjure up a vibratory force which is applied equally over the entire surface of the diaphragm, it may be seen that the natural tendencies of the diaphragm's mechanical system will not have much influence over the final movement.

The explanation of the function of the air load resistance in this connection was



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The EL84 may be used for higher powers too. Two tubes in push-pull will provide outputs of up to 17W at an overall distortion of 4%.
At maximum ratings one EL84 has a plate dissipation of 12W and gives an output of 5-6W for an input signal of less than 5V r.m.s.
Supplies of the EL84 for replacement in British equipments are available from the companies mentioned below.

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Small button noval 9-pin

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In Canada Rogers Majestic Electronics Limited, Dept. HM, 11-19 Brentcliffe Road. Toronto 17, Ontario, Canada.

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EDGAR M. VILLCHUR,
Acoustic Research, Inc.
24 Thorndike Street,
Cambridge 41, Mass.

Employment Register . . .

Positions Wanted and Positions Open are listed here at no charge to industry nor to individuals who are members of the Audio Engineering Society. Positions Wanted listings from non-members are handled at a charge of $1.00, which must accompany the request. For insertion in this column, brief announcements should be sent to AUDIO, P. O. Box 629, Mineola, N. Y., before the fifth of the month preceding the date of issue.

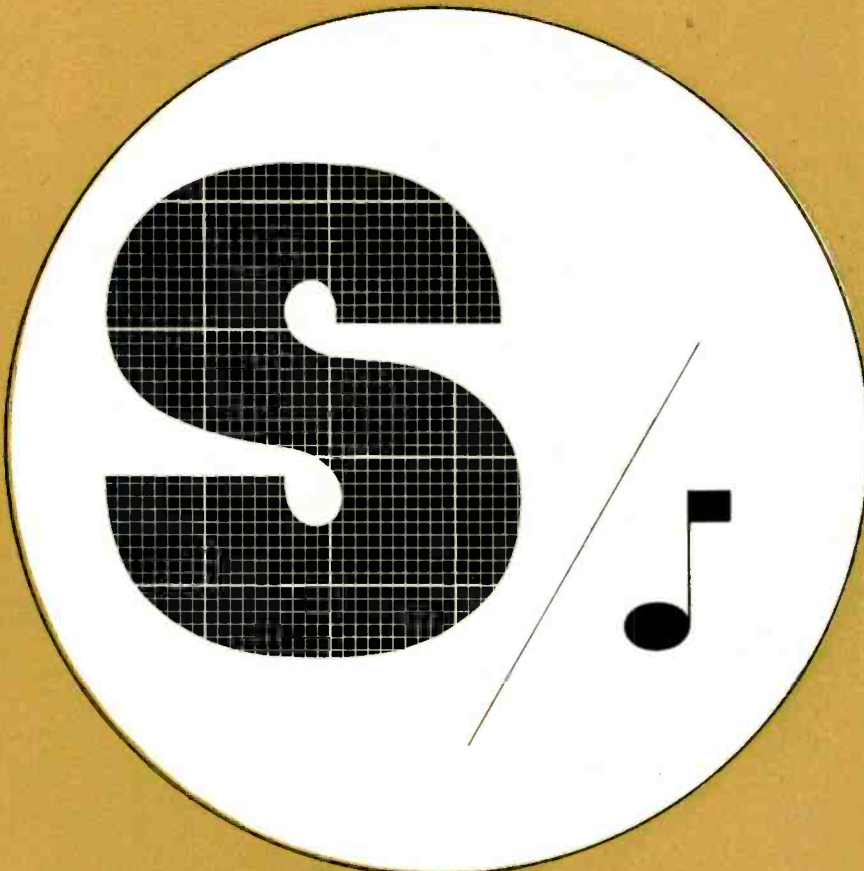
★ WANTED Hi-Fi Salesman—Leading audio outlet in one of South's largest cities needs hi-fi manager to allow owners to put more time in commercial sound. Must be amiable, aggressive, and have instinctive sales ability. Working interest possible later date. Hospitalization, paid vacation, and pleasant surroundings. Any salary requested in line with ability considered. Send full resume immediately. Box 1001, AUDIO.

NEW LITERATURE

● Shure Brothers, Inc., 222 Hartrey Ave., Evanston, Ill., announces a new General Catalog 56, covering the company's microphones, microphone cartridges, microphone accessories, phono pickup cartridges, and magnetic recording heads. Questions have been anticipated so that all persons buying the products described will find the information needed to evaluate the usefulness of a given model. To those persons engaged in buying, selling, and installing the produces listed, Catalog 56 will be a good source of technical and general data which will be of great assistance in forming recommendations. Available on request. **P-1**

● Allied Radio Corporation, 100 N. Western Ave., Chicago 80, Ill., reflects the growth of the entire electronics industry in its new 356-page 1957 catalog which lists more than 27,000 items. Featuring extensive listings of high-fidelity components and systems, this new catalog is an excellent directory of equipment in the audio industry. As an aid to those who may want guidance in the selection of components, the expanded hi-fi section of this catalog includes introductory material which thoroughly covers the fundamentals of hi-fi. Build-it-yourself enthusiasts will find a bigger-than-ever selection of amplifier kits, plus expanded listings of custom cabinet kits for speakers and other hi-fi components. This is a good catalog so be sure and write for it. It is free. **P-2**

● James B. Lansing, Sound, Inc., 2439 Fletcher Drive, Los Angeles 39, California, manufacturers of "JBL Signature" enclosures, loudspeakers, and speaker systems, has issued a 6-page catalog leaflet for their complete line of high- and low-frequency drivers, extended range speakers, dividing networks, and enclosures. In addition to individual listings of the components, the combinations of speakers and enclosures are presented in tabular form as an aid in choosing a speaker installation. **P-3**



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EDITOR'S REPORT

TO THE NEWCOMER

IT HAS NEVER seemed quite clear to us why the dyed-in-the-wool audio fan should almost invariably be the type of music lover who is referred to as a "long hair." As we see it, the desire to reproduce sound as true to life as possible should be common to all—whether for reproducing Buxtehude, Brahms, boogie-woogie, or bird calls. In fact, it is quite likely that visitors to the Fall audio shows will even be treated to some key jingling.

Ever since we returned from the first Mexican hi-fi show last November, we have had a modest passion for the music from that country—even including that heard at bullfights. Furthermore, any interest we may have personally in jazz is likely to be centered around Dixieland groups. A few days ago we received from Dauntless International a few samples of their releases in these categories, including "The Brave Bulls" and "The Dukes of Dixieland." Realism? Hah! Just close your eyes and you are there. We used to think that a hi-fi installation was only used to its limits on perhaps one or two hours of broadcast programs each week, but when a really excellent program came over it was worth waiting for and thoroughly justified a system that was working to only thirty per cent of capacity most of the time. The reproduction of any music becomes more and more exciting as the realism increases, and these two records brought the story home to us most forcefully.

Those who are constantly alert to every new improvement know that the whole approach to high fidelity involves a certain amount of work, but that the rewards are more than adequate. As always, many who are new to hi-fi see their first copy of AUDIO at one of the shows. The engineer is likely to think it not sufficiently technical—the layman may think just the opposite. But in spite of unfamiliar terms which are indigenous to the art, AUDIO is intended to be intensely practical. The jargon of hi-fi may be strange, but it enables us to discuss equipment with mutual understanding. AUDIO's function is primarily that of serving as the medium of exchange of information.

THE ROAD TO GOOD INTENTIONS

Not everything runs smoothly all the time. After an issue in which one or two errors occur, we step up our care in proofreading, and sometimes we have an issue in which not a single typo appears. But unless the proofreader is a mathematical genius—and none of ours is—he can be excused for not catching an omission of an exponent in an equation when the author himself left it out. On page 41 of the August issue in the last formula in the second column, the numerator should read $1.463 \times 10^7 R^2$—the ^{7} was omitted. It makes a difference in the final calculations. The first reader to call our attention to this error stoutly maintained that he had calculated the volume of a cabinet for a 10-inch speaker with a resonant frequency of 55 cps and ended up with a box which had a volume of .00461 cubic inches. Of course he couldn't get the speaker into it, but that is the way it figured out. Then, in further checking this article, we noted that the eighth line from the bottom of the third column on page 40 should read $l + 1.7R$ instead of $1 + 1.7R$. So in spite of our good intentions, we missed the boat.

We don't think this is as bad as pure ignorance in print can be, however. It seems that when a subject gets popular—as hi-fi has, and justly, within the past five or six years—everyone gets into the act and "overnight authorities" appear from nowhere. We recently saw some copy about a commercial hi-fi system in which the amplifier was described in the following terms: "Although rated 25 watt, with less than 1% distortion, this amplifier will deliver with ease a 26-watt peak where exceptionally heavy passages will require it." Another morsel in this same literature says that this amplifier "deserves the *epitaph* of High Deluxe." (Italics ours.) If everything said about this equipment is true, it is likely to need one soon. (Technically, the 26:25 ratio corresponds to a difference in power output of 0.16 db. Furthermore, the untrained human ear can rarely detect a difference of less than 2 db on program material.)

While we may be amused by these "johnny-come-lately's" to the hi-fi business, we must also remember that it is possible to be entertained and to learn something at the same time, and we will have an opportunity at

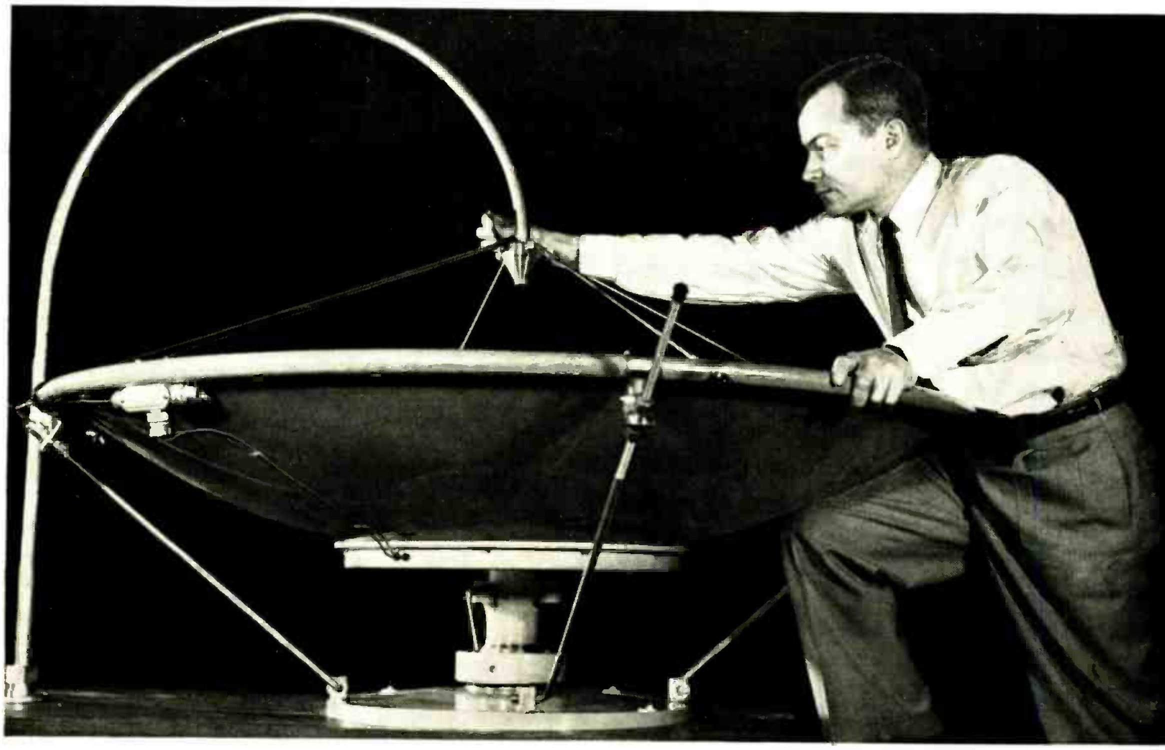
ANOTHER BRIGGS CONCERT

Those who were so fortunate as to attend Gilbert Briggs' lecture-demonstration at Carnegie Hall last October know for themselves that GAB himself is a superb entertainer, and that he is also one who can teach at the same time. Mr. Briggs is one of the Johnny-come-early's in hi-fi, although he modestly admits (in "High Fidelity—the Why and How for Amateurs") that he is "not able to write from experience prior to 1933."

Since then, however, he has become a thoroughly respected international authority on loudspeakers, and in presenting his lecture-demonstrations he has succeeded in entertaining as well as educating his audiences on every occasion. If one learned nothing else beyond a correlation between the indicated power output on peaks and the resulting sound volume, it would be sufficient excuse for attending the concert, for while we are accustomed to measuring audio power on constant tones, very few of us have the facilities for indicating with any degree of accuracy the absolute value of peak power in program material. Most people who have been in audio professionally have a reasonable familiarity with established listening levels, and these can be correlated to sound power if we make certain assumptions regarding the ratio of "program level" to "peak level." But the layman who is led to believe that it is possible for him to achieve satisfactory reproduction only by the use of a hundred or so watts—or on the other hand that he can get along without any more than five watts, perhaps—can well see for himself that the information he has been given may not check with the proof offered to his ears.

We respectfully suggest that you attend this year's concert, which is entirely new with respect to program material and—except for E. Power Biggs—artists. It is to be presented at Carnegie Hall (New York) on Wednesday evening, October 3rd, at 8:30 p.m. Tickets are available at the Carnegie Hall box office and at the leading hi-fi dealers, and since they were purposely made inexpensive it is likely that the Hall will again be filled completely.

TEACHING A GIANT TO TAKE SHORT STEPS



Bell Laboratories' Dr. J. W. Fitzwilliam adjusts a wave-guide feed to a parabolic dish reflector. Dr. Fitzwilliam, who has a Ph.D. in physics from Massachusetts Institute of Technology, leads the practical development of Bell's new 11,000-mc. system. Components had to be developed to operate in a frequency band not previously utilized.

The giant microwave highway that carries your TV programs along with telephone conversations from coast to coast has a versatile new partner — an entirely new microwave system which was created, and is now being developed, at Bell Laboratories. The new system operates at 11,000 megacycles — a much higher frequency than ever before used in telephone service.

Bell's present microwave systems — operating at 4000 megacycles — were designed for heavy traffic and long distances. The new system is designed especially for lighter traffic and shorter distances—up to 200 miles. Its traffic capacity is extremely flexible. Depending on traffic needs, the system can provide only one one-way or as many as three two-way broadband channels. Each two-way channel can carry 200 telephone conversations simultaneously or one television program in color or black and white in each direction along a route. The new microwave system, which is already being operated experimentally, will be valuable in providing additional telephone service and television programs for cities in remote areas.

This is another example of how research and development work at Bell Telephone Laboratories help the Bell Telephone System to serve you better.

Mr. L. C. Tillotson, who originated the new system, adjusts the klystron-isolator combination which made the system feasible. Mr. Tillotson, an M.S. from the University of Missouri, is in charge of research in microwave applications.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT

Transistor Action

PAUL PENFIELD, Jr.*

The physical principles underlying transistor action are discussed, and the basis of operation for a number of junction devices reviewed. No mathematics is required to understand this intuitive explanation.

TRANSISTORS ARE NOW so common that engineers and radio hobbyists are beginning to make wide use of them in audio applications. If the designer of transistor circuits is to be anything more than a "tinker" he will want to know something about the physical principles underlying the devices he is using. While it is true that good circuit design can be done by using the "black box" technique, in which the actual device is replaced by an equivalent circuit for computational purposes, nevertheless the astute engineer can make better use of physical transistors if he has a clear understanding of the physical principles involved in transistor action.

Much literature is available for those readers with considerable mathematical training; however a clear and simple explanation of transistor action in intuitive terms is not available. Either such explanations bring in much extraneous material and bore the reader, or else skip over the important parts, or else arrange the material in a fashion which prevents the reader from seeing similarities in the various junction devices, which similarities can be used to advantage in the explanation. No good intuitive explanation of junction transistor action is available.

This article has, I hope, hit a mean between too much background material and too little, and has arranged the explanations in such a way that similarities between various junction devices become immediately apparent. In connection with the former statement, the author assumes that the reader has some intellectual awareness (not an unwarranted assumption for the readers of AUDIO) and is not unwilling to accept some of the preliminary statements concerning modern physical theories without proof. If the reader has had some experience with transistors, so much the better. And if he has made an attempt in the past to understand transistor action, also so much the better.

Part I—Physical Fundamentals

With this short introduction, we can proceed to the business at hand. The article is divided into seven sections, which should be read sequentially. At the end of each section is a short review of the important points covered.

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It should not astound the reader to find that modern physicists believe all matter to be made of "atoms," each composed of a central body, the "nucleus," and one or more "electrons" which may be thought of for the purposes at hand as revolving around the nucleus. Each electron has associated with it a negative charge of value denoted by "*e*." The atom as a whole is electrically neutral, the nucleus having a positive charge of *e* times the number of electrons revolving around it.

It will simplify our explanation if we consider the electrons in any atom divided into two categories: "bound electrons" and "valence electrons." It is the valence electrons, ranging in number from zero up through seven, that determine some of the chemical properties of elements.

A group of atoms of the same kind (that is, the same number of electrons in each atom) forms material that is known as a single "element." Hydrogen and oxygen are examples of elements. In addition, atoms can combine with atoms of other elements in certain ways to make "molecules" which in turn form material that is known as a "compound," to distinguish it from an element.

Material present in the world is often classified generally speaking as "solid," "liquid," or "gaseous." One important type of solid is known as a "crystal." Crystalline substances are characterized by the fact that their individual atoms or molecules are arranged in a definite mathematical pattern. The forces which act to hold together a crystal are exceedingly strong. One such force arises from the "covalent bond," which is a configuration of two valence electrons, one from each of two atoms, between which the bond is located. This configuration happens to be quite stable. Note that two electrons are required to form this bond.

With respect to electrical conduction properties, solids can be classified as either "conductors," "insulators," or "semiconductors," with surprisingly little ambiguity. In conductors, the valence electrons are quite free to move about the material without much opposing force. On the other hand, in insulators, the electrons are *not* free to move about, hence cannot flow to form a current. Typical conductors are copper, silver, aluminum, brass, etc., including most other metals. Typical insulators are wood, paper, mica, glass, cloth, etc. An example of a semiconductor, of which there are many known, is crystalline germanium. In order to explain semiconduction further, we'll look at the germanium crystal structure.

Germanium is the most-used material for making junction devices. A germanium atom has four valence electrons. It can form a stable crystal structure by forming four covalent bonds, with its four neighboring atoms. The configuration, that is the crystal lattice, is in three-dimensional space, and is known as the diamond structure, because crystalline diamond has the same form. Often the structure is represented in two-dimensional space by rows and columns of germanium atoms, as in *Fig.* 1. Since the three-dimensional distribution of atoms is quite hard to picture, we will not attempt to draw it here.

Since all four valence electrons are used up, there is none left over to contribute toward a conduction current. Thus one might at first think that crystalline germanium is an insulator. However, two means exist to produce current-carrying, or "conduction," electrons within a sample of germanium crystal. First, thermal agitation of the atoms[1] can at room temperature be sufficient to knock a few electrons out of their covalent bonds. Not many, but a few. This situation is shown diagrammatically in *Fig.* 2. And in addition, if the specimen is illuminated with light[2], the light energy of the photons can disrupt a normal covalent bond. These two means of producing conduction electrons prevent crystalline germanium from being an insulator.

Now let's think about what happens to the conduction electron and the bond it left. The electron may merely drift away through the material. Since the

[1] Remember that, when viewing things from an atomic level, temperature is merely a measure of the rate at which particles are "bouncing around"—the higher the temperature, the faster the atoms, which can move somewhat within their specified position in the crystal lattice, jiggle around.

[2] Remember that ordinary light can be thought of as little packages, or "photons," of energy.

covalent bonds in the lattice can accommodate only two electrons, it cannot become a permanent fixture at any one spot in the lattice. Or else it may immediately fall back into the bond it left. In general, the electron is removed with such energy that it drifts away from the spot where it was. The bond, on the other hand, is now lacking an electron. A bond in this state is called a "hole." A surprising feature of the lattice is that this hole can move in roughly the same fashion as an excess electron. Its movement, of course, consists of having an electron from a nearby bond jump into the original bond, thus moving the hole to the spot where the electron came from. The hole, being the lack of an electron, possesses a positive charge equal to *e*. For the purposes of transistor physics, the hole may be thought of as a particle with a positive charge *e*, and with characteristics similar to those of a conduction electron.

A hole can re-combine with an electron by the simple process of coming close enough so that their electric attraction will cause the electron to "fall into the hole," to put it crudely. Sometimes this process is accompanied by a release of energy in the form of a photon; more often it is not. (Of course if the hole and electron could not recombine, the crystal would eventually fall apart from lack of covalent bonds. Needless to say, this doesn't happen.)

Since the concept of the hole as a current carrier is paramount in the discussion that follows, the reader should fix in his mind the following facts about the hole: (1) It may be created by somehow drawing an electron away from the covalent bond, (2) It and an accompanying electron may be simultaneously created by thermal agitation within the crystal, (3) It and an accompanying conduction electron may be created by an incident photon, (4) The hole may be considered as a positively charged particle when thinking of its current-carrying abilities, (5) A hole and a conduction electron will re-combine if they happen to meet, and (6) A flow of holes in one direction just as much constitutes current as a flow of electrons in the opposite direction.

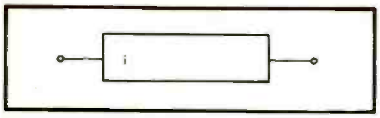


Fig. 3. A piece of intrinsic germanium with two leads, one at either end, like a common resistor. It can be used as a small photocell.

With what we know about a germanium crystal already, we can see that a single piece of germanium, made with two leads, similar to a resistor, (see *Fig.* 3) could perhaps perform some useful functions. For example, the temperature dependence of the "intrinsic current," that formed by thermal agitation, could be utilized in making the device act as a thermometer, with a conductivity that would decrease with increasing temperature. Fortunately, more reliable and more sensitive electrical thermometers, such as thermistors, are available.

However, the device is used as a photocell. Incident light produces electron-hole pairs, which, if a voltage is applied across the device, increase the current flowing. The so-called Germanium Photoresistor (type 1N189) is an example of commercial use of photoconductivity. (Actually, for reasons which we won't go into here, n-type germanium, as described below, is used rather than intrinsic germanium in this photoresistor.)

From this section the reader should understand in an intuitive sort of way the difference between insulators, conductors, and semiconductors. He should remember that germanium forms a stable crystal lattice in which all valence electrons are used up, but that conduction particles (electrons and holes) can be formed even at room temperature by thermal agitation, and also by incident photons. Holes can be treated in much the same way as electrons—as real particles. A flow of holes in one direction just as much constitutes current as a flow of electrons in the opposite direction.

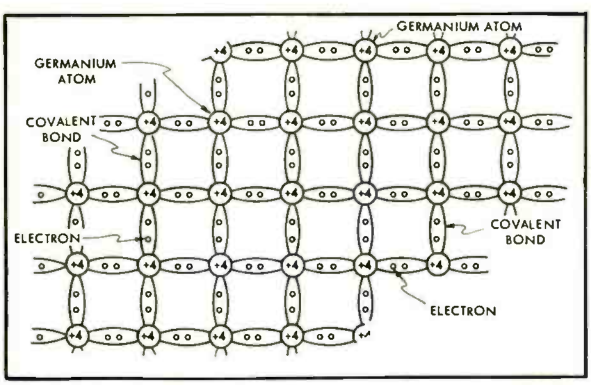
Part II—Impurities in a Germanium Crystal

The useful properties of semiconductors do not end with the pure crystals. With controlled amounts of special impurities, useful devices can be made.

Remember that in the last section we were talking about a pure sample of germanium. This was a semiconductor because the germanium had four valence electrons, all of which formed covalent bonds. If, however, one of the germanium atoms is replaced by an atom with only three valence electrons, such as indium, there will be a hole automatically formed in the lattice. The impurity atom does not break up the lattice structure—instead it fits in as well as it can, forming a hole. Of course, the crystal as a whole is still electrically neutral—the indium atom has one less positive charge in its nucleus. But nevertheless a conduction particle—namely, a hole—has been formed in a crystal which otherwise had none, except for occasional thermally or light-caused pairs. The situation is represented in *Fig.* 4.

A crystal of germanium "doped" with indium atoms (say one for every fifty million or so germanium atoms) can carry current and therefore is a better conductor than pure germanium. Because the current carriers are almost exclusively positively-charged holes, it is known as "p-type" germanium. The indium atoms are known as "acceptors" because they form bonds which accept electrons from nearby bonds, forming holes. Note that holes have been introduced without forming corresponding conduction electrons.

Similarly, a crystal can be doped with an element with five valence electrons, such as antimony, to form "n-type" germanium. The antimony atoms are called "donors" because when they fit



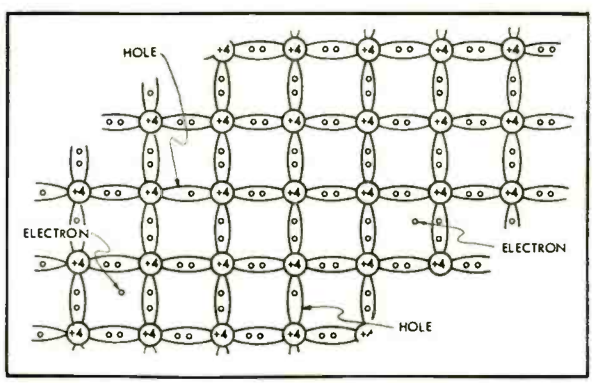


Fig. 1 (left). Representation of pure germanium crystal. Each germanium atom forms four covalent bonds with its four adjacent neighbors. Fig. 2 (right). Intrinsic germanium. Note the temperature-caused holes and electrons.

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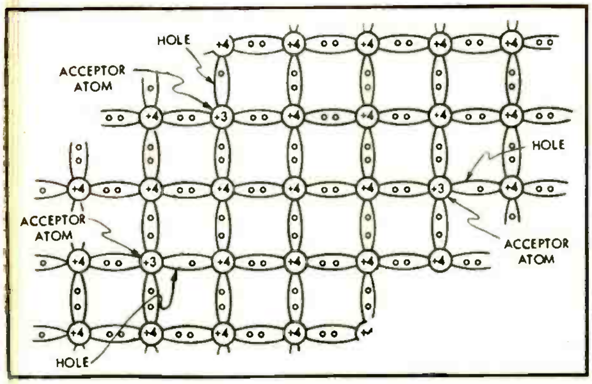

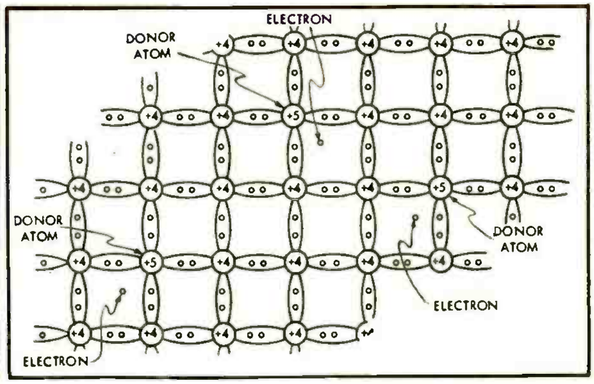

Fig. 4 (left). The addition of acceptors to otherwise pure germanium creates holes without creating excess electrons. Fig. 5 (right). The addition of donors to otherwise pure germanium creates conduction electrons without corresponding holes.

into the lattice there is an extra electron left over which is free to act as a current carrier. This is represented in *Fig.* 5. At very low temperatures (much below room temperature), the carrier introduced is attracted to the impurity atom, because they have opposite charges. However, thermal agitation shakes off these impurity carriers relatively easily.

Pure germanium, free to conduct only because of thermally-generated carrier pairs, is said to possess "intrinsic conductivity," as opposed to "n-type conductivity" (predominantly by means of excess electrons) or "p-type conductivity" (predominantly by means of holes).

The role played by the three types of germanium, p-type, n-type, and pure, is very important in transistor physics. The reader will want to remember from this section that: (1) in n-type germanium, formed by the introduction of donor atoms, the principal current-carrying particle is the electron, and the remaining donor atom in the lattice structure has a local positive charge, which however, does not succeed in "trapping" an electron and keeping it tied down at normal temperatures; (2) in p-type germanium, formed by the introduction of acceptor atoms, the principal current-carrying particle is the hole, and the remaining acceptor atoms in the lattice structure have a local negative charge, which however, does not succeed in "trapping" a hole and keeping it tied down at normal temperatures; (3) suitable juxtaposition of n-type, p-type, and intrinsic areas produces useful devices.

Part III—Action at a Junction

If we have a crystal of germanium which is half p-type and half n-type, the surface separating the two areas is known as a "p-n junction." On one side of the junction we see acceptor atoms with their local negative charge distributed throughout the area, and holes also distributed. On the other side are immovable donor atoms and many conduction electrons wandering about. Each side is at first glance electronically neutral—with equal positive and negative charge. Right near the junction there will be some diffusion of electrons and holes, with some re-combination taking place. As a result the remaining acceptor and donor atoms set up a small electric field, and the equilibrium condition of the crystal is that further diffusion of electrons and holes be stopped by a small electric field localized right at the junction.

Although the existence of this localized electric field means that the two sides of the crystal are at a slightly different electric potential, the reader should not jump to any conclusions such as that of the junction being replaced by a battery, or anything so foolish. The junction of course cannot supply power to an external resistor, and furthermore the potential difference between the two sides is a function of the temperature, and in addition can be varied by applying external power, as we shall see later.

In order to understand the rectifying action at a junction, consider the piece of crystal with a p-n junction in it, with leads attached to each end of the crystal, on either side of the junction, as shown in *Fig.* 6.

Normally, enough electrons and holes have diffused together so that quite near the junction there are no carriers (i.e. electrons or holes) present—and more carriers will not come near the junction because of the small localized electric field set up, as explained earlier. Now, if a battery is connected so that its positive terminal is connected to the p-region, and its negative terminal to the n-region, holes in the p-region will be driven away from the end of the crystal by the action of the battery, and more holes will flow into the crystal from the battery (that is, some bonds near the end of the crystal will lose one electron). Similarly, at the other end of the crystal, electrons are being driven away from the end by the action of the external battery, and more supplied to the crystal. With the externally-caused electric field in such a direction to push the holes and electrons toward each other, the crystal is said to be biased in the "forward" direction. When the electrons and holes reach the center of the crystal, they pass right through the junction, and in general travel a small ways into the other half of the crystal, whereupon they combine with carriers of opposite sign, thereby vanishing. But since more holes and electrons are continually being supplied by the battery, continued current flows through the device.

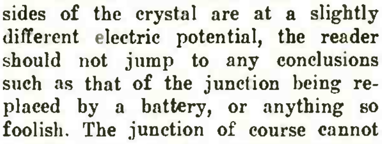

Fig. 6. A p-n junction is the surface separating p-type from n-type germanium. Here is a junction diode, using one p-n junction.

On the other hand, if the battery leads were reversed, so that the positive terminal went to the n-type germanium, and the negative terminal to the p-region, the action would be such as to draw the electrons and holes within the crystal away from each other—that is, toward the ends of the crystal. Clearly very little current can flow in this situation, since the electrons and holes cannot recombine easily.

Thus we see that this device, known as a "junction diode," can pass current easily in only one direction. The common 1N91 is an example of such a rectifier. Crystal rectifiers, made both from germanium and silicon, are in limited use already, and are expected to replace vacuum tube rectifiers in many applications as soon as the price falls a bit more.

The forward current in these devices is limited by the I^2R losses within the germanium, and also by the fact that the junction electric field never is completely eliminated by the externally-applied field. The reverse current that flows is produced mainly by imperfections in the crystal construction, or else by thermally-generated carrier pairs. If a thermally-generated pair occurs near enough to the junction so that there are no other carriers present, the hole will be attracted by the p-region, and the electron will move toward the n-region, and their motion will constitute current. And if a reversely-connected junction diode is illuminated with light, incident photons will produce carrier pairs, increasing the current. The effect is made use of in photodiodes, as explained in the next section.

The principles the reader should retain from this section are: (1) the surface between n-type and p-type material is known as a p-n junction, and a two-terminal device employing a p-n junction is known as a junction diode. (2) At thermal equilibrium with no external voltage applied, a slight electric field is set up across the junction which keeps the holes on one side and the electrons on the other. (3) If a diode is biased in the forward direction, the holes and electrons are pushed by the external power source toward the junction, near which they re-combine. (4) If a diode is biased in the reverse direction, the holes and electrons are pulled away from each other and away from the junction, so little current flows. (5) When a diode is reversely biased, any carriers, whether hole or electron, which are placed near the junction will flow toward the end of the diode.

Part IV—Some Other Junction Devices

The last statement in the last section is extremely important and is fundamental to an understanding of transistor action. "When a diode is reversely biased, any carriers, whether hole or electron, which are placed near the junction will flow toward the end of the diode." If the reader understands nothing at all from the last sections but this, he's still ready to proceed.

In the last section we described the action of a junction diode. Now let's take that same diode, and establish a reverse bias on it by connecting an external battery with its positive terminal on the n-region, and its negative terminal on the p-region. The reverse current is now due only to thermally-generated carrier pairs created in the vicinity of the junction. However, if we shine light on the junction, more hole-electron pairs will be formed, and consequently more current will flow through the device. When connected and used in this way, the device is known as a "junction photo-diode"—the 1N188 is an example of a germanium photodiode. It is possible under good conditions to achieve a yield of nearly 1—that is, one hole-electron pair for every light quantum hitting the diode. The device is thus seen to be a practical, very small, sensitive photocell.

However, illumination and thermal agitation are not the only ways to introduce holes or electrons near a reversely-biased junction. Consider the case of a three-region piece of germanium—with two p-regions at the ends, and a small, narrow n-region in the middle. See *Fig.* 7. Suppose each region is brought out to a terminal, and that between the middle and right regions a reverse bias is applied—by applying the positive terminal of a battery to the middle region, and the negative terminal to the end. Thus one junction is reversely biased. And little current will flow. Now, however, we shall connect a small battery between the middle region and the left end—

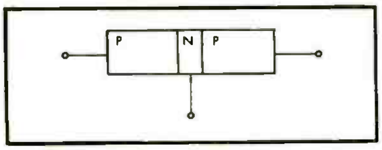

Fig. 7. A two-junction device, with each of the three regions brought out to a terminal.

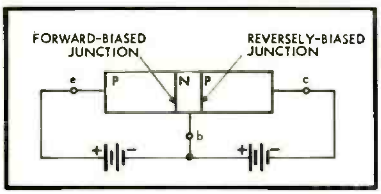

Fig. 8. Normal biasing of the p-n-p junction transistor. The emitter junction is biased forward, the collector junction backward.

this time in the forward direction. What will be the result of this connection, shown in *Fig.* 8?

At first glance, one might be tempted to treat the two junctions separately, and say that the one will remain nonconducting, and the other will conduct. However, this is not the effect observed. Instead, holes that enter the middle n-region from the forward-connected left-hand junction will see only the other junction ahead of them —and will act just like any carrier introduced in the region of a reversely-biased junction—they will flow through the junction and out the other end of the crystal. A few, to be sure, will re-combine with the electrons within the n-region, but the vast majority, especially if the n-region is thin, will proceed through both junctions and thus pass right through the crystal.

If the reader hasn't guessed it by now, the three-terminal device we have been talking about is a "p-n-p junction transistor." The end terminal which emits the holes into the middle region is known, appropriately enough, as the "emitter." The other end terminal, which collects all the holes which the emitter injects, is known as the "collector." The middle region is called the "base." The theory given above for the operation of the transistor is known as "transistor action"—the control of current through a reversely-biased junction by means of current injected near the junction by another electrode (in this case another junction).

Because of its importance let's go through it again: First, a reverse bias is set up between the base and the collector—that is, across the collector junction. The only collector current which flows (if the transistor is shielded from light) is due to thermally-generated hole-electron pairs created near the collector junction. Now, however, a forward bias is set up between the base and the emitter—that is, across the emitter junction. Thus, much current flows through the emitter. The question becomes, "what happens to the emitter current once it reaches the base?" First, a small portion of the emitter current is due to electrons which flow across the emitter junction from the base—these recombine with holes somewhere within the emitter. Secondly, some of the holes that enter the base re-combine with electrons within the base. These two together constitute the current which flows through the base lead. However, if the transistor is properly designed, the vast majority of holes pass right through the base into the collector, and serve to increase the collector current. Of course, superimposed upon the emitter current might be some sort of fluctuating signal which requires amplification.

But now the question may arise, "so what?" We just saw that the collector current is always (in the normal operating region) less than the emitter current. Is that amplification? Well, it's not too hard to see that, no matter what the collector-to-base voltage is, so long as the collector junction is biased reversely, the collector current is determined almost completely by the emitter current. In other words, a large resistor in series with the collector which changes the collector voltage when the collector current changes, will not appreciably affect the amount of the collector current, which will still be determined by the emitter current alone. Thus our input signal, at a very small voltage, can be increased to several times this voltage—in other words the transistor connected this way will amplify.

Since the base terminal is common

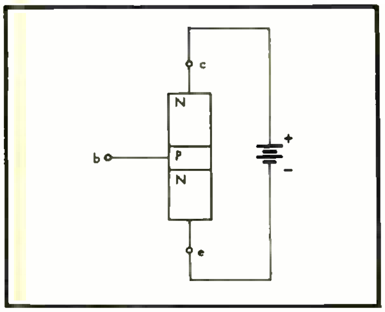

Fig. 9. Common-emitter biasing method for a p-n-p junction transistor.

to both the input and the output of the simple amplifier, it is called a common-base, or grounded-base configuration. We will see in the next section that in another configuration the device can act as a current amplifier.

This section is, of course, the most important section in the article. The sections before this merely served to introduce certain concepts used here. The following three sections will further describe transistor action, and will describe a few more commercially available junction devices of interest. Out of this section the reader should have learned: (1) A photo-diode is merely a reversely-biased diode whose current is controlled by incident light. The incident photons produce electron-hole pairs near the junction. A small, practical, sensitive photocell is the result. (2) A p-n-p junction transistor is merely a three-terminal device having two p-n junctions "back-to-back," separated by a small n-region. The collector current is determined, in the grounded-base configuration, by the emitter current only—not by the collector voltage. A small, efficient, amplifying device is seen to result. (3) Transistor action is merely the control of current through a reversely-biased junction by means of injecting proper carriers in the vicinity of the junction from another electrode.

Part V—Grounded-Emitter Operation

We saw in the last section that transistor action is merely the control of current through a reversely-biased junction by means of current from another source deposited near the junction. In a p-n-p junction transistor with the base lead common to both the collector and emitter circuits, a majority of holes coming from the emitter pass right through the base region into the collector. Since the collector current is less than the emitter current, the transistor does not amplify current, although we saw that it would amplify voltage. Let us call the fraction of emitter current which *does* reach the collector α.

α will normally be just a trifle less than one—for the sake of example, let's say that $\alpha = 0.95$. If we call the emitter current i_e, the collector current i_c, and the base current i_b, we immediately see that

$$i_c = \alpha i_e \qquad (1)$$

and

$$i_b = (1-\alpha)\ i_e \qquad (2)$$

and therefore

$$i_c = \left(\frac{\alpha}{1-\alpha}\right) i_b = \beta\, i_b \qquad (3)$$

where β is called the "grounded-emitter current gain," and

$$\beta = \frac{\alpha}{1-\alpha}$$

so when $\alpha = 0.95$, $\beta = 19$.

If we consider the base as the input terminal, and the collector as the output terminal, we can see from Eq. *(3)* that the collector current is many times greater than the base current, so when the transistor is operated in the grounded-emitter configuration, that is with the emitter common between the input circuit and the output circuit, current amplification takes place.

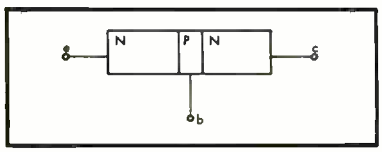

Fig. 10. An n-p-n junction transistor behaves in exactly the opposite way as a p-n-p junction transistor. All polarities are reversed.

Furthermore, by the same sort of reasoning as was employed in the last section, this current can be made to flow through a large load resistor, so voltage amplification occurs as well.

However, this mathematical derivation may not be at all convincing to the reader, so we'll go through the grounded-emitter stage again, from a physical viewpoint.

Consider the case when a battery is placed directly between the collector and the emitter, with the base left unconnected, as in *Fig.* 9. Of course, for the p-n-p junction transistor under consideration, the collector should be connected to the negative battery terminal, and the emitter to the positive. In this case, the collector junction is biased in the reverse direction. In addition, the potential of the base is slightly higher than the potential of the emitter. For if it were not, emitter current would flow, one twentieth of which would remain in the base to charge it up to the point where no more current will flow. This is the condition of the transistor for equilibrium. Now consider the case when an electron appears in the base region for one reason or another. Perhaps it was introduced in through the base lead, in which case it represents base current. The potential of the base region is lowered somewhat by the presence of the electron, with the result that the emitter injects holes into the base to try to raise its potential up to the point of equilibrium. For each electron in the hole region, the emitter injects twenty, or $1/(1-\alpha)$ holes—one of which recombines with the electron, and 19 of which flow through the base into the collector. Thus a very small amount of current through the base can control a rather large amount of current through the collector. In fact, 1 milliampere through the base can control 19 milliamperes through the collector, or $\alpha/(1-\alpha)$ milliamperes. Thus the current gain is seen again to be $\alpha/(1-\alpha)$. This is, of course, the same result we achieved two paragraphs ago by considering the device mathematically.

The reader should recognize the fact that this "transistor current multiplication" is merely another manifestation of transistor action, and is quite equivalent to the statement about transistor action made at the end of the last section.

The reader should note the following pertinent points arrived at in this section: (1) In the grounded-emitter configuration, the transistor is capable, to a first approximation, of a current gain of $\alpha/(1-\alpha)$. (2) This transistor current multiplication (often referred to as "hook multiplication") is merely another manifestation of transistor action—and thus is entirely equivalent to the former statement of transistor action.

Part VI—Other Two-Junction Devices

In this section we will discuss two more two-junction devices—both of which rely for operation on transistor action.

Besides p-n-p junction transistors, n-p-n junction transistors exist as well. See *Fig.* 10. Transistor action is exactly the same in these n-p-n units, except that all battery polarities and current directions must be reversed. For example, instead of injecting holes into the base, the n-p-n emitter injects electrons. The n-p-n transistor is exactly the same, to a first approximation, but opposite in polarity to a p-n-p transistor.

Let us consider an n-p-n transistor operating grounded-emitter—that is, with only one battery connected between the collector and the emitter, with the collector positive[3] as shown in *Fig.* 11. As a first approximation, we stated in the last section that no current would flow. As a matter of fact, however, thermally-generated electron-hole pairs will be created near the reversely-

[3] From his knowledge of transistor action the reader should be able to verify in his own mind that the collector junction will be biased reversely with this connection.

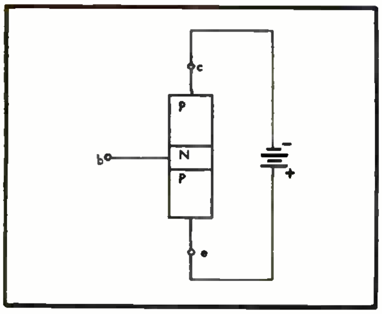

Fig. 11 A grounded-emitter n-p-n junction transistor. This is correct biasing for use as a photo-transistor.

biased collector junction, the electron of which will be pulled by the positive terminal of the battery into the collector, and the hole of which will proceed into the base. In order to counteract the presence of the hole in the base, the emitter must inject 20, or $1/(1-\alpha)$ electrons into the base, one of which will re-combine with the hole, and 19 of which will pass through into the collector. Since this is so, the collector current will be twenty times the rate of creation of carrier pairs due to thermal agitation alone. In short, the problem of thermal current in the grounded-emitter stage is greater than the problem when the transistor is fed with the base common. "Bias stabilization" under widely varying temperatures is often a severe problem—although there are techniques for reducing the effect considerably.

So hook multiplication is a problem when thermal current is considered. However, it can be used to advantage in certain cases. Consider, for example, the same n-p-n transistor with its base disconnected, and normally-biased as in *Fig.* 11, and with the reversely-biased collector junction illuminated. For every light-caused electron-hole pair formed, twenty electrons will flow through the collector circuit. Thus, in effect, the photo-diode current is multiplied by the hook multiplication ratio—$1/(1-\alpha)$. This device is known as a "photo-transistor," and is often described as a photo-diode with a built-in amplifier. Texas Instruments type 800 is typical of modern photo-transistors.

From this section the reader should retain the following points: (1) n-p-n junction transistors operate in exactly the same way as p-n-p junction transistors, except that all battery polarities are reversed. (2) Grounded-emitter transistors with the base left open-circuited exhibit hook multiplication of thermally-generated current. (3) Photo-transistors use the inherent hook multiplication of transistors to advantage in producing a more sensitive photocell than the photo-diode. For some purposes they can be thought of as a photo-diode with a built-in amplifier.

Part VII—Three-Junction Devices

A device can be made which is analogous to the photo-transistor in the same way that an ordinary p-n-p junction transistor is analogous to a photo-diode. For this operation, some current is injected by a fourth element placed quite near the collector junction. This element serves the same purpose as the emitter of a normal junction transistor, and so in the composite device is called the emitter. What was formerly the collector plays the role of the base, so it is now known as the base. What formerly was the emitter now becomes the collector.

The device, known as a "p-n hook transistor" is shown in *Fig.* 12. Federal Telecommunication Labs makes an experimental model, type CP-611. The device can be most easily understood by considering it connected grounded-base. In this connection, the three elements at the right (as in *Fig.* 13) form a hook multiplier—the same way that an n-p-n transistor normally would. Emitter current injected at the left passes into, and 95 per cent (or α) of it through, the base region. The portion which passes through the collector junction in the middle finds itself in what looks like the base of an n-p-n junction transistor, so biased that hook multiplication will occur. For each hole so present, 20 or $1/(1-\alpha)$ electrons will be drawn from the collector region to the far right, 19 of which will again pass through the reversely-biased junction in the middle into what is called the base of the composite hook transistor. If the base is grounded, these will flow out of the base, in which case the "collector current" will be many times the "emitter current." In fact, if the region at the left has a normal current gain of α_1, and the three elements at the right taken together have a current gain of α_2, (both less than unity), the ratio of collector current to emitter current will be $\alpha_1/(1-\alpha_2)$, or approximately β_2.

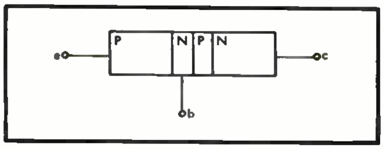

Fig. 12. A three-junction device, three of whose sections are brought out to terminals. This is the hook transistor.

Note that the base was grounded in the last discussion. The device in this configuration possesses a current gain greater than one—something which a normal junction transistor does not. It should be noted that care must be taken in designing circuits around the hook transistor, since it, like the point contact transistor, which also can have a current gain greater than 1, is unstable in certain configurations. In fact, too much resistance in the base circuit can make the device unstable.

However, Federal Telecommunication Labs reports that in their transistor, the over-all current gain from emitter to collector is very much a function of the collector current, dropping down to practically 1 for low-current operation. For this reason, circuit design problems may be less severe than otherwise expected.

Another possible device similar in form to the hook transistor may find use someday. We shall call it the hook photocell. If a hook transistor is arranged in some stable arrangement, with the base removed from ground by means of a series resistor, and then the center, reversely-biased junction is illuminated by a light source, a current multiplication will occur which is somewhat more than that due to one hook multiplication alone. Thus the device could be more sensitive than the photo-transistor. Whether a device of this sort will ever find much practical use remains to be seen, but it is mentioned here so that it may be considered a logical extension of the practical devices. The problem of a very large thermally-generated current would limit the usefulness of the hook photocell drastically.

Attempts to make a five-terminal transistor using two hook multiplications within the same crystal will probably be doomed to failure, for the injected carriers must be placed square in the middle of the middle region of the hook transistor for such a device, and the problems of building such a device out of a single crystal are quite difficult, as the reader may be able to see. This is not to say that useful five-terminal devices will not be made using junctions and transistor action—but they will probably have two or more terminals attached to one region, as present tetrode transistors and double-base diodes do.

Out of this section the reader should

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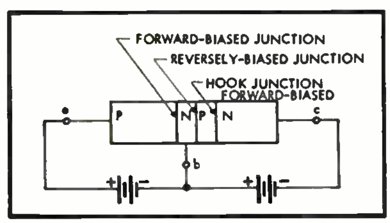

Fig. 13. Correct biasing for the hook transistor. This is the same as the p-n-p junction transistor. Only difference is that the collector has a "built-in hook mechanism."

Ported Loudspeaker Cabinets

JAMES MOIR*

A thorough understanding of the author's presentation will enable anyone to design and construct a bass-reflex cabinet which will provide improved performance over conventional "boxes with holes in them."

PORTED OR REFLEX CABINETS are deservedly popular as loudspeaker mountings at the present time, their special merits being the extension of the low-frequency range that may be obtained in a relatively small volume, coupled with an appreciable reduction in the amplitude distortion generated by the loudspeaker. The theory, construction, and operation is an interesting study and it is proposed to comment on some of the aspects in which present theory and practice appear to be at variance.

The first major advantage is the increase in the low-frequency output that is obtainable from a reflex cabinet when compared to the output obtainable from the same speaker unit mounted in a flat baffle, or in many of the alternative enclosures. The increase in output is the result of several contributory factors.

(a) Utilization of the acoustic power output from both sides of the cone.
(b) The close association of two radiating surfaces vibrating in the same phase.
(c) The addition of an Helmholtz resonator to the acoustic system.

Some of the many possible forms are illustrated in *Fig.* 1 from which it will be appreciated that the characteristic feature of all ported cabinets is the addition of an Helmholtz resonator coupled to the rear of the cone, the resonating elements being the acoustic capacitance of the box volume and the acoustic inductance of the mass of air contained in the port and tunnel. At, and in the vicinity of resonance, there is a considerable movement of air through the port and the energy radiated as sound from the port may exceed that radiated from the front of the diaphragm by a factor of several times. If the phase of the radiation from the port is the same (within ± 90 deg.) as that from the front of the diaphragm the total sound output will be increased. It may be shown that the combination of acoustic elements is such that the backward wave from the speaker diaphragm is reversed in phase and thus appears at the port opening *in phase* with the radiation from the front of the cone. The exact mechanism of the phase reversal will not be pursued at this point for the agreement between calculated and measured values of some of the elements in the acoustic phase changing path is poor. Actual measurements of the relative phase of the sound pressure at the port and diaphragm confirm the qualitative theory however.

Though the radiation from the port is in phase with that from the diaphragm in the vicinity of resonance it deviates considerably both above and below the resonant frequency. As the resonant frequency is usually chosen to be near the bottom end of the audio range, the deviation from phase identity below the resonant frequency is not of great consequence. Above the resonant frequency the phase difference can also reach 180 deg. and as this would reduce the total sound output it is necessary to attenuate the high-frequency radiation from the port by adding absorbent material to the interior of the enclosure. A qualitative comparison between the sound output with and without a ported cabinet is given by *Fig.* 2 from which it will be seen that some worthwhile gain is obtained over about one octave above and below the resonant frequency but the effective sound output at very low frequencies is actually reduced by the addition of the acoustic resonator.

Design Procedure

The first problem to be met when ap-

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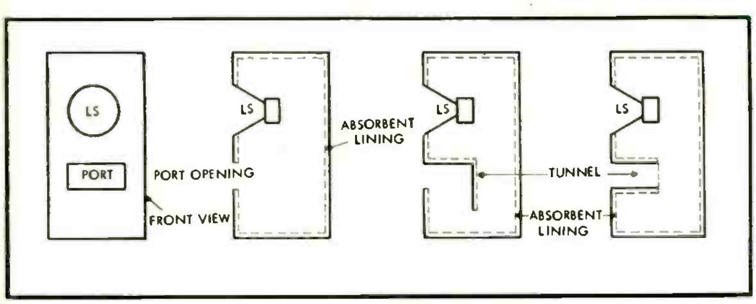

Fig. 1. Typical arrangements of ported cabinets showing two possible positions of the tunnel or duct.

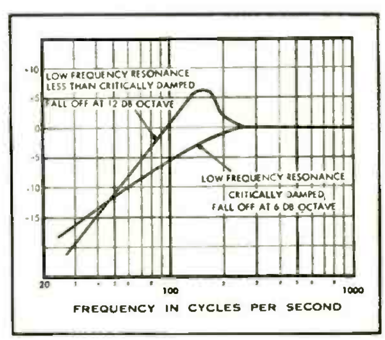

Fig. 2. Effect of damping of low-frequency resonance on acoustic output of a cone loudspeaker.

proaching the design of a ported cabinet is that of choosing the resonant frequency for which the enclosure is to be designed. A full discussion of the reasons governing the choice would require more space than is available and it will be shortened to the point of saying that the resonant frequency of the enclosure is usually chosen to be the same as the resonant frequency of the speaker cone. The acoustic coupling between the resonant enclosure and the resonant mechanical system of the cone and surround is assumed to be such that the electrical impedance/frequency curve of the speaker voice coil will have "maximum flatness." A typical sort of result is illustrated by *Fig.* 3 from which it will be seen that the over-all impedance/frequency curve exhibits the double humped form characteristic of coupled electrical circuits, certainly a major advantage, for as previously pointed out,[1] a flat impedance/frequency curve results in minimum amplitude distortion from the amplifier output stage.

The acoustic resonant frequency of the enclosure is controlled by the physical dimensions of the enclosure volume, the port area, and the tunnel length interpreted as in *Fig.* 4. The relation may be approached either by calculating the equivalent electrical circuit elements or by a more direct approach involving the physical dimensions only. The former gives a clearer insight into the basic process and is invaluable in any investigation but the latter method is shorter and is quite adequate for the enclosure designer. Several analyses have been made but the one most closely in agreement with measurements is that due to Planer and Boswell.[2] Their work leads to an expression for the resonant frequency,

$$f_r = \frac{2150}{\sqrt{V(1\sqrt{A} + L/A)}} \; cps \qquad (1)$$

where

V = box volume

A = port area

L = effective tunnel length

with all dimensions in inch units.

A critical comparison of the calculated and measured resonant frequencies of a dozen or more enclosures indicated that while none of the published design equations were in perfect agreement with practice, the expression quoted consistently gave the best agreement.

To the enquiring mind, marginal disagreements between theory and practice are often of greater interest than complete agreement so the subject will be pursued in an endeavor to account for the discrepancies. The factors entering into the design equations are enclosure volume V, port area A, and tunnel length L, and as the effective values of these may differ somewhat from their physical values they will be considered in turn. In the simple case where no tunnel is employed there would not appear to be any great margin for error in determining box volume V, though the literature is a bit inconsistent in deciding whether the volume of any absorbent lining should be deducted from the chamber volume to obtain the effective volume. Qualitative considerations suggest and experiment confirms that the volume of permeable linings such as fibreglass or hair felt should not be deducted from the casing volume but that allowance should be made for the volume of the more impermeable materials, such as insulation board, cane fibre or asbestos fibre tiles.

As far as can be ascertained prior literature is completely in error in dealing with the effective volume of an enclosure that includes a tunnel, the unanimous and apparently reasonable decision being that the tunnel volume should be subtracted from the internal volume in order to obtain the effective volume. This outlook would seem to be based on the simplifying assumption that the air in the tunnel takes no part in the compression and expansion cycle which characterises the acoustic regime in the volume V but merely undergoes translation along the tunnel. A little thought will suggest that this assumption is probably untenable but any doubts were resolved in a relatively simple manner.

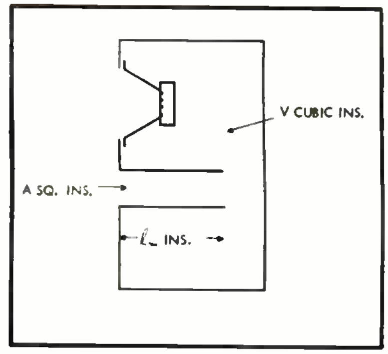

Fig. 4. Parameters important in the design of a ported cabinet.

Experimental Determination

A ported enclosure was constructed in which the tunnel volume represented some 30 per cent of the enclosure volume and of such a shape that the tunnel could be added either on the inside or outside of the box as indicated in *Fig.* 5. This artifice maintains the tunnel length substantially constant but allows the tunnel volume to be removed from the cabinet volume. The resonant frequency of the enclosure was then measured (using a precision low-frequency oscillator) with the tunnel in both positions. In neither example tested was there any indication that the position of the tunnel had any significant effect upon the resonant frequency although the test method employed was capable of detecting a frequency shift of less than one tenth of that expected from calculations based on the normal assumption.

The actual experimental verifications were carried out by two competent engineers well versed in the conventional theory and quite skeptical about the writer's preliminary suggestion that the accepted theories were in error. We may say with some confidence that the tunnel volume should *not* be subtracted from the enclosure volume to obtain the effective volume of the enclosure.

Speaker's Volume

Prior literature is also quite unanimous and apparently in error about the correction to be made for the volume occupied by the speaker unit, specifying that the effective volume of the speaker unit is that shown in solid at (A) in *Fig.* 6. Once again some preliminary theorizing suggested that the effective volume of a

[1] J. Moir, "transients and loudspeaker damping." Wireless World, May, 1950.

[2] Planer and Boswell, "Vented loudspeaker enclosures." Audio Engineering, May, 1948.

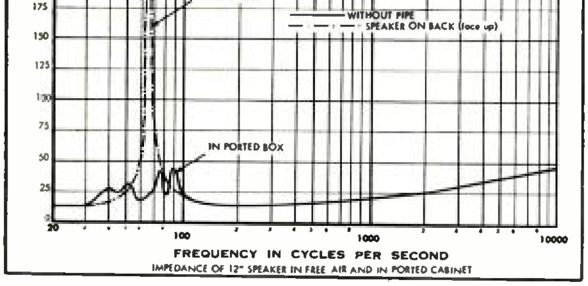

Fig. 3. Impedance of a typical 12-inch speaker in free air and in a ported cabinet.

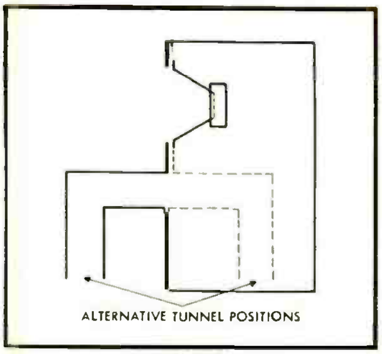

Fig. 5. Cabinet arrangement for experimental determination of effective volume of tunnel.

speaker unit is in fact only that of the iron parts and does *not* include the volume enclosed by the conical diaphragm. An enclosure divided into two half sections by a partition in the form of a thin infinitely flexible and massless diaphragm behaves as a single volume, for the diaphragm offers no obstruction—either resistive or reactive—to the movement of vibrating air particles in the vicinity of the partition. The air volume enclosed by the conical diaphragm is similarly tightly coupled to the volume of the enclosure.

Once again any doubts were resolved by a simple experimental attack. Measurements of resonant frequency of an enclosure of normal volume are insufficient to determine any change due to the insertion of a speaker unit but the use of an enclosure having an internal volume of little more than one cubic foot permits the change in resonant frequency to be accurately determined. The resonant frequency of the small enclosure was determined with and without the speaker unit, the effective volume of the speaker unit being determined by calculation from the two experimentally determined frequencies. It was confirmed by inserting wood blocks of known volume into the empty enclosure to bring the resonant frequency up to that of the enclosure with the loudspeaker.

The effective volume of the speaker determined by these two methods differed from an estimate of the volume of the iron parts, as shown at (B) in *Fig.* 6, by less than 3 per cent and bore no relation to the volume enclosed by the speaker outline.

The foregoing discussion enables the effective volume of an enclosure to be determined leaving the port area A and the effective length of the port or tunnel L to be determined. Unless a port of slit shape is adopted the effective area is the same as the physical area and it thus presents no difficulty in its determination.

The effective length of the tunnel may, and generally does, differ appreciably from its physical (i.e. measured) length. Helmholtz resonator theory presupposes that the air in the tunnel undergoes a translatory motion along the tunnel but that the air particles immediately outside the tunnel ends are stationary. This is clearly an oversimplification but an accurate mathematical determination of the effect of the air movement outside the tunnel is a difficult process that has exercised many investigators because of its importance in determining the effective length of an organ pipe.

Movement of the air outside the ends of the tunnel will clearly increase the mass of air in resonant motion and result in the effective length of tunnel being greater than the physical length. Rayleigh has proposed to allow for these "end effects" by adding an end correction $l_c = 0.4D$ to the measured length of tunnel and his proposal is confirmed at least for measurements of engineering accuracy. D is the diameter of the port if circular or the diameter of the circle having the same area as the port where the port is non-circular. The effective length of tunnel L to be used in equation (*1*) is therefore the measured length l_m plus the correction l_c. Where the port is the chamber wall thickness only the effective tunnel length will differ from the measured tunnel length by an appreciable amount for the correction length l_c, being a function of port area only, becomes greater than the physical length. With the modifications discussed, the equation presented by Boswell and Planer appears to predict the value of enclosure resonant frequency with an error of less than 2 per cent when any simple form of construction is employed.

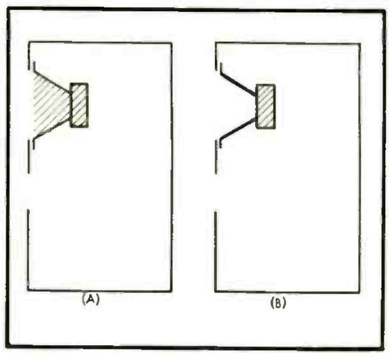

Fig. 6. Effective volume of loudspeaker unit.

The design procedure based on the Planer and Boswell equation is presented in the form of a single set of curves in *Fig.* 7, which covers the design of any size of speaker unit in any size of enclosure and with any value of enclosure resonant frequency.

Other Variables

The resonant frequency is, however, a function of (among other things) the enclosure shape. Thus when a spherical resonator with a circular opening is employed, the resonant frequency is determined almost entirely by the volume V and port area A and may be accurately calculated. At the other extreme a chamber in the form of a long narrow pipe has a resonant frequency which is deter-

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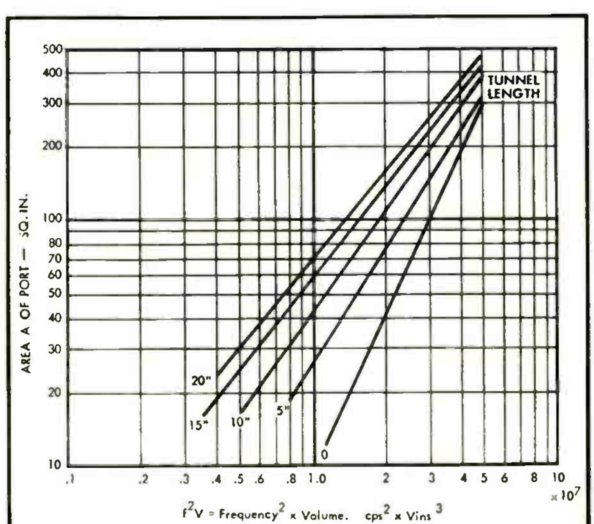
Fig. 7. Design relations of ported enclosures.



A Semicircular Exponential Horn

One answer to limitations in bass response

REUBEN M. CARES, M.D.*

One answer to the limitations in bass response is arrived at by a serious experimenter who analyzed all the literature on the complicated subject of horns and other accepted methods of achieving satisfactory reproduction and then used his head to work out a horn structure which solved his requirements.

RESONANT CHAMBERS are essential to all musical instruments, whether stringed, woodwind, brass or of percussion type. Music in the lower registers and "bottom bass" depends on three familiar forms of transducers. Thus the bass viol or cello has a body with a vented enclosure resembling a bass reflex cabinet for speakers. Brass and wood-winds are all actuated by some type of horn-loading of the sound source —vibrating lip or reeds. The tympani enclose air cavities of large volume, as duplicated by speaker enclosures of infinite baffle type.

The lower the register of a musical instrument, the larger must be the enclosed air column or mass coupled to the sound source. A woofer-enclosure usually differs in that one desires a wider frequency range than its musical counterpart, plus higher dynamic levels. The most vigorous fortissimo from the bass viol can hardly approach the loudness of a 30-watt amplifier speaker system at rated output capable of reproducing the instrument's pitch and timbre. The problem is that of undistorted reproduction of bass within the energy range of the audio system.

The appraisal of various speakers and their enclosures as regards low-frequency response is ultimately subjective. Musical tastes, auditory acuity[1] and volume-level preference, other things being equal, comprise a greater number of variables than may be accommodated by established electro-acoustic standards.

This physiologic principle applies not only to speakers and enclosures, but also to listening evaluation of amplifiers which are identical electronically. McProud[2] called attention to this puzzling phenomenon in a detailed review of amplifier design. Identical series of laboratory bench measurements of two well-designed amplifiers will give different results in a listening test. As emphasized by McProud, we don't know yet how to measure certain characteristics which are subjective and of indefinable aesthetic values.

Listening tests thus depend not only on electronic parameters but also on the imponderables of psycho-acoustic phenomena. This accounts for the public acceptance of a multiplicity of designs in commercial and custom-built enclosures. Regardless of standard acoustic formulas, considerable deviation from ideal speaker-enclosure design will still appeal to some segment of the critical listening public. This exists since conditions beyond control of the manufacturer or audio engineer include acceptable costs (a matter of cultural indoctrination), room acoustics, and most important, the degree of auditory and musical discrimination of the consumer.

Present convention (implying domestic restraint or other home influence) dictates, except for the very well-heeled minority, that an audio system, including the speaker enclosure, should be housed in a cabinet which has, at the most, the bulk of a desk or buffet. Any piece of electronic cabinetry larger than this 25–30 cubic foot size in the average living room disturbs a balance in room furnishing in the average American home.

This arbitrary limit in size is a question of mores. A natural musical instrument is tolerated with no undue regard for its size. The permanent presence of a piano is rarely challenged even in a grand size. Fortunately, the prestige attached to this single large household instrument is gradually being applied to high-fidelity units. One limitation to home music systems still applies —that the large volume be unobtrusive. The larger the system, the more disguise is used—as built-in shelving, corner cabinetry, and the like.

Problems of Speaker Enclosure Choice

The three main types of air chambers for bass range—vented boxes, closed chambers, and horns—are present in numerous modifications of speaker-enclosures. Of these, Plach and Williams[3]

TABLE I ACOUSTIC ANALOGIES OF INSTRUMENTS OF LOWER REGISTER TO SPEAKER ENCLOSURES							
Instrument	Audio Spectrum Kcps.	Resonant Chamber	Horn Type	Mouthpiece (Spkr. Chamber)	Throat	Air Column	Mouth (Bell)
CLARINET (Boehm)	.15-14	HORN	CONE (cyl.)	CONICAL	1"	20"	2"
TRUMPET	.18-11	HORN	CONE	HEMISPHERICAL CUP	1/4"	8'	6"
FRENCH HORN	.09-8	HORN	EXPONENTIAL	CONICAL	1/2"	9-18'	15"
TROMBONE	.08-8	HORN	CONICAL	CONICAL	3/8"	9-13'	7"
TUBA	.04-7	HORN	EXPONENTIAL	CONICAL	1/2"	14'	24"
CELLO	.06-8	VENTED BOX					
BASS VIOL	.04-9	VENTED BOX					
TYMPANI	.042-9	INFINITE BAFFLE					
ORGAN (Church)	.016-12	OPEN PIPE	CYLINDER				

* *Director of Laboratories and Chairman of Audio-Visual Committee, Kings Park State Hospital, Kings Park, N. Y.*

[1] As with visual focussing accommodation which decreases steadily above middle age, the audible frequency range decreases with age. At 20 years many can hear to 20,000 cps or higher. After middle age few people can hear beyond 14 or 15 kcps.

[2] C. G. McProud, "Amplifiers and Preamplifiers." AUDIO, January, 1955, p. 23.

[3] D. J. Plach and P. B. Williams, "Horn-loaded loudspeakers." *Radio and Television News*, May, 1952.

TABLE II

LOW-FREQUENCY EXPONENTIAL HORNS

Cutoff cps	Wave-length L feet	Area Doubles $Sx^2 = 2s1^2$ inches	Flare Rate m*	Throat Diameter 2% of L inches	Path Length ½L feet	Mouth Diameter ¼L** feet
200	5.6	3.84	.176	1.3	2.8	1.4
100	11.2	7.68	.088	2.6	5.6	2.8
50	22.4	15.37	.044	5.2	11.2	5.6
25	44.8	30.75	.022	10.4	22.4	11.2

* Flare rate is sufficiently gradual to approach a conical horn and thus allow extended lengths of straight wall sections.

** Within reasonable limits, circumference of any polyhedral opening may equal a wavelength; minimum diameter is 1/16 wavelength to avoid waveform distortion.

Exponential formula — $S_x = S_1 \epsilon^{mx}$

among many others, have indicated that properly designed horn-loading gives the best performance and output for bass reproduction, particularly in the critical 30–100 cps range.

No other audio-visual component of well-designed home music systems approaches the physical space requirements of speaker enclosures. The need for extended sound paths in the acoustic horn-loaded devices without undue bulk has been fairly well met by a "telescoping" compression of the horn by the folded horn principle. Even more bulk or space-enclosure is needed with infinite baffles. The folded-horn, obviously, does not physically duplicate the configuration of lowest register instruments. The latter require dimensions and construction universally standardized to avoid structural deviations that will alter the pitch, timbre, and tone range. The size and shape of the mouthpiece, the continuous air column in *smooth curved* shapes and the bell or acoustic mouth have mutually dependent specifications. With any noticeable change in the design of a trombone, for example, a new instrument is born—subject to musical acceptance or rejection.

Table I compares speaker-coupled chambers to enclosures which form part of bass musical instruments. For use with speakers, the horn is most adaptable since it can be altered in its throat, path or mouth dimensions to allow for any desired acoustic impedance. Souther[4] found in comparative studies that low-frequency response curves for resonant chambers were increasingly efficient in this order—flat baffles, enclosed boxes, vented boxes, and horns. Below 100 cps, he felt that a minimum of 12 cubic feet of enclosed air is needed in any chamber.

Some Features of Horn Acoustics

According to Olsen[5] "A horn is an acoustic transducer of varying cross-sectional areas capable of presenting any value of acoustic impedance to the sound generator." Plach and Williams had, in another study,[6] defined a horn as "a device that presents to the speaker a complex load consisting of a useful resistive component acting for acoustic radiation and a quadrature component which is mass-like or inductive in nature."

As early as 1816[7] it was demonstrated in analysis of brass instruments that the shape of the horn—hyperbolic, parabolic, or conical—determined the pitch. Horns for music have existed since biblical times. The facility in modifying the register, timbre, volume, and frequency range have inspired innumerable forms of horns for centuries.

The authoritative Grove's Dictionary of Music decades ago noted that changes in pitch were long recognized following modifications of the mouth area, air column, and even the throat (mouthpiece). Musicians have habitually used the hand to stop the bell or mouth of horn instruments to flatten the pitch. This, according to Grove, (without benefit of modern wave-form studies), is due to an "inharmonic series of tones." The size and shape of the mouthpiece and throat of a wind instrument govern largely the characteristic fundamental and harmonic tones. The pronounced suppression of fundamentals in a violin or cello by the use of a tiny mute on the bridge is a physical damping effect known long before electro-acoustic damping.

The importance of the length of a horn has been known for centuries. Giant straight horns, roughly conical or exponential, have been in outdoor use for hundreds of years among the mountaineers of Switzerland, South America, and the Himalayan Mountains for literal peak-to-peak voice communication over miles-wide distances. The wooden Swiss Alpenhorn runs to eight feet in length and even more.

Compared to the cylindrical flute or clarinet, brass instruments with horn shapes are capable of yielding a larger number of partial tones; i. e., intermediate low-frequencies. This is what engineers strive for in audio systems utilizing in acoustic formulas the empirical experience of musicians of the past.

One additional significant feature is that increased blowing or overblowing of any musical horn will cause an increase in the number of harmonic tones. By analogy, a speaker horn enclosure heard at a 1-watt output may not have the same profile of fundamental and harmonic combined tones as at 20- or 30-watt output. This may account for variable listener acceptance of an audio system where volume settings are changed for individual preference. The different combinations of harmonics are hard to measure since many oscilloscopes will not manifest much less than a sizeable 3 per cent harmonic distortion of the complex wave forms. The trained ear appears to be more sensitive or discriminatory.

The semicircular exponential horn enclosure as part of the author's music unit. It is detached to avoid acoustic feedback. Behind left and right grill-drawer compartments are phono and professional tape deck. Center top grill conceals separate TV speaker in a ventilator shaft, and tuner front end controls a remote third speaker. Built-in desk balances speaker enclosure. The center section and speaker horn enclosure are on casters and roll out for maintenance. Subassembly of desk, and left and right halves of shelves are screwed and dry-doweled for ready disassembly of entire unit for possible future reinstallation. *Unit constructed by Fred Nelson, Kings Park, N. Y.*

[4] H. T. Souther, "Design elements for improved bass response in loudspeaker systems." AUDIO ENGINEERING, May, 1951.

[5] H. F. Olsen, *Elements of Acoustic Engineering*. Van Nostrand, 1938.

[6] D. J. Plach and P. B. Williams, "Loudspeaker enclosures." AUDIO ENGINEERING, July, 1951.

[7] *Encyclopedia Britannica. 11th Ed., 13*: 691. New York University Press, 1910.

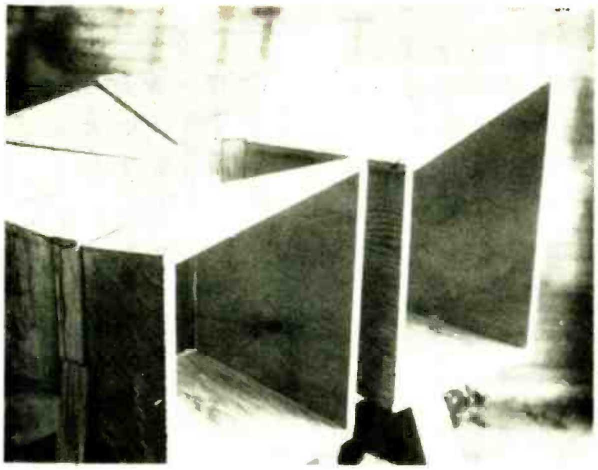


Fig. 1. The semicircular horn before enclosing it in another speaker cabinet. The left orifice is for a 15-in. speaker, tapering to join a 100-sq.-in. throat; the right opening is the mouth of the horn.

sons of space, exist which make for mutual interdependence of speaker construction with the enclosure or other air-coupling devices employed.

Limitations to True Bass Response

A. In the Speaker-Amplifier System

(1) *Damping*

Clements' detailed analysis on damping effects[8] showed that horn-loading is one solution to unavoidable attenuation of low frequencies which occurs with high amplifier damping factors. The latter amplifier feature may effect as much as a 10-db loss in speaker cones with heavy magnets, resonant at or below 60 cps according to this observer. This over-damping may be offset by matched horn-loading as well as by the recent methods of adjustable feed-back or variable internal amplifier impedance. However, the additional voice-coil damping by a powerful speaker magnet remains unaffected.

The bass-reflex cabinet for speaker loading gives too sharp a phase reinforcement at cone resonance and requires debatable amounts of internal padding. A closed box for infinite baffle effect must be quite large in volume and still will tend to restrict its bass loading to a narrow band in the audio spectrum.

In reviewing the merits of inverse feedback amplifiers, Childs[9] felt that all three desirables—perfect damping, perfect transient response, and sustained flat output at the bass end—are impossible to obtain simultaneously. Mutually antagonistic forces exist in the electronic and mechanical circuits of the amplifier-woofer-enclosure complex. Cone-to-air acoustic impedance coupling, which varies inversely with frequency, can produce spurious cone excursions thereby degrading the general response. For this reason horn-loading is most adaptable for critical coupling to a given system since any degree of acoustic impedance can be tailor-made. Mouth, throat, flare rate, and horn path can all be designed for fairly predictable acoustic behavior.

(2) *Speaker Design*

Bass reproduction by a speaker requires high current and a low voice-coil mass. At 50 cps a woofer will consume as much as a 2 amp. current in the voice coil at 15-watts input. There is a geometrical rise in current requirements the lower the frequency one reaches. One can double the cone mass to extend the bass end, but the small increment is offset by over a 50-per-cent loss in the speaker efficiency. Increasing the compliance of the cone suspension would also lower resonance but defeat good transient response.

Other limitations, omitted for reasons of space, exist which make for mutual interdependence of speaker construction with the enclosure or other air-coupling devices employed.

B. In the Enclosure

(1) *Dimensions of Horn Mouth*

Most enclosures for home use do not comply with acoustical specifications for the horn mouth. Practical tests indicate that the mouth diameter of an exponential horn should be at least 1/4 or 1/3 of a wave length at the cutoff frequency. Less than this may induce harmonic breakup. To efficiently reproduce a 50-cps note, the indicated diameter of 80 inches for a half-wave length is rarely available, even in home-built outfits. It is inadequate mouth area that is, in part, responsible for dips or maxima in hass-response curves. An attempt to avoid this deficit is illustrated in the principle of corner-wall extension of the horn mouth in the Klipsch-type horn design. This, of course, immobilizes the enclosure to the corners of a room which is not always feasible in the home.

Completely flat response of even the larger commerical enclosures down to fundamental tones of 40 or 30 cps is illusory. What one often hears, considerably attenuated, are some of the harmonies. Further, no finite exponential horn has an absolute zero output below its calculated cutoff. The rolloff incidental to the design is included in response curves to prove the merits of the particular enclosure.

(2) *Horn Rate of Flare*

Available exponential horn designs call for straight-sided walls at various

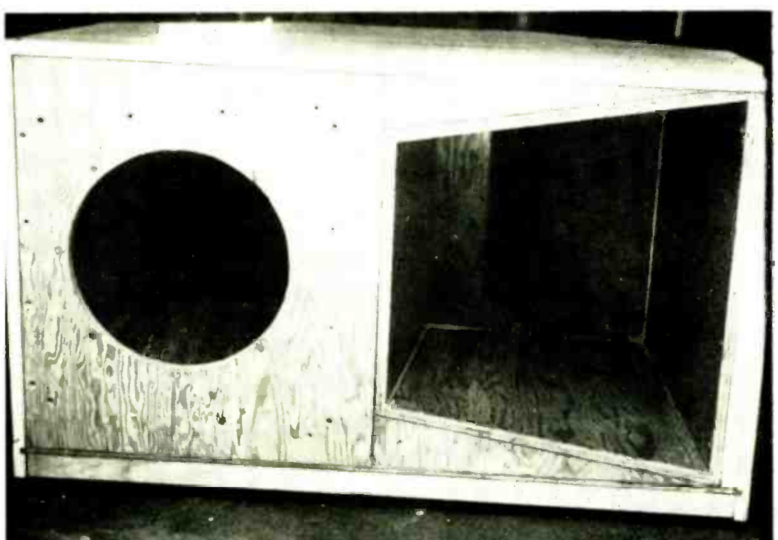


Fig. 3. The speaker is installed on its baffle board and enclosed in the raw cabinet.

[8] W. Clements, "A new approach to loudspeaker damping." Audio Engineering, August, 1951.
[9] U. J. Childs, "Dynamic negative feedback." Audio Engineering, February, 1952.

acute axial angulations along the sound path, usually to save space. In wood-wall construction, these are not true curved-wall exponential horns, but cones. They have exponential dimensions at considerably separated junctional planes, where the air column starts a new axial direction. Such sharp reversals of the sound path, from 120 to 170 deg. in common designs, cause harmonic break-up and wasteful energy absorption by enclosure walls. Where the diameter of a plane approaches ¼ or ½ wavelength dimensions at mid-frequencies, (above 300), unavoidable phase-cancellations arise.

Fig. 2. Front view—left is the speaker housing, with the horn mouth shown at the right. The two are connected by a semicircular horn.

(3) *Path Length in Multi-way Systems*

For a straight conical horn such as a square-sectioned megaphone with a 50-cps cutoff as determined by the flare, a half-wave path length of over 10 feet is theoretically indicated. This is far too long to preserve phase relationship to a treble speaker located in a different radiation plane. As Langham[10] indicates, the short tweeter-to-ear path as compared to a long woofer-to-ear path *must* interfere with correct phasing; the resulting "divided presence" may be unpleasant. Two-, three-, or four-way systems, each with its proper horn-loading, may widely deviate from required equidistant speaker-to-ear paths. Equal path-lengths are best obtained with coaxial systems. This is achieved at a cost of lowered acoustical efficiency due to spatial limitations along the sound-path axis for two or three drivers with their mutually incompatible horn couplings.

At 30 cps cutoff, specified horn dimensions are alarming for home use (see Table II). In addition, cabinet resonance should be below that of the speaker to avoid additional spurious peaks. That well-known nemesis, the law of diminishing returns, applies with painful clarity, the lower one reaches for cutoff frequency.

The need for a large mouth and a long path length can be occasionally met in home installations. A divided exponential horn 7 feet long with a mouth 40 × 22 in. has recently been built by one purist in a four-way system to occupy an entire spacious clothes closet.[11] Another bold individual[12] built a "concrete monster" with a horn 10 or 12 feet long planted in his backyard and, having torn away a wall of his living room, had the horn mouth of 55-in. square form part of the wall. The chap who spawned this figuratively hyperbolic exaggeration (or is it really?) of low bass design, can rightly claim good bass response down to 30 cps. But how about phase agreements between, say, a 22-foot woofer-to-ear travel and a 10-foot tweeter-to-ear path of treble sound for a listener facing the system from a living room chair?

(4) *Frequency Range Restrictions*

A horn designed for the lower bass automatically limits the upper range propagation since it cannot meet the higher flare rate requirements for frequencies far above cut-off. A tuba cannot efficiently produce the treble notes of a trumpet, much less those of a clarinet or flute. The effective upper limit in a folded horn of Klipsch design is about 400 cps[13] since above these frequencies the horn diameter along its axis approaches actual dimensions or multiples of the wave lengths. The resulting reflections and defractions that arise in the tortuous and sharply angulated sound-path cause phase cancellations, spurious resonances, and varying absorption by the walls of plywood, regardless of constructional rigidity. Thus, the advantage of folding or telescoping an exponential horn to avoid awkward length is partly nullified by distortions inevitable for frequencies a number of octaves above cutoff. An approach to good reproduction of a specific segment of the audio spectrum is seen in the present 2-, 3-, and 4-way systems. Strictly speaking, proper narrow-range horn designs would call for an 8- or 10-way system to eliminate distortions, an impractical solution under present thinking.

(5) *Enclosure Construction and Unwanted Absorption*

(*Continued on page 80*)

Fig. 4. The finished cabinet. On the top is seen a carpenter's rule for scale.

[10] J. R. Langham, "*High-Fidelity Techniques*," pp. 25–28. Gernsback Publications, N. Y., 1950.

[11] E. V. Ketcham, "Evolution of the 'Horn'." AUDIO, pp. 23, December, 1954.

[12] J. Ferguson, "The Concrete Monster." AUDIO, p. 17, July, 1954.

[13] D. J. Plach and P. B. Williams, "A laboratory reference standard loudspeaker system." AUDIO ENGINEERING, p. 34, October, 1954.

Distortion in Tape Recording

Common sense, careful thinking, and a set of accurate measurements will enable anyone to choose an operating point which will give the best over-all quality from his tape recorder. The author tells you how.

HERMAN BURSTEIN* and HENRY C. POLLAK

More and more audio fans, especially in areas having one or more "good music" FM stations, are making off-the-air tape recordings. Often the program source is live—symphony, chamber music, instrumentalist, singer, or choral group—while at other times the source consists of a first rate disc or tape recording. In either case, many owners of tape recorders have numerous opportunities to capture musical moments worth preserving, either indefinitely or until a better rendition comes along. Moreover, some recordists make tapes of their own singing or instrumental playing, which they are eager to hear for pleasure or improvement.

Unfortunately, the recording does not always sound "clean" in playback. It may lack the effortless, silky quality of the original source. Due to distortion, it may have a more or less grating quality, either constantly or only during loud passages. This situation is not confined to amateur recordings. Sometimes professional recordings contain objectionable distortion.

Distortion, presuming none in the source, may be due either to a fault in the tape recorder or to an excessive amount of signal applied to the tape. The latter is of concern here, that is, distortion resulting from high signal levels, and it shall be assumed that the tape recorder heads and electronics (amplifiers and bias oscillator) are in proper condition.

Although in a direct sense over-recording—that is, the desire for a high signal to noise ratio—may be blamed for distortion, in a basic sense the desire for wide frequency range, perhaps unnecessarily wide, may also be partly at fault. This can be true in two ways. First, in order to maintain good response out to 15,000 cps or so at a speed as low as 7.5 ips, the amount of high-frequency preemphasis required in recording may be sufficient to cause tape overload at treble frequencies. Above 7,500 cps, where most of the boost occurs, there would be virtually no audible harmonic distortion inasmuch as the harmonics fall outside most persons' hearing range as well as outside the recorder's pass band, which cuts off sharply beyond 15,000 cps or earlier. However, in any nonlinear system there would still be intermodulation products generated by interaction between two high frequencies or between a low and a high frequency; many of these products would be within range of the ear and the recorder.

The desire for extended high-frequency response can also be responsible for distortion by virtue of the required bias setting. Over the bias range customarily used, an increase in bias generally causes distortion to fall, while a decrease in bias generally causes distortion to rise. However, increased bias also results in greater attenuation of high-frequency response. The desire to maintain high-frequency response well beyond 10,000 cps at low tape speed may lead to bias reduction, thereby resulting in greater distortion at a given recording level.

The following discussion seeks to throw light on:

1. The relative changes in harmonic and intermodulation distortion as input level is varied.
2. The relative changes in harmonic and intermodulation distortion as bias is varied; determination of bias for minimum distortion.
3. Variation among tapes with respect to intermodulation distortion.
4. Method of setting bias so as to yield the optimum combination of high signal-to-noise ratio, wide frequency range, and low distortion.

It should be made clear that the measurements described in the following discussion are not definitive in the sense of providing exact values under given recording conditions. Rather, they are broadly indicative of what happens. The values may fluctuate as the test is repeated at a different time, on a different machine, with a different tape, at different temperature or humidity, and so on. However, the tests have been repeated sufficiently to indicate reliably the general nature of the observed phenomena.

The measurements underlying the following discussion were made on two professional tape recorders in the $2,000 class, operating at 15 or 7.5 ips, and using a commercial high quality tape. The machines have separate record and playback heads, permitting immediate plotting of results. Test equipment consisted of an audio oscillator, an oscilloscope, a sensitive a.c. VTVM, a harmonic distortion tester which measures the total signal content after the fundamental has been filtered out, and an SMPTE type IM tester which, using 60 and 6,000 cps respectively in 4:1 ratio, measures the extent to which the high frequency is modulated by the low frequency.

Variation of Distortion With Input Level

Invariably, tape recorder specifications make no mention of IM distortion, referring only to harmonic distortion. Tape recorders have a VU meter or other type of recording level indicator to show when recording level is such as to produce 1 or 2 or 3 per cent harmonic distortion. However, as *Fig.* 1 reveals, when harmonic distortion is still at relatively innocuous levels, below 3 per cent or so, IM distortion can be disruptive—20 or 30 per cent or more.

The measurements in *Fig.* 1 were made on a machine operating at 15 ips with bias set approximately at optimum, in the manner described later. The 0 db reference input level for measuring IM distortion was equated to that for harmonic distortion by adjusting these input levels for equal peak-to-peak readings on an oscilloscope.

Figure 1 indicates that IM distortion begins to rise much earlier than harmonic distortion, and that the rate of increase is far greater for IM distortion. After IM distortion has reached about 4 or 5 per cent, it rises very precipitously. It may be observed, therefore, that in the effort to add a few db to signal-to-noise ratio, the recordist runs the risk of trading a slight decrease in noise for a large increase in IM distortion.

For the purposes of the measurements underlying this discussion, the recorder was adjusted so that its VU meter indicated 0 when IM distortion was approximately at the maximum level considered tolerable for high fidelity purposes, say about 2 or 3 per cent.

In actual use, however, the recorder should be adjusted so that the VU meter indicates 0 for a signal perhaps 8 or 10 db *below* that which causes maximum

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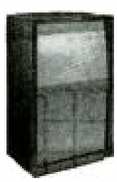

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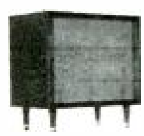

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allowable distortion, because on transients the pointer of the VU meter may lag 8 db or more behind peak signal level. If in actual use, the meter were calibrated to read 0 for a steady-state signal which produces 2 or 3 per cent IM distortion, allowing the needle to hit 0 when recording program material would often bring the reading into the region of extreme distortion, albeit briefly. Therefore, it is necessary to allow a margin in adjusting the VU meter. Even so, unless the recordist uses discretion, based on the nature of the music he is recording, fortissimo portions of a musical work, or at least the attacks, can be marred by the breakup and fuzziness symptomatic of distortion, even though the VU meter indicates only 0.

The recordist is forced into a choice among three alternatives: (1) to accept occasional high distortion in exchange for an improved signal-to-noise ratio; (2) to make some sacrifice in signal-to-noise ratio (which means relatively more hum, tube noise, and tape hiss) in exchange for low distortion throughout the recording; (3) to ride gain, reducing input level during loud passages, which means exchanging dynamic range for low distortion throughout a recording. The last alternative implies ability and willingness to compare the program source against a score and accurately anticipate changes in level.

The recordist's decision on the course to follow will be influenced by the tape recorder he is using and purposes for which it is employed. If it is a quality machine with a high signal-to-noise ratio, he may well follow the expedient yet satisfactory course of setting recording level just low enough so that peak passages are recorded at a level of distortion which, at least for a brief period, has no appreciable effect upon the listener. On the other hand, if the machine's signal-to-noise ratio is inferior, the preferable course may be to accept some obvious distortion during peaks for the sake of keeping background noise comfortably low throughout the recording. The program source can also influence the decision. For example, a relatively high input level might be used to record the spoken voice because in this instance a considerable amount of distortion can usually go unnoticed. On the other hand, one might have to exercise considerable more restraint in setting gain for an organ or piano in order to obtain a pleasing similarity to the original.

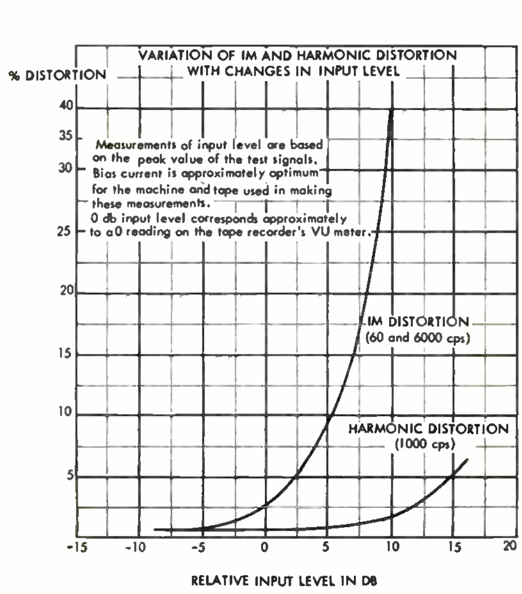
Variation of Distortion With Bias

Figure 2 indicates the effect of bias current on distortion, using two relatively high input levels. It must be taken into account that as bias varies so does the amount of signal recorded on the tape. In short, tape output as well as distortion varies with bias. However, we are only interested here in how distortion varies with bias. Therefore it is necessary to hold tape output constant. For this reason, the input level was constantly adjusted to maintain a fixed indication on the VU meter *in playback.* Curves 1 and 2 are based on a playback indication of 0 db on the VU meter. Curves 3 and 4 result from levels 3 db higher. At the 0 VU playback level, with bias set for minimum IM distortion, the harmonic distortion test signal was matched to the IM test signal by comparing peak-to-peak playback amplitudes on the oscilloscope.

Figure 2 reveals that: (1) IM distortion once again varies much more than harmonic distortion; (2) Distortion does not indefinitely continue to decline as bias is increased, but rises again, and this rise is sharper in the case of IM distortion; (3) The higher the input level, the more critical is the bias setting for minimum distortion; thus, in order to find the minimum-distortion bias with ease, it is merely necessary to use a very high input level. (4) A rise in input signal level produces the least increase in distortion when bias is set for minimum distortion.

From the above it can be concluded that to the extent the recordist seeks to maximize signal-to-noise ratio by turning up gain, the more important it becomes that he adjust bias properly for the particular tape he is using. Otherwise he may get much more distortion, especially IM, than is acceptable.

(An interesting phenomenon is displayed by the left portion of the curves in *Fig.* 2. If bias current is reduced enough below the normal working range, distortion drops again. Inasmuch as a reduction in bias current serves to improve high frequency response, it might seem that one might profitably operate in the area of extremely low bias current. However, there is good reason for not doing so. The reduction in distortion achieved by using very low bias current is most striking for high input levels. At low input levels, however, distortion re-



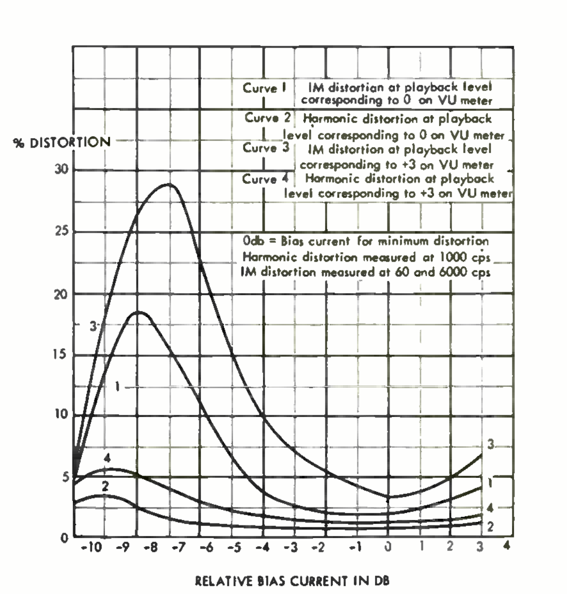
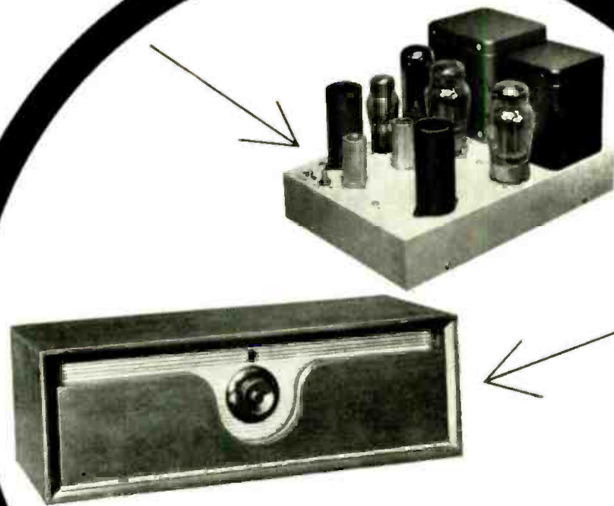


Fig. 1 (left). Variation of IM and harmonic distortion with changes in input level. Fig. 2 (right). Variation of IM and harmonic distortion with changes in bias current.



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340A POWER AMPLIFIER. 35 watts continuous, 30 to 22,000 cycles with less than 0.5% distortion. Frequency response within 1 db. 5-100,000 cps., 0 to 5 watts output. Intermodulation less than 1.0% at 35 watts, 40 cps and 2 KC, 4:1 ratio...$159.00

440B CONTROL PREAMPLIFIER. Maximum flexibility with 12 controls, 25 record crossover combinations • five inputs: three high level, two low level • noise level at maximum volume better than 95 db. below 1.5 volts output • 1000 ohms cathode follower matched to 340A power amplifier...Price, less cabinet, $135.00. Blond or mahogany hardwood cabinet, $15.00.

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mains higher than when operating in the normal bias range. Furthermore, the amount of recorded signal drops at low bias values, so that to maintain the same amount of tape output requires considerably greater power from the output stage supplying the record head.)

Variation in Distortion Among Tapes

Using a relatively high recording signal, several popular brands of tape were compared with respect to IM distortion. Input level was varied so that each tape produced the same output level as read on the VU meter during playback. Bias was adjusted for each tape until minimum distortion was obtained. Following were the results.

Tape	Minimum IM Distortion	Relative Bias Setting
A (reference)	7.6%	0.00 db
B	9.0	.75
C	11.0	−.50
D	10.0	0.00
E	3.5	−1.00

It is interesting to note that the bias setting for minimum distortion varied only moderately from tape to tape, while the amount of distortion varied considerably more. However, these findings would not be sufficient on which to base the choice of a tape. It would be further necessary to consider the tape's frequency characteristics at the bias current resulting in minimum distortion, the *shape* of its output versus bias curves for different frequencies, its noise properties, and so on.

Determination of Optimum Bias Current

Let us assume that on the basis of curves such as in *Fig.* 2, the bias current for minimum distortion has been ascertained, using a given machine and a particular tape. However, depending upon the tape speed and upon the brand and kind of tape (regular, high output, long-play, etc.), high-frequency response may be inadequate at this bias current.

As previously stated, treble response goes down as bias is increased. This is a wavelength effect. Inasmuch as a given frequency results in a shorter wavelength at reduced tape speed, the problem of poor treble response due to high bias current is most serious at the lower speeds such as 7.5 and 3.75 ips. Consequently at these speeds, in order to maintain satisfactory response, it is probably necessary to use less bias than the amount permitting minimum distortion. This means greater distortion for a given amount of tape output, or less output for the same distortion (lower signal-to-noise ratio), or a compromise between the two.

Figure 3 indicates the procedure to be used in determining optimum bias current. It is assumed that the tape recorder provides ready means for varying bias current and for varying treble preemphasis in recording. It is further assumed that playback equalization is fixed (in accordance with the NARTB standard for 15 ips). Curves 1 and 2 in *Fig.* 3, representing variation of IM distortion with bias, have been redrawn from *Fig.* 2. 0 db bias represents bias current for least distortion.

When the tape recorder represented in *Fig.* 3 is operating at 15 ips, Curves 3 and 4 respectively show how response at 400 cps and at 15,000 cps varies with bias; input level was kept low enough to avoid any possibility of saturation. 400 cps is used as a reference frequency, not being affected by equalization used in the record preamplifier. When 0 db (minimum distortion) bias current is used, response at 15,000 cps is 1.5 db higher than at 400 cps. In order for frequency response to be perfectly flat at 15,000 cps, it is necessary either to increase the amount of bias current to 1.4 db or reduce the amount of treble preemphasis. Since a rise in bias current would increase distortion, the desirable step is to lower the treble boost.

Thus it can be seen that at a speed as high as 15 ips, at least for the machine and tape represented in *Fig.* 3, one can set bias for minimum distortion and yet maintain response out to 15,000 cps. (It should be noted that a final determination of the amount of treble preemphasis required would depend upon a frequency-response run. Possibly, if response at 15,000 cps is kept flat, there would be excessive boost at lower treble frequencies. Thus in order to achieve the flattest possible response over the treble range as a whole, it may be necessary to accept response which is a few db down at 15,000 cps.)

Now let us consider the situation where the tape recorder represented in *Fig.* 3 operates at 7.5 ips. Curve 5 shows the 15,000-cps response at 7.5 ips as bias is varied. At minimum distortion bias, 15,000 cps response is about 10 db below 400 cps. Possibly this situation can be improved by increasing the amount of treble boost in the record amplifier. On the other hand, increasing the treble boost may cause appreciably greater tape overload in the upper treble range. Let us therefore assume that Curve 5 is based on the maximum amount of treble boost which may be safely used, taking into account the typical distribution of musical energy over the frequency range;[1] any additional treble boost would increase the likelihood of distortion.

Consequently, in order to maintain response out to 15,000 cycles at 7.5 ips, it is necessary to reduce bias. Curves 3 and 5 intersect at approximately −3.6 db bias; at this reduced bias, flat response out to 15,000 cps can be had. However, as bias is reduced to −3.6 db, IM distortion rises from 3.5 to 8.5 per cent for the signal level represented by Curve 1. On the other hand, by sacrificing 3 db in signal-to-noise ratio—that is, reducing signal level to the proportions represented by Curve 2—IM distortion can be kept at only 3 per cent when bias is −3.6 db.

(*Continued on page 81*)

[1] See the article by Herman Burstein, "Tape Recording Equalization," *Radio & Television News*, February 1956.

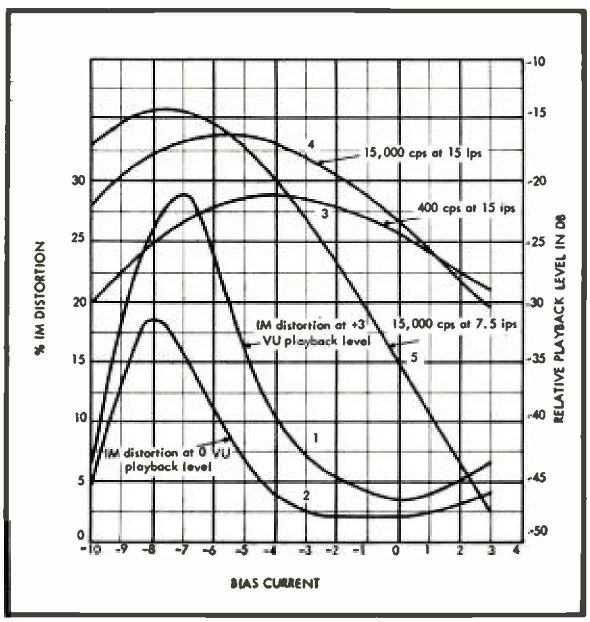
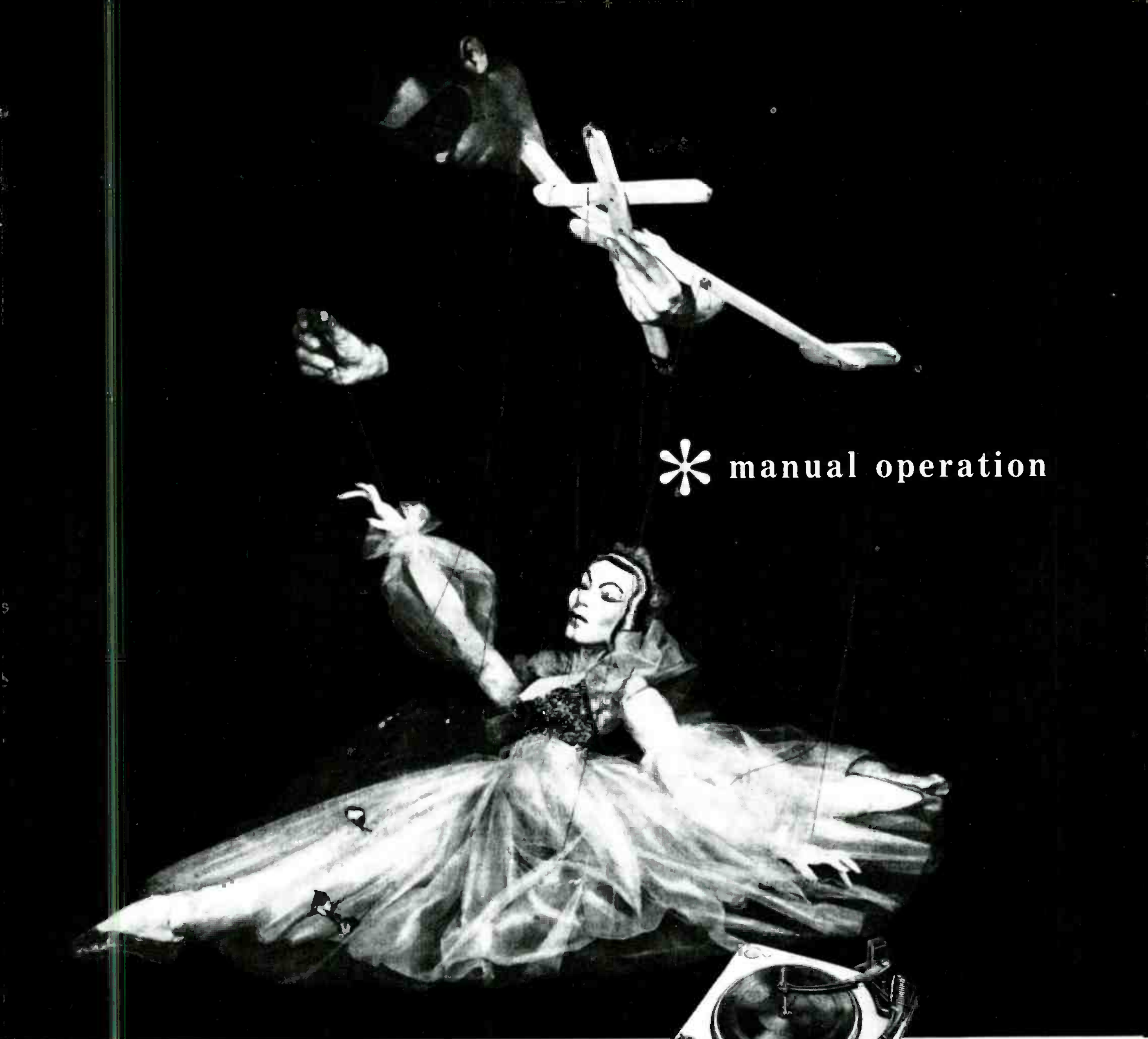


Fig. 3. Determination of optimum bias current.



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Improved Circuit for Electrostatic Tweeters

CHARLES ERWIN COHN*

Build this simple "second channel" amplifier to provide a distortion-free driver for your inexpensive electrostatic tweeter and listen to the improvement in its performance.

Recent new developments have made it possible to get performance from low-cost hi-fi systems which is often quite competitive with that which can be obtained from the more expensive outfits. One of the most important of these developments is the electrostatic tweeter, which enables the treble end of a set's spectrum to be extended out to the limit of audibility with very little cost. It is actually a condenser speaker, whose light cone facilitates the necessary response. Units have been brought out by several manufacturers, but one of the better ones presently available as a separate component is the Kingdom-Lorenz SKL-100, which sells for about $5.00.

The circuit recommended for use with this unit is shown in *Fig.* 1. In this arrangement the speaker signal is taken off the power amplifier plate, with RC coupling circuits inserted for application of polarization voltage and filtering out the lower frequencies. This arrangement is certainly simple, but it has certain advantages which might limit the effective use of the tweeter. First, it depends on the high-frequency response of the output transformer, which might drop off in cheaper units, keeping the highs away from the tweeter. Second, in this connection the tweeter is exposed to all the high-frequency distortion products developed in the power output stage. If the original speaker did not reproduce these sounds and they are then brought out in a tweeter, the net result might be just the opposite of the expected improvement.

* *7720 Marquette Ave., Chicago 49, Ill.*

With the cost of a tube and a few extra components, the above deficiencies can be remedied by use of the circuit shown in *Fig.* 2. This is essentially a separate output channel for the tweeter, an idea similar to the multichannel amplifiers which often appear in the literature. However, due to the liberal requirements of this application, the circuit can be considerably simpler than the usual multichannel design. For example, because of the relatively small proportion of signal power in the higher frequencies and the consequent small amount of power that must be fed to the tweeter, voltage amplifiers are quite adequate. The circuit of *Fig.* 2 uses a 6SN7 or similar dual medium-mu triode as a two-stage voltage amplifier taking a signal from the power-output-tube grid and feeding it to the tweeter.

Looking at the circuit in detail, the 250 μμf capacitor and 0.1-meg. resistor form a high-pass filter which transmits to the first section of the 6SN7 the signal at the grid of the power output tube, cutting off frequencies below about 5000 cps. If the main amplifier has a push-pull output stage, a similar dummy RC circuit should be connected to the grid of the other power tube to keep the two sides in balance. It might be thought that less effect on the main amplifier would be had by using a smaller capacitor and larger resistor, keeping the RC product constant; but if this is carried too far the Miller-effect input capacitance of the tube, which would run about 50 μμf or so, would begin to have a marked effect on the performance of the circuit. Actually, the values used would not have much effect at the lower frequencies where the main amplifier does its work.

Between the two amplifier stages is placed a similar RC circuit, with a pot used instead of a fixed resistor. This pot serves as a treble control to adjust the amount of signal going to the tweeter for the listener's taste. This is another advantage over the simple circuit of *Fig.* 1. The electrostatic tweeter is connected to the plate of the second tube, drawing both signal and polarizing voltage from this connection. The B+ return of this tube (shown as B++) should be connected to the highest-voltage well-filtered B+ point available in the set. However, the tweeter manufacturer's rating of 300 volts should not be exceeded. The B+ return of the first tube can go to any convenient source. Decoupling networks may be necessary in some cases to prevent interaction with other circuits in the set.

To get the most out of this tweeter and circuit, it will be necessary to see that the high frequencies are not getting lost in the early parts of the set. For example, the input capacitance of triodes, which due to Miller effect can run as

(*Continued on page 85*)

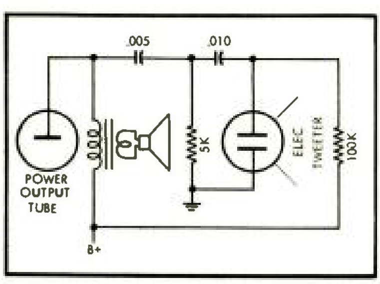
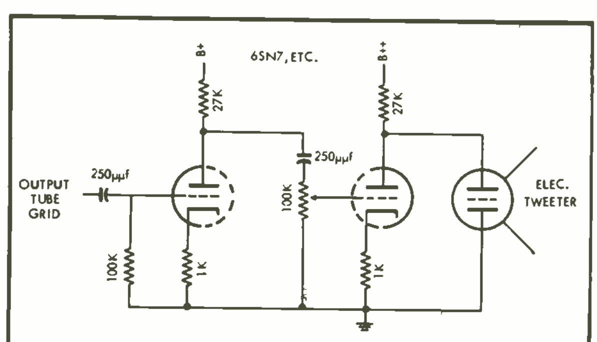


Fig. 1. Usual circuit recommended for connecting an electrostatic tweeter to the output stage of an amplifier.

Fig. 2. With a separate amplifier for driving the tweeter, distortion of output stage is avoided



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But one thing *has* remained constant: Bozak's refusal to compromise, in even the slightest degree, with the basic principles of good audio engineering. Today, as in 1949, Bozak Quality Loudspeakers are recognized by experienced engineers and listeners as Best by Design, Best by Test, and *Best by Ear*.

Many of the details of design pioneered by Bozak are being imitated today, but the quality of Bozak Sound is not duplicated. No other loudspeakers equal their responsiveness to the most subtle tonal and dynamic values of the original sound, nor approach them in realism, listening ease, and ability to give sustained satisfaction.

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The Interaction Concept in Feedback Design

NORMAN H. CROWHURST*

A new attack, followed by mathematical proof, on the problems of visualizing the behaviour of feedback amplifiers, enables these circuits to be better understood and more easily predicted.

In Two Parts—Part I

IN THE DESIGN of a complete amplifier there are so many variables to consider, some of which may be somewhat difficult to determine, that it is often difficult to know where to begin. The available design data usually predicts only the performance of the amplifier as a complete loop. In consequence, the effect of any circuit change has to be determined by calculating out the complete loop performance again. The process of approaching a design optimum can become extremely protracted,

In the old-fashioned amplifier without feedback, it was a relatively simple matter to localize the various components contributing to the over-all performance. The frequency and phase response were merely a summation of the responses of the individual stages and the over-all distortion was a combination of the distortion of the individual stages. But, as soon as feedback is applied, this is no longer true. For this reason some amplifier designers have sought a method of approach to negative feedback design that will separate the effect of closing the feedback loop in a manner similar to the way the performance of individual stages can be isolated.

The difficulty in this can be seen from the simple case when the feedback path consists of only resistors. Closing the loop can introduce considerable additional frequency discrimination not present in the absence of feedback. In theory a network consisting of resistors

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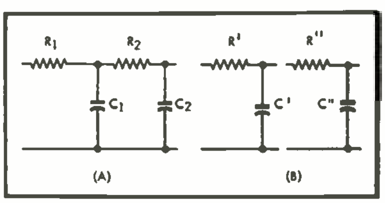


Fig. 1. Equivalent interacting and non-interacting networks producing a high-frequency rolloff. Equivalence is discussed in the text, and the mathematical treatment given in the appendix.

only cannot introduce frequency discrimination, so it is difficult to see how the closing of the loop can be visualized as contributing some erratic frequency discrimination to the over-all performance.

It is further evident that, although the resistors in the feedback path may have the same value, the result of closing the loop will not necessarily be consistent for this particular combination of resistors: it is further dependent upon the amplification and response characteristic of the forward part of the amplifier.

This, of course, is further complicated when the feedback path does contain frequency discriminating elements. Then the closing of the feedback loop produces a difference in response dependent upon (a) the nature of the performance with the loop open, (b) the over-all gain and response around the loop to be closed and (c) the response of the feedback path only.

Basic Elements

How then can we regard the closing of the feedback loop as contributing something to the performance of the amplifier that can be isolated and considered as a separate entity? It is at this point that the interaction concept proves a useful tool. To apply this concept, the over-all performance is considered as being built up from a number of two element networks, consisting of resistance and a single reactance. Each of these, according to its configuration, will contribute to either a low- or high-frequency rolloff:

A resistance in series with a capacitance in shunt produces a high-frequency rolloff.

A capacitor in series with a resistance in shunt produces a low-frequency rolloff.

With combinations of inductance and resistance the order is reversed. Most modern amplifiers avoid the use of inductances as far as possible, the only inductances normally encountered being associated with the output transformer.

In resistance/capacitance coupled stages the resistances are those of the actual circuit, plus the plate resistances of the tubes, while the capacitances are (1) the coupling capacitors effecting low-frequency rolloff, and (2) stray circuit capacitance effecting high-frequency rolloff.

The same theory can be applied to the computation of either low- or high-frequency performance. For this reason in this article we shall not go into both in detail but the high-frequency performance will be considered and the low-frequency response can always be interpreted from this, merely by reversing the position of the various elements.

Interacting Pairs

Consider the two pairs of resistances and capacitors shown in *Fig.* 1. At (A) the four elements are connected together in tandem. At (B) they are considered as separate two element networks. These two networks may be separated in fact by a stage of amplifiers to prevent interaction between their respective components.

In either case the over-all response of the combined networks will take the general form shown in *Fig.* 2. Each pair

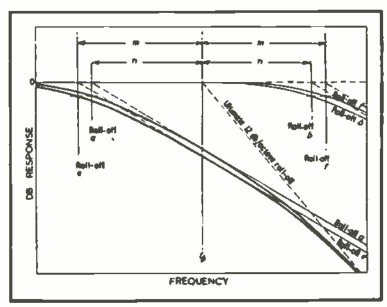
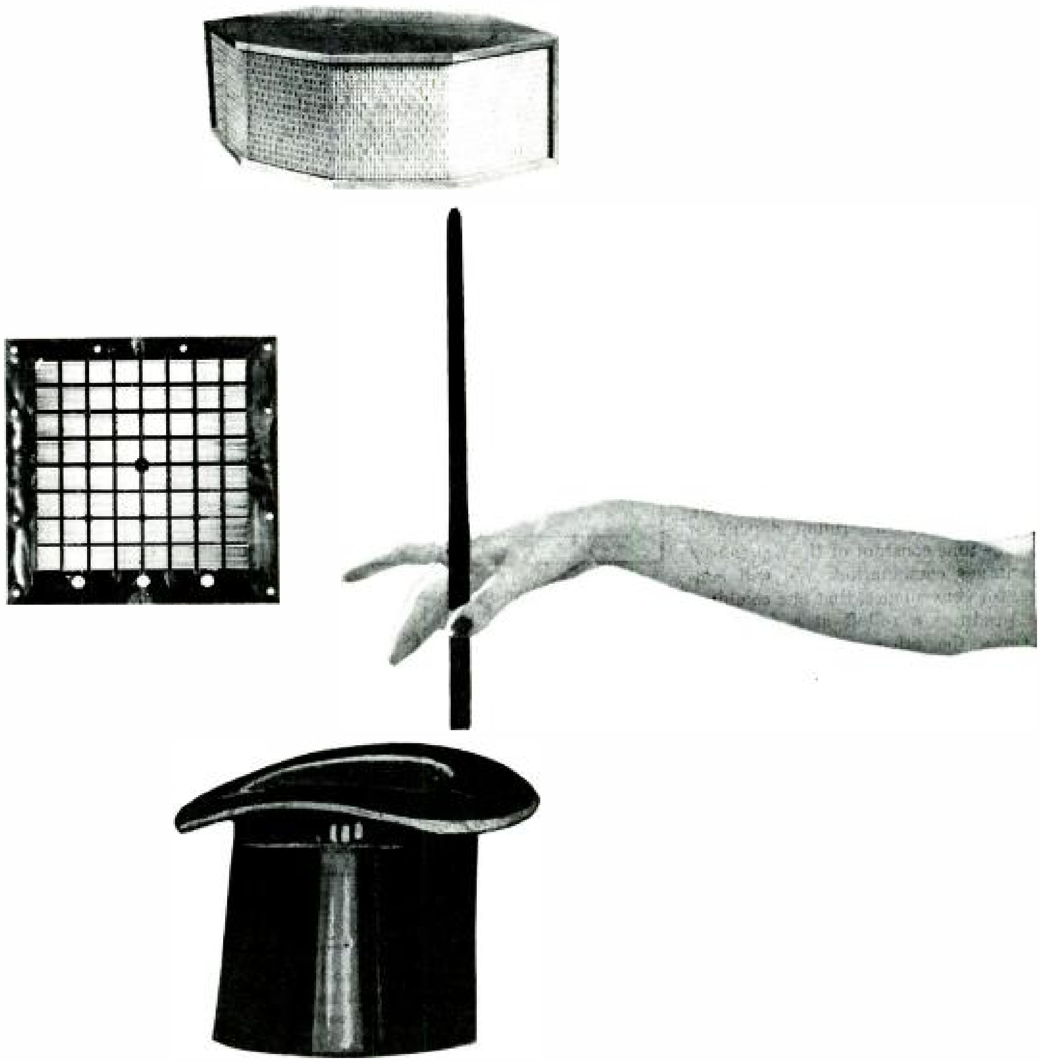


Fig. 2. Illustrating the way interaction modifies response in the circuit of (A) in Fig. 1. The ultimate 12 db/octave roll-off is the same whether interaction occurs or not, but interaction increases attenuation in the vicinity of the frequency f_0, where phase shift is 90 deg. and roll-off sides 6 db/octave.



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The key to JansZen's audio magic is the exclusive electrostatic radiator. Its virtually massless, stretched diaphragm, driven over its entire surface by an electrostatic field, transforms electrical energy directly into acoustical energy with no trace of breakup and no resonances within the audible range. These radiators are unaffected by temperature and humidity changes . . . so stable and dependable we guarantee them two full years.

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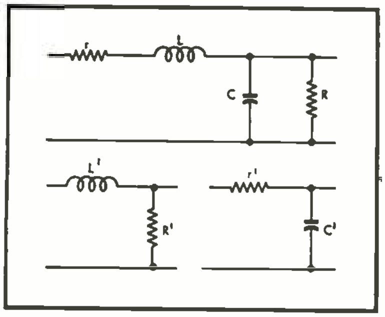


Fig. 3. Interaction also occurs when opposite kinds of reactance are combined in a circuit, as at (A). Sometimes this can be resolved into non-interacting equivalents, as at (B), but quite frequently the interaction goes into a region that cannot be represented by real values in this form.

of elements will contribute to a composite rolloff—each two-element network will produce its own rolloff dependent upon the time constant of the resistance/capacitance combination. We will consider, for convenience, that one combination produces a rolloff at a frequency n^2 times the other combination. This means that one rolloff will be n times a mean frequency while the other will be the same frequency divided by n.

We can assume that the connected arrangement of (A) in *Fig.* 1 can be represented by separate elements as at (B). In this case we can represent the one in terms of the other using real values throughout. If the two networks were not connected together in (A) C_1 would act with R_1 and C_2 would act with R_2. But because of the interconnection C_1 acts with R_1 and also partially with R_2 which means that C_1 will not be shunting such a high value of resistance as R_1 by itself. At the other end C_2 is not feeding out of the simple resistor R_2 as a source but has an additional component of resistance source due to the presence of R_1.

If R_2 is very large compared to R_1 the constant k, used in the formula given in the appendix, will be very small, signifying that there is little interaction between the rolloff effects of R_1 and C_1 and R_2 and C_2. As shown in *Fig.* 2 the effect of interconnection is to spread the equivalent non-interacting components to frequencies further apart, to the ratio represented by m in the formula in the appendix and also in the figure.

The mean frequency remains unchanged in this case so, as shown in *Fig.* 2, the combined response of the over-all arrangement reaches the same ultimate rolloff whether an interconnection is made between R_1 and C_1 with R_2 and C_2 or not. The effect of the interconnection changes the response to a maximum degree at the mid-frequncy, which is a mean between the rolloffs of the individual two-element networks and in this example always deteriorates or increases the attenuation of the response in this range.

As has been shown in previous articles, the attenuation at this mean frequency has a slope of 6 db per octave while the transfer phase shift is 90 deg. In this case interaction does not alter the phase shift at this particular frequency but it does alter the over-all attenuation at the 6-db-per-octave slope point.

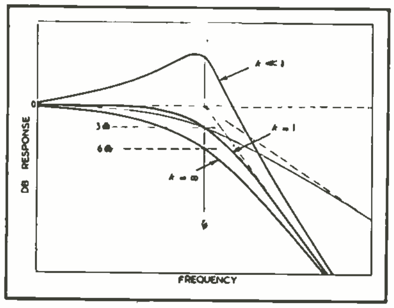


Fig. 4. Variation in response with value of the interaction factor, k, for values of n = 1. This combination can never be represented by real values in the form of (B) in Fig. 3.

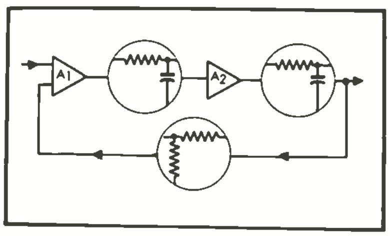


Fig. 5. When single reactance rolloffs are separated by amplifier stages so as not to interact in simple amplification, the addition of feedback causes interaction, and modifies the response in a manner somewhat similar to the circuit of (A) in Fig. 3.

Inductance and Capacitance

If we next apply this concept to the signal coupling network represented in *Fig.* 3 which has both inductance and capacitance in the same circuit we shall find that a similar method can be applied.

First consider some effects of different combinations of values. If L in (A) is made negligible in effect compared to the other components, C would then be shunting a virtual source consisting of the two resistance components in parallel. On the other hand, if L becomes relatively large, so as to isolate r from C, the effect of C in producing a rolloff could be considered as acting solely upon R.

A similar comparison can be made by considering C to be negligible so that L is acting in series with both the resistors. In this case the effective resistance to be compared with L will be the combined value of the two in series. On the other hand, if C exercises considerable shunting effect upon R, L can be regarded as producing an increased series reactance compared only with r.

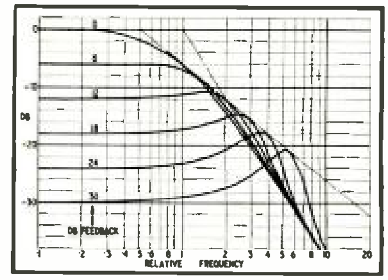


Fig 6. Showing the effect of different amounts of negative feedback on the response of the arrangement of Fig. 5, in the particular case when n = 1. Other cases follow the same pattern from a different starting point.

This being the case the time constant or rolloff comparisons which we make will take a mean position between the two extremes: the time constant for L combined with the resistance will be taken as a mean between r and the combination of the two resistors in series; the time constant for C will be taken as a combination with the mean value of R and the parallel combination of the two.

The equivalent non-interacting network is shown at (B) in *Fig.* 3 using L' and R' where R' is the mean value just described as combined with L; and r' and C' where r' is similarly the mean value combined with C.

Sometimes the equivalent can be expressed in terms of real components but this is not always possible.

First we will consider the special case where the effective time constant of both arrangements is the same. In other words following the nomenclature of *Fig.* 2, $n = 1$. This is shown at *Fig.* 4. Notice that we still have an interaction factor, similar to that used in the arrangement of *Fig.* 1, of $k = r/R$. For any particular case (value of n) the value of k will determine the attenuation at the mean frequency, which is still the frequency

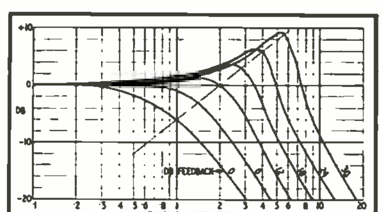


Fig.7. The curves of Fig. 6 replotted to the same zero reference, so the effect of feedback on the over-all response can be better seen.

Counterpoint II MODEL FM-100

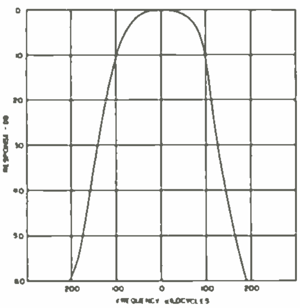
notes & technical specifications

Counterpoint II is a dazzling new FM tuner. Only 3¼" high including its graceful runners, it embodies a highly sensitive and stable tuner with control features including Variable Automatic Frequency Control, Variable inter-station noise suppressor, FM rumble filter, Output level control, and Discriminator Balance Tuning meter.

RF SECTION

Circuits: FM: Armstrong circuit with dual limiters (pentode and dynamic diode) & Foster-Seeley Discriminator.
Variable Automatic Frequency Control—Low Noise Front End consisting of Tuned Triode Grounded Grid Amplifier and Triode Mixer. Rumble Filter.
Variable Automatic Noise Gate.
Sensitivity: FM: 3 microvolts for 30 db quieting; 2 microvolts for 20 db quieting.
Selectivity: IF Bandwidth: 200 KC @ 6 db down.
Discriminator: 375 KC Peak to Peak.
Frequency Range: FM: 88-108 MC.
FM Drift: ±5 KM max.
Image Rejection: 40 db.
IF Rejection: 70 db.
Antenna Input: 300 ohms.
Distortion: Less than 1% harmonic.
Frequency Response: ±1/2 db 20 to 20,000 c.p.s. including standard 75 microsecond deemphasis.
Radiation: Within FCC Requirements.
Hum Level: 60 db below 100% modulation.

Model FM-100



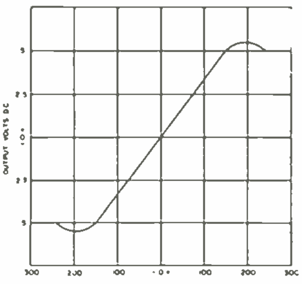
FM selectivity characteristics

AUDIO SECTION

Output Level: 2-1/2 volts for 100% modulation; 1 volt for 30% modulation.
Level control permits attenuation to lower levels.
Output Impedance: Low impedance Cathode Follower. High impedance Multiplex Terminal.

OVERALL SPECIFICATIONS

Controls: 2 Front Panel: Tuning and Concentric ANG, AFC & Power.
3 Rear Panel: Meter Balance, Output Level, Rumble Filter.
Tube Complement: (Total, 8) 1-12AT7, 1-6BK7A, 1-6C4, 3-6AU6, 1-6AL5, 1-12AU7, Selenium Rectifier. 1-1N34 crystal diode.
Dimensions: 12½" wide x 2⅞" (with runners: 3¼") high x 7⅛" deep (not including knobs).
Power Consumption: 35 watts.
Shipping Weight: 12 lbs.
Finish: Escutcheon and cages: brushed copper—Display panel for escutcheon and knobs: mat black—Edge lighted dial glass: yellow and white.
Functional Features: (a) Counterweighted Tuning Control: (b) Variable AFC Control: (c) Output Level Control: (d) Discriminator Balance Tuning Meter: (e) Variable Automatic Noise Gate Control: (f) Rumble Filter Switch.



FM discriminator characteristics

SPECIAL NOTES

(a) Safety Interlock Power Cord disconnects power when cage is removed.
(b) Printed circuit used throughout employs dip soldered copper-clad laminated phenolic plastic board.
(c) Simple mechanical disassembly makes board easily available for service.
(d) Face up mounting of Counterpoint II permissible without special precaution.

OPTIONAL ACCESSORIES

(a) Brass finished escutcheon available on special order.
(b) Brass finished cage available on special order.

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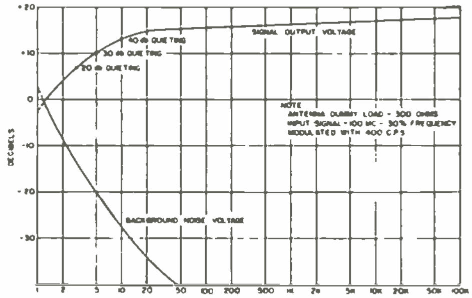

FM detector output voltage characteristics

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where the attenuation slope is 6 db per octave and the transfer phase shift 90 deg.

For large values of k when $n = 1$, as represented in Eq. (*13*) in the appendix, the attenuation at the 6-db-slope point approaches 6 db. This is when r is large compared with R, and L and C have values such that the time constants, represented by a and b in Eq. (*8*) are both at the same frequency.

As k is reduced to the point where it has unity value the maximal flatness curve is reached, in which the 6-db-per-octave slope point is at an attenuation of 3 db. Further reduction in the value of k below unity produces a kind of interaction that causes the response to go into peaking. This is shown in *Fig.* 4.

In this case the whole range of values of k produces an equivalent that cannot be represented by separate networks as at (B) in *Fig.* 3. Only when the two frequencies are divergent, that is, n is greater than *1*, can any values of k exert an influence pulling the two frequencies together (instead of separating them as represented in *Fig.* 2) in the range where the attenuation at the 6-db-per-octave slope point is greater than 6 db. From the 6 db point upwards it is not possible to represent the arrangement by real non-interacting networks as at (B) in *Fig.* 3.

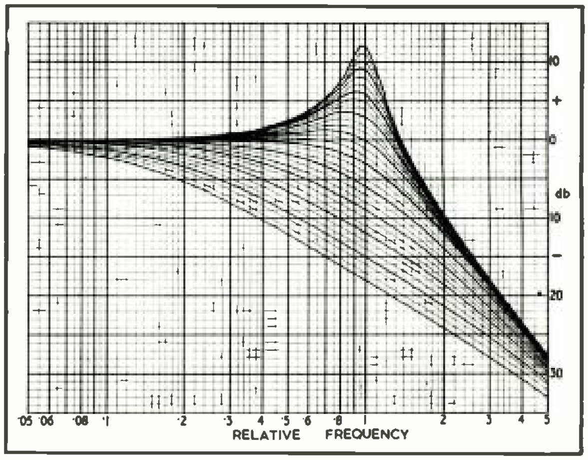

Fig. 9. Family of response curves applicable to two stage arrangements of Fig. 1, or 5, using f_0 as the reference frequency. The value of this frequency, and the required curve, can be identified from Fig. 8.

From the foregoing then we can see that the coupling together of two networks producing a rolloff in the same direction and employing the same kind of reactance (in the example given both were capacitance) the effect of interaction is to spread the equivalent contributing rolloffs to frequencies further apart; but when two different reactances are combined so as to produce a rolloff at the same end of the frequency response the effect of the interaction by coupling them into the same circuit is to pull the equivalent rolloff frequencies together, until the point is reached where the response is 6 db down at the 6-db-slope point; after which the equivalent pairs have imaginary values and the shape of the resultant response goes first to the maximal flatness curve and thereafter into peaking.

INTERACTION DUE TO FEEDBACK

Now we come to the form of interaction which is of particular concern in this article—the one in which amplification is used and the loop is completed producing feedback.

Two-Stage Case

Take first the case of an amplifier in which there are two reactances in the loop, contributing to high-frequency rolloff represented emblematically at *Fig.* 5. As shown by the theoretical treatment in the appendix, application of feedback over these two similar networks produces a variation in response very similar to that of the second case considered in *Fig.* 3. Interaction caused by the application of a specified amount of feedback pulls the equivalent rolloff frequencies together; but it also moves them both further out in the frequency scale. *Figure* 6 shows the effective variation as increasing amount of feedback is applied, taking into account the reduction in gain caused by the feedback interaction. It will be noticed that the 6-db-slope point may be considered as sliding down a line at a slope of 6 db per octave. The ultimate 12-db-per-octave slope is

(*Continued on page 84*)

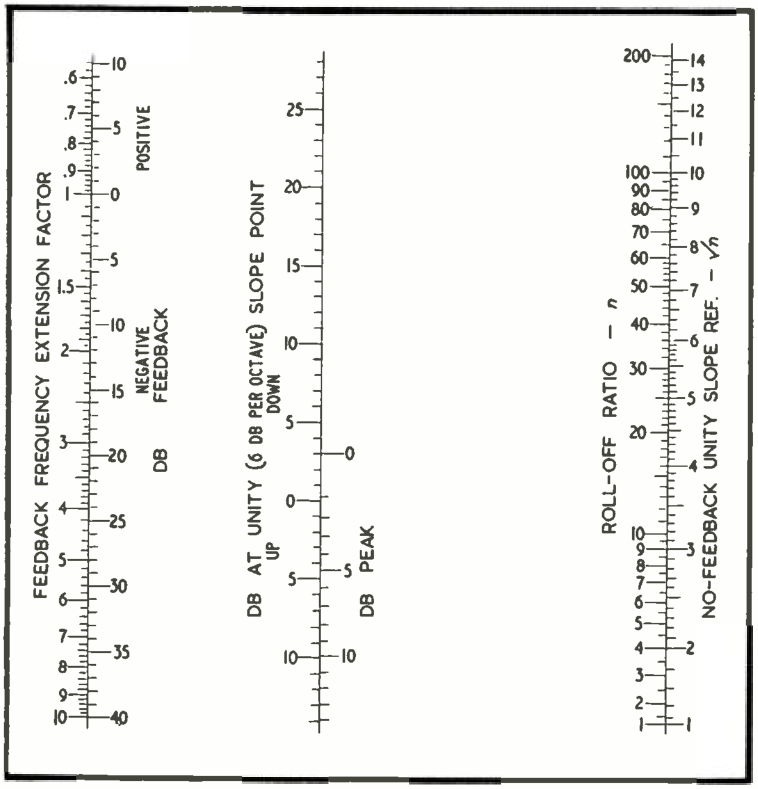

Fig. 8. Chart giving all the essential data to predict the response of a two-stage feedback loop. The frequency extension scale at the left of the left scale shows the ratio by which the unity slope frequency is extended. Ratio n is the ratio between the times constants or rolloffs of the two stages. The square root scale on the right of the right scale facilitates calculation of the unity slope point in the absence of feedback.

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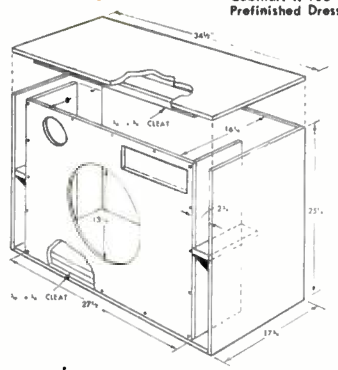

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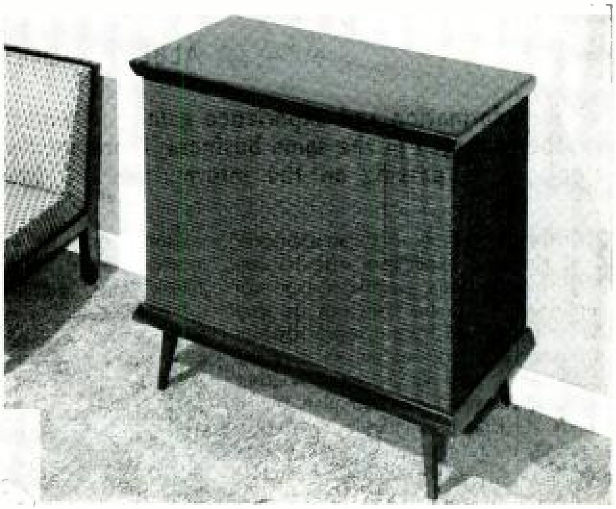

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3-Way	15"	Triplex	KT-32	169.50	Low Boy Bass-Ultraflex	K-105	48.00	P-205	39.00
2-Way†	15"	——	KT-21	99.50	Corner* Bass-Ultraflex	K-103	48.00	P-203	39.00
2-Way†	15"	——	KT-21	99.50	Low Boy Bass-Ultraflex	K-105	48.00	P-205	39.00
2-Way†	12"	Concerto	KT-22	73.00	Corner* Bass-Ultraflex	K-107	39.00	P-207	36.00
2-Way†	12"	Concerto	KT-22	73.00	Low Boy Bass-Ultraflex	K-109	39.00	P-209	36.00
2-Way†	8"	Contemporary	KDU-10	24.75	Corner* Bass-Ultraflex	K-111	23.00	P-211	25.00
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Contracts Against Competitive Employment

ALBERT WOODRUFF GRAY*

While information and experience gained in working for one company may be of extreme value to another engaged in the same business, there are times when restrictions operate—both against the employee in passing on the information and against the company that attempts to prevent it.

In the contracts of a manufacturer of electrical capacitors with its employees it was stipulated by the employee, "That he will not at any time during said employment disclose to anyone any information he may acquire during said employment relating to any of the processes, formulae, plans, circuit devices or methods developed, acquired, manufactured or practised at any time by said corporation in its business and that he will not use any of said processes, formulae, plans, circuit devices or methods or his knowledge of the same except in the course of his employment by the corporation."

Approximately 8,000 of the employment contracts of this manufacturer contained this stipulation and as a consequence, this stipulation featured in litigation involving a great majority if not all of the manufacturers of electrical capacitors in the United States.

"It is quite clear," said the court in denying the application for an injunction against the employment by competitors of those who had signed these agreements, "that the contract goes beyond the protection of trade secrets and embraces anything that the employee saw or learned during his employment. The agreement given this construction puts a restraint upon the employees' right to labor or exercise their skill greater than is necessary for the fair protection of this employer and therefore, such agreement is unenforceable."

To this the court added a quotation from an earlier decision by one of the Federal courts. "The law is settled that a contract in restraint of labor which seeks to prevent one of the contracting parties from exercising his skill or labor generally, without limitation as to time or place or which attempts to put a restraint upon his right to labor or to exercise his skill greater than is necessary for the fair protection of the other party, is void."[1]

Closely similar circumstances were involved in an action before the New Jersey courts a few years later. There the employment contract by the manufacturer of hearing aid instruments with the manager of a district sales office provided, "Upon the expiration or termination of this contract from any cause whatsoever the manager agrees that he will not engage directly or indirectly in the business of manufacturing and/or selling any products or devices of the kind or similar to the products or devices at such time being manufactured and sold by the manufacturer or in any way engage in competition with the manufacturer or any agents or managers of the manufacturer, either directly or indirectly, as principal or as agent or employee in the territory or within an area extending fifty miles on every side thereof during the period of twelve months from the date of termination or expiration."

This manager after leaving that employment had engaged in selling a competing product within the area prescribed by this agreement. In forbidding him continuing in that employment the court outlined the features that are necessary to a valid and enforceable contract of this character.

"It is entirely settled in this state that a negative covenant ancillary to a contract of employment is valid and enforceable if it is reasonably limited in time, space and scope. In determining the validity of a covenant consideration should be given to the nature of the product and the business of the employer.

"In these days of modern transportation and communication it would appear that with respect to a business of nationwide scope, in the development of which large sums of money have been expended for advertising and good will a covenant whereby the employee agrees not to engage in competitive employment for a period of one year within a radius of 50 miles is not to be held so unreasonable as to justify the court withholding relief."[2]

In contrast to this agreement held reasonable and enforceable by the New Jersey court is one held invalid by the Supreme Court of Indiana a few months ago. Stipulations against employment by a competitor in this agreement were:

"Employee for a period of three years after leaving company's employment for any reason whatsoever shall not in the United States or Canada, without first obtaining company's written permission, engage in or enter the employment of or act as advisor or consultant to any person, firm or corporation engaged in or about to become engaged in the manufacture" of the products of this employer. The area of this employee's activities had been restricted to northern Indiana.

In its refusal to lend aid to the enforcement of this stipulation against the employee who had subsequently entered the employ of a competitor the court said:

"As an incident to his business the employer was entitled to contract with regard to and thus to protect the good will of his business. Elements of this good will include 'secret or confidential information' such as the names and addresses and requirements of customers and the advantages acquired through representative contact with the trade in the area of their application. These are property rights which the employer is entitled to protect."

Then in a comment on the rights of the employee under such circumstances the court continued, "However the same is not true regarding the skill of the employee as acquired or the general knowledge or information he has obtained which is not directly related to the good will or value of the employer's business.

"Knowledge, skill and information, except trade secrets and confidential information, become a part of the employee's personal equipment. They belong to him as an individual for the transaction of any business in which he may engage just the same as any

* *112-20 Seventy Second Drive, Forest Hills, New York.*

[1] Sprague Electric Co. v. Cornell Dubilier Electric Corp., *62 F. S.* 1, August 7, 1945.

[2] Sonotone Corporation v. Hall, *64 Atl. 2d 473, New Jersey*, March 9, 1945.

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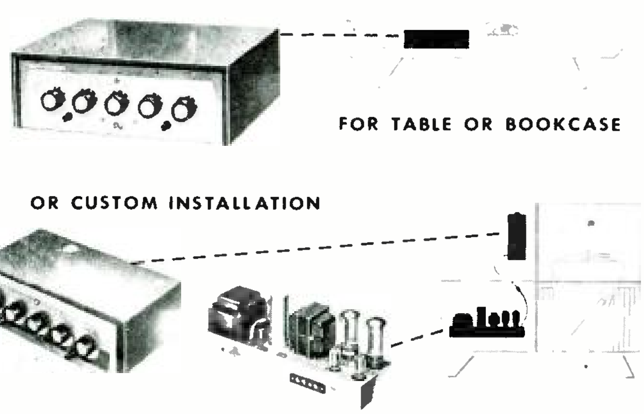

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part of the skill, knowledge or information or education that was received by him before entering the employment. Therefore on the termination of his employment he has a right to take them with him. These things cannot be taken from him although he may forget or abandon them.

"An employee may contract to conditionally forego these personal attainments as a consideration for his employment only where their use adverse to his employer would result in irreparable injury to the employer. This would occur only in the area of his employment. Therefore a covenant which would limit his employment with a competitor beyond the scope of his present employment is void."[3]

Not only must these restrictions against the employment by competitors or the undertaking of a competitive business be reasonable in the area affected but reasonable in the period of time they continue.

In another contract against such competitive employment involved in an action in the New York courts, it was provided that the restriction against competition "continue in full force as to all its stipulations for an indefinite period after its expiration until terminated by notice in writing by either party one year in advance."

In its affirmance of the decision of a lower court which had characterized this restraining provision as, "Such a restraint savors of servitude unrelieved by an obligation to support on the part of the master," the Court of Appeals of that state held:

"An employee will not be perpetually restrained from working for another except to prevent a breach of contract. The surrender for an unlimited time of the right to use the skill, knowledge and experience which a workman brings to the service of his employer as a condition, has never been enforced by injunction."[4]

In the old decisions of the courts contracts against competitive employment, in the opinion of the courts of those days, had no good in them. "The mischief which may arise from them (1) to the party by the loss of his livelihood and the subsistence of his family and (2) to the public by depriving it of a useful member," was adhered to with the anti-monopoly fanaticism that has characterized our law from its earliest days. "Another reason," according to those ancient decisions, "is the great abuses these voluntary restraints are liable to do, as for instance from corporations who are perpetually laboring for exclusive advantages in trade and to reduce it into as few hands as possible."

The English judge uttering that comment nearly two and a half centuries ago might well have recalled the famous comment of Cromwell, quoted by a contemporary Federal judge as one that should be written over the portals of every church, every school, every court house and legislative body in the United States, "I beseech ye in the bowels of Christ, think that ye may be mistaken."[5]

However it was to be asserted in a later English decision that, "Contracts for the partial restraint of trade are upheld, not because they are advantageous to the individual with whom the contract is made and the sacrifice by that much of the rights of the community, but because it is for the benefit of the public at large that they should be enforced.

"Many of these partial restraints on trade are consistent with public convenience and the general interest and have been supported. And of such a class of cases is a tradesman, manufacturer or professional man taking a clerk or servant into his service with a contract that he will not carry on the same trade or profession within certain limits.

"In such a case the public derives an advantage in the unrestrained choice which such a stipulation gives to the employer of able assistants and the security it affords that the master will not withhold from the servant instruction in the secrets of his trade and the communication of his own skill and experience, from the fear of his afterwards having a rival in the same business."[6]

Many years later this recognition of the right to restrain the hiring of employees by competitors was set out in an opinion of a Federal judge, later President of the United States, William Howard Taft:

"The contract must be one in which there is a main purpose to which the covenant in restraint of trade is merely ancillary," was asserted here to be the law. "The covenant is inserted only to protect one of the parties from the injury which in the execution of the contract or enjoyment of its fruits, he may suffer from the unrestrained competition of the other. The main purpose of the contract suggests the measure of protection needed and furnishes a sufficiently uniform standard by which the validity of such restraints may be judicially determined. In such a case if the restraint exceeds the necessity presented by the main purpose of the contract it is void for two reasons. First, because it oppresses one party to the contract without any corresponding benefit to the other. And, second, because it tends to a monopoly."[7]

Before a Connecticut court a few months ago was an appeal in an action to enforce a stipulation of this character against a former employee, that, "The employee agrees also that for a period of two years after the termination for any cause of said employment that he will not, either in competition with or for a competitor of the employer, solicit, sell or install to any of the employer's customers whom said employee may in the course of his employment, have served.

"The employee also agrees that for a period of two years after the termination for any cause, of said employment, he will not either in competition with or for a competitor of the employer sell, solicit or install within an area of 35 miles from the city of Waterbury."

In holding that the restraints imposed on the employee were excessive and hence, the contract unenforceable, the Connecticut court summarized the principles of the established law.

"It is well known that an employee gives little thought to a restriction such as we are concerned with because he is anxious and therefore intent upon getting a job and is willing to make such promises as are declared necessary as a condition precedent.

"On the other hand the employer, too, is engaged in a struggle for survival and may attempt every effort to gain and retain the good will of his customers. A reasonable balance must be maintained and each conflict must be fully evaluated on its own merits.

"Almost without exception the law is that where the restriction is excessive in the beginning and its reach is greater than is necessary for the employer's protection against 'unfair' competition, or it provides for restraint of an employee from competing after the termination of his employment in a territory exceeding that in which the employer does his business, the restriction has been considered excessive and therefore invalid.

"The test of its validity is the reasonableness of the restraint it imposes. To meet this test successfully the restraint must be limited in its operation with respect to time and place and afford no more than a fair and just protection to the interests of the party in whose favor it is to operate without unduly interfering with public interest."[8]

[3] Donahue v. Permacel Tape Corp., *127 N.E. 2d 235, Indiana,* June 20, 1955.

[4] Kaumagraph Co. v. Stampagraph Co., *138 N.E. 485, New York,* January 23, 1923.

[5] Learned Hand: *Spirit of Liberty,* page 229.

[6] Mallan v. May, *11 Mees. & W. 652.*

[7] United States v. Addyston Pipe & Steel Co., *85 Fed. 271,* page 80. February 8, 1898.

[8] Nesko Corporation v. Fontaine, *110 Atl. 2d 631,* Connecticut, February 19, 1954.

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The Conn Electronic Organ

IN TWO PARTS—PART 2

RICHARD H. DORF*

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UP TO NOW we have said simply that each note is keyed by applying a positive 75 volts to the oscillator plate. The actual conditions are complicated by the coupler system, whose function is to play more than one note when a single key is pressed.

When all couplers are in off position, pushing the C_3 key will supply plate voltage only to the C_3 generator and that will be the only one to sound. When playing on the Swell and the 4′ rocker tablet at the left of the manual is pressed, both C_3 and C_4 will sound. With the 2⅔′ tab pressed, G_4 will sound. (This is approximately the third harmonic of C_3, equivalent to a 2⅔′ rank on a pipe organ.) This process continues with the remainder of the coupler tablets in the manner shown in the keying chart of *Fig.* 11.

Obviously, then, the keying circuits must provide for as many switches per key as there are registers and couplers, and for a method of making registers speak or remain silent at will. The mechanics of the system used by Conn are new and are shown to some extent by *Fig.* 12. In this photo, the manual in position is the Great; note the two coupler tabs, SWELL TO GREAT 8′ and GREAT TO GREAT 4′ at its left. Above this, the Swell manual has been swung up to show the key switches on its underside; note that the white undersides of the swell keys can just be seen at the top.

There are six registers in the Swell, and for each there is one switch wire or finger. All fingers are molded in a lower plastic dowel (or rear dowel, as it would be with the manual in playing position). The fingers are also held in a second dowel which moves downward when a key is pressed (they move outward toward the reader with the manual upended in the photos). The movement of the dowel bends the fingers and causes the free end of each to contact one of the six keying rods which run lengthwise of the manual. These rods carry +75 volts. Since each finger is connected to an oscillator plate, the contact keys the oscillators.

Let us move at this point to *Fig.* 13 and look at the drawing of the Swell keyboard switches. The mechanism here is shown in playing position. A key pressing down on the actuator causes it to move downward as indicated by the arrow. It causes all the keying fingers to move down so that each finger touches the rod beneath it which is running at right angles to the fingers (through the page as viewed). Notice the peculiar cross-section shapes of the keying rods. Each consists of a metal extruded or drawn bar in a D shape with a projection from the straight part of the D. The thick black outline around everything but the projection represents an insulating sleeve. When the bare projection points up, a finger hitting it makes electrical contact. When the bar is rotated so that the projection points to the right, the finger strikes the insulating jacket and no contact is made. The bars are rotated by the rocker coupler tablets at the left of the manual, so that the position of a tablet determines whether its bar shall or shall not contact its row of fingers. The bar rotating mechanisms, six of them for the Swell, are plainly

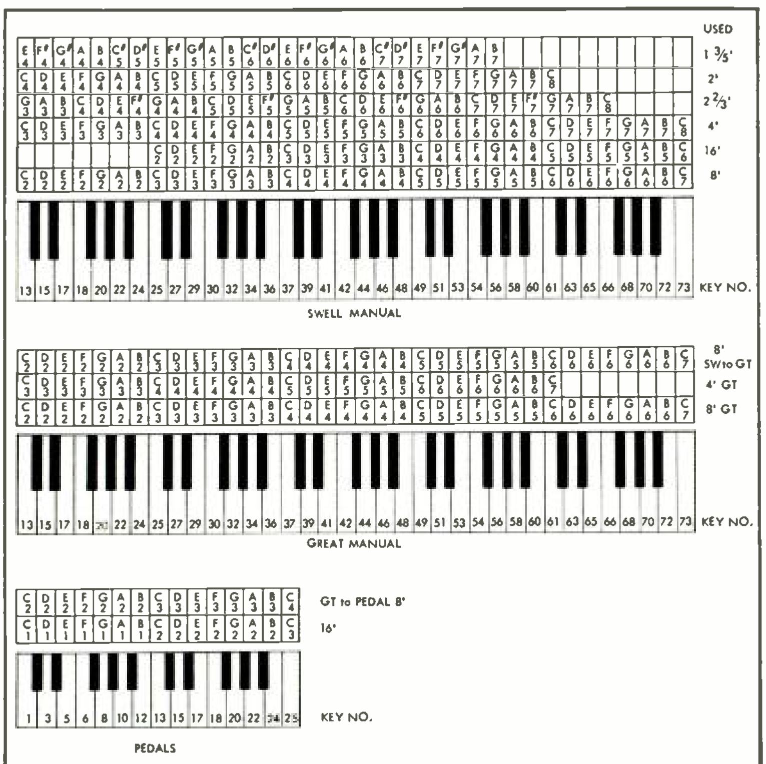

Fig. 11. Interconnections of the coupler circuits in the three sections, simplified by labeling only the white keys.

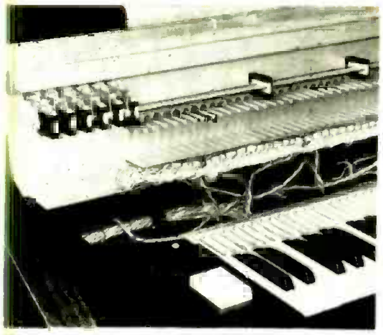

Fig. 12. Swell manual hinged up to show keying springs and coupler operation.

shown at the upper left in *Fig.* 12.

On the Swell manual the second finger from the top under every key is connected to the plate of the oscillator which generates the unison note of that key; for instance the second finger from the top under the E_4 key is connected to the E_4 generator. This finger is therefore the 8-foot or unison finger and the rod which it contacts is the 8′ rod. Whenever the 8′ tab is positioned so that the bare projection on that rod points up, the 8′ note of every key will be heard.

The same E_4 is also the 4′ tone for key E_3; since, according to *Fig.* 13 the 4′ finger is the third from the top, the E_4 oscillator plate is also connected to the third finger from the top under the E_3 key. It is also the 2⅔′ tone for key A_3, the 2′ tone of key E_2, and the 1⅗′ tone of key C_2, as well as the 16′ tone for E_5, so it is connected to the corresponding finger under each of these keys, as indicated by the figure. Since the great manual has a SWELL TO GREAT 8′ coupler, E_4 is also connected to the topmost spring under key E_4 of the Great manual, which operates in the same way but has only three couplings including its own unison.

The keying chart shows in detail all of these connections; they are made by the wiring harness which can be seen under the finger assembly in *Fig.* 12. It should be noted that the 100,000-ohm time-constant and isolating resistor shown in *Fig.* 5 in the oscillator plate circuit is actually located on each finger strip, but has been omitted in *Fig.* 13 to avoid confusion. This assembly is ingenious and effective, and takes the place of solenoid-operated devices which have for many years added to the cost and complexity of pipe organs which employ this kind of coupling as well as earlier organs made by Conn.

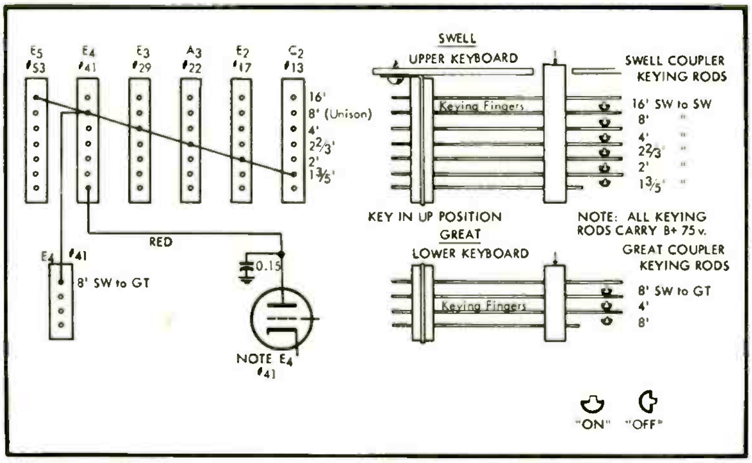

Fig. 13. Diagram of coupler action applied to keying mechanism.

Mixer Circuits

The mixer circuits of the Conn Organ are filters and filter amplifiers which modify the spectrum characteristics of the passband and impart formants to the pulse signals. In addition, they operate both as formants and as level controls for the flute signals, which are not quite sine waves and thus contain harmonics. Lastly, they do, for certain stops, mix quantities of both flute and string or pulse tone.

Figure 14 is a complete schematic of the mixer circuits for the Great stops. We can examine the voices here one by one. The TRUMPET stop is voiced by passing string tone through a formant circuit. (The theory of formants is fully explained in the writer's book, mentioned previously.) Great string tone from the preamplifier of *Fig.* 7 is fed to the grid of the left V_1 triode through isolating and attenuating resistor R_1, and through a filter network consisting of R_2 and C_1 as the series element (R_1 is also a series element here) and L_1–C_2 as the shunt element. R_2–C_1 causes emphasis of highs and L_1–C_2 imparts a resonance to the preemphasized tone; the result is a trumpet quality which, fed to the grid of the tube, emerges amplified at the plate across load resistor R_3. The plate output is fed through isolating resistor R_4 to the great output bus and thence through blocking capacitor C_3 and voltage divider R_5–R_6 to the input of the main preamplifier. Note that the outputs of all the filter triodes are fed to the preamplifier in the same manner.

The stop tablet for the trumpet operates a s.p.s.t. switch which is normally closed, shorting the tube grid to ground. When the stop is to be heard, flicking down the tab opens the switch, removing the short. The tabs, switches, and some other components are seen in the photo of *Fig.* 15, which shows the underside of the mixer assembly.

The second triode of V_1 handles two stops, GAMBA and DULCIANA. Great String tone is fed through both R_1 and R_7 to the grid, these two acting as the series

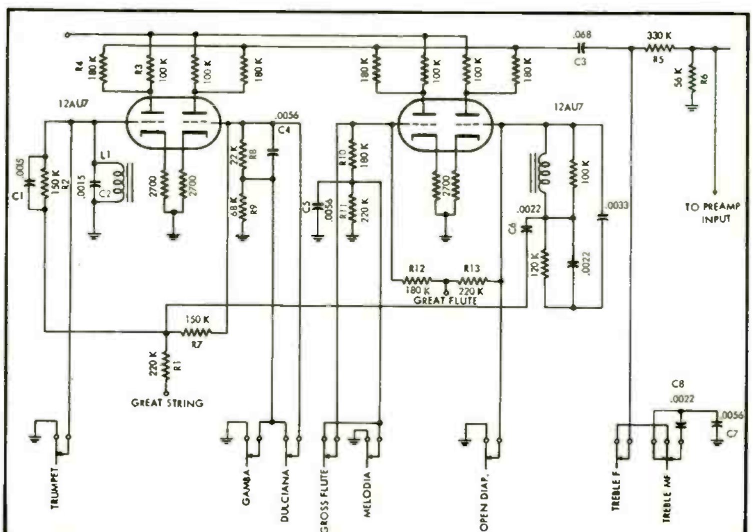

Fig. 14. Schematic of the Great mixer network and filters.

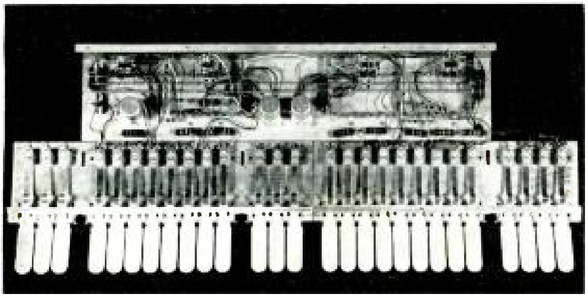

Fig. 15. Underside of stop tab switches and mixer chassis.

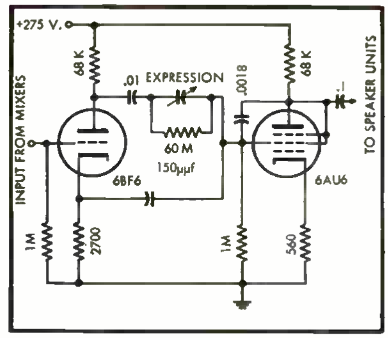

Fig. 17 Main preamplifier, with expression control in form of variable capacitor which is actuated by swell pedal.

leg of a voltage divider, with R_8–C_4–R_9 as the shunt leg. With the GAMBA and DULCIANA switches on (open), the tone at the grid has a slight rolloff due to the shunting effect of C_4, but not a great deal because of R_9 in series with the C_4–R_8 combination. With both switches closed, the grid is shorted to ground and neither stop is heard. With the GAMBA switch open (on) the C_4–R_8 combination is shorted and only R_9 appears between grid and ground. The attenuated pulse tone goes to grid, giving a very stringy quality. With only the DULCIANA switch open, R_9 is shorted to ground, and only C_4–R_8 remains in the grid circuit, giving the string tone a definite, though not great rolloff, so that a soft and not strident string tone is heard.

The left half of V_1 also handles two stops, but these are of a flute character. With only the MELODIA switch open, C_5–R_{11} is between grid and ground, rolling off much of the existing harmonic content of the flute tone which is fed to grid through R_{12} and giving a very rounded, smooth tone. With only the GROSS FLUTE switch open, R_{10} is between grid and ground, leaving the harmonic content intact and yielding a flute tone which is of greater complexity and interest.

The last triode of V_2 uses a mixture of flute and string to achieve a full-bodied, penetrating OPEN DIAPASON. Flute tone goes directly to the grid through R_{13}, where it is rounded and given a slight formant by the grid-circuit components. String tone is also introduced through C_6 at a different point. Speaking of the diapason is controlled simply by shorting the grid.

There are two additional tabs connected with the Great division, TREBLE F (*forte*) and TREBLE MF (*mezzo-forte*). With these switches in the off positions as shown, the output of the entire great bus is shunted to ground by C_7, attenuating the higher frequencies. This is part of the normal voicing of the organ, in conjunction with the stop filters and the generator output amplitudes, and the scaling or level is appropriate for normal organ use over the entire pitch range. If treble sound—over-all, not just tone fundamentals—is to be emphasized somewhat, as might be desirable to add some brilliance to existing ensembles, the TREBLE MF tab is pressed down. This places C_8 in series with C_7, reducing the net capacitance of the shunt and causing highs to rise relative to bass and middle. If an additional treble emphasis is desired, as it might be when playing on a single manual to emphasize melody, the TREBLE F tab is pushed. This completely disconnects the capacitive shunt. If both tabs are pressed, TREBLE F will, of course, take precedence.

The swell and pedal mixers are shown schematically in *Fig.* 16. The first two tabs give the same treble-emphasis results as their counterparts in the great circuit. The left grid of V_1 has a simple tuned formant circuit fed by the Swell string tone from the Swell bus preamplifiers, which are similar to those shown for the Great in *Fig.* 7. The OBOE and ENGLISH HORN switches operate to select the capacitance value across the inductor and thus the frequency range of the formant, which differs for the two voices. The second triode of V_1 is fed by Swell flute tone and contains two series rolloff networks, one of which is appropriate to the HARMONIC FLUTE and the other to the GEDECKT or stopped flute.

The first triode of V_2 is fed by Swell string tone and contains in series two rolloff networks plus a simple resistor. The switch circuits for STRING DIAPASON, ECHO SALICIONAL, and VIOLA DA GAMBA can easily be traced to show that the first puts all the rolloff in the circuit, the second only some for a stringier tone, and the last none at all, leaving only the 47,000-ohm resistor.

The final triode handles the pedal stops. The characteristics of the three voices are determined almost entirely by the rolloff due to the series 100,000-ohm resistor and the .047-µf capacitor to ground. The three series grid resistors and the switches give three different levels. There is, of course, some change in quality when the total grid resistance is changed because this resistance shunts the .047-µf capacitor.

Amplifiers and Speakers

Collected tone from the combined mixer outputs is fed to the input of the main preamplifier diagrammed in *Fig.* 17. This circuit includes the swell shoe or expression control, which is capacitive and has been designed to get around the

(*Continued on page 87*)

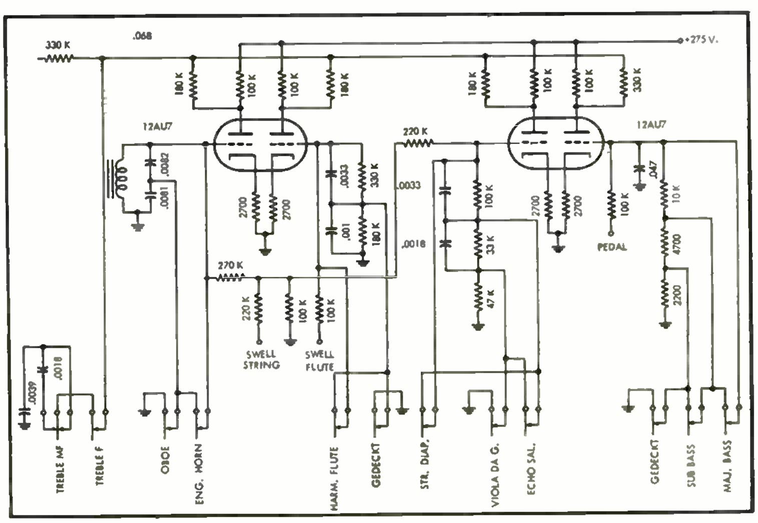

Fig. 16. Schematic of Swell and Pedal mixer network.

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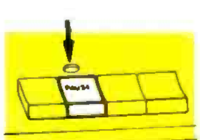

"PAUSAMATIC" INTERVAL CONTROL: Automatically regulates wait period between records. Adjustable as follows: 78 rpm adjusts from 5 seconds to 2⅓ minutes; 45 rpm from 9 seconds to 4 minutes; 33⅓ rpm from 12 seconds to 5½ minutes. The interval selector is located directly above the PAUSE button.

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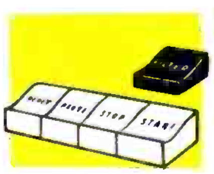

5 PUSHBUTTONS Control ALL Operations!

- **REPEAT** — Used two ways: for repeating entire record or portion of the record.
- **PAUSE** — Adjusts wait period between records.
- **STOP** — Stops unit at any time! Arm picks up and goes to rest position. It is not necessary to remove or discharge the records that remain on the Magic Wand Spindle. Unit set in operation again by merely pushing the START Button.
- **START** — Starts operation. Also rejects . . . permitting record change at any time.
- **FILTER** — Screens out surface noises. Button located behind START button.

ONE KNOB CONTROLS ALL THREE SPEEDS: With 3-speed rim drive for 33⅓, 45 or 78 rpm. A simple turn of the setting knob sets the speed desired. No other adjustments or settings necessary. When set to "Zero," (STOP position) the idler wheel automatically disengages.

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NOISE REDUCING TONE ARM: Constructed of special damped plastic and suspended in ball bearings, it eliminates stylus displacement and guarantees equal stylus pressure. Spring loaded, knurled screw underneath tone arm enables weight adjustment to be made without the use of tools.

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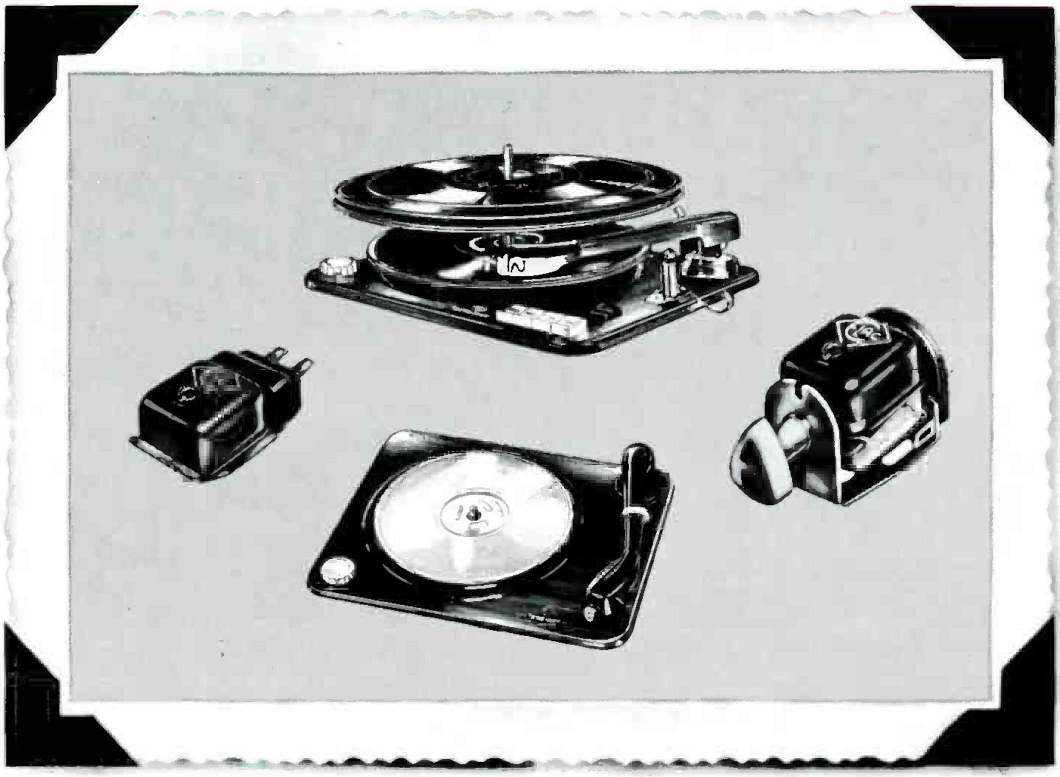

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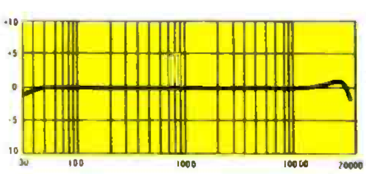
★ **RESPONSE:** Under average home conditions, the MIRATWIN delivers an amazing response of within 2 db from 30 to over 18,500 cycles at 33⅓ rpm, and within 4 db to 22 500 cycles at 78 rpm. Equally outstanding is the freedom from resonant peaks throughout the entire range — a characteristic maintained even when the Cartridge works into unusually high load capacitances. These features, combined with superb internal damping, produce unsurpassed transient response!

★ **TRANSIENT RESPONSE:** This is very wide and very flat and the freedom from resonant peaks as well as superb internal damping produces an unsurpassed transient response. Even the square waves are reproduced as faithfully as when they are recorded.



The downward slope in response below 30 cycles of the 33⅓ rpm cartridge audibly minimizes the peaks that are due to arm resonance. It also improves the transient response of associated amplifiers by reducing response to sub-sonic transients, which sometimes trigger even the very fine amplifiers into a hangover or outright oscillation.

★ **NEEDLE CHATTER:** Completely negligible . . . probably the lowest ever achieved! Also, the freedom from peaks and the smooth response, along with the extremely wide range, results in an unprecedented low scratch level, even from old recordings.

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★ **PLUS** . . . THE EASIEST STYLUS REPLACEMENT YOU'VE EVER SEEN . . . Good reasons why an independent testing laboratory stated that the New MIRATWIN "EXCEEDS ITS OWN SPECIFICATIONS"! **Complete with holder for quick installation.**

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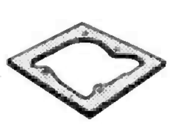

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AUDIOCLINIC ? ?

JOSEPH GIOVANELLI*

NOTE: Many letters have been received here stating that more of my column should be devoted to fundamentals of electronics, both practical and theoretical, in order to help those just beginning their pursuit of good sound reproduction. However, it is you, the individual readers, who set the level of this column by the nature of the questions you submit. A brief look at the previous columns will show that some of the subjects covered have been those concerning servicing of equipment, definitions of basic terms, and methods of impedance measurement, all as a direct result of your questions.

Of course, shortage of space makes it necessary for many questions of general interest to remain unprinted. These, and the ones of only limited interest, are answered by mail in the same manner as those answered in the column. Since there is considerable delay between the receipt of a question and its appearance here, even those to be printed are answered by mail as soon as possible. It is the function of the column to make the information supplied to the writer of the question available to all readers.

Your questions should be sent to me at the address below. Please include a stamped, self-addressed envelope to facilitate a reply.

Tape Clicks

Q. *I have trouble with some of my tapes which is very hard to describe. During the playback of the tapes, I hear a sharp click which recurs once in five seconds and gradually increases in frequency. It does not seem to be recorded on the tape, since I can play it back again and find that the clicks occur in other places on the tape than those noted during the first playback. The clicks do not occur with all the tapes that I have. What causes this and what can I do to prevent it? J. E. Dyson, Jr., Fort Collins, Colo.*

A. It is likely that your problem is caused by the generation of static electricity. The best thing I can recommend is that you clean all surfaces which come in contact with the tape. If your machine is one which employs pressure pads to maintain intimate tape contact with the heads, special attention should be given to these parts when cleaning. Use alcohol, never carbon tetrachloride. If the trouble still persists, then try demagnetizing the heads. This should be done with a demagnetizer made specifically for this purpose. A magnetized head can cause all kinds of unexplainable emanations from the output of the machine.

The fact that some of your tapes are not affected in this way is not at all mysterious. It probably depends upon the moisture content of the tape and upon the amount of plasticizer used in the base. In a climate such as yours, it would be well to store tapes in moisture-proof cans to prevent loss of moisture and plasticizer. Indeed, when tape is to be stored for long periods of time, these cans should always be used. Cans used for storing motion picture film will serve nicely in this capacity. For a further discussion of maintenance of tape recorders, see Audioclinic in the January, 1956 issue of Audio magazine.

Line Fuses

Q. *The line fuse in my amplifier is constantly burning out. What can I do to service the amplifier myself? H. Carleton, Brooklyn, N. Y.*

A. This condition indicates one of two things: either the fuses you are using to replace the original ones are the wrong size or the primary of the power transformer is for some reason drawing too much current. The current rating of the fuse must be greater than that of the average current the amplifier draws, since the amplifier's transformer, when the switch is first thrown, must build up a backvoltage. During that instant a very large current will flow, large enough to burn a fuse out if sufficient compensation in its size is not made. For the exact size of the fuse, consult the manufacturer's instruction manual. It will be in the vicinity of 3 amperes in most cases.

Having made sure that the size of the fuse used is correct, we can then proceed to the problem of why the transformer is drawing too much current. First, remove the rectifier tube and place a new fuse in the circuit. Turn on the equipment and see whether the fuse blows again. If it does, then it may well indicate that the transformer is no longer usable or that something has happened to the filament supply, or the high voltage connections on the rectifier socket. In one instance, someone had spilled some liquid into the amplifier, which arced across the rectifier plate terminals of the socket. We scraped it away with a knife and the unit functioned normally. If the fuse does not blow, it may indicate that the rectifier has shorted internally. Replace it and try again. If the fuse goes, it probably indicates that one of the filters has shorted or, in certain types of amplifiers, the plate bypass capacitor in the output stage has shorted. Remove one side of each of the various capacitors, one at a time, and try again to see if the fuse still goes. If all of this is done and the trouble still persists, then it may be that the primary of the output transformer has shorted to its core. To test for this, disconnect the B+ lead (red) and try again. Another trouble, though far less common, is for the coupling capacitor or capacitors which feed the output tubes to short. This will cause the output tubes to draw too much current, which can then cause the primary to draw excessive current, possibly enough to blow the fuse.

Record Changers

Q. *What should I look for when selecting a record changer or turntable and which would be more satisfactory? Max Wellburn, Aimes, Iowa.*

A. Your personal preference must be the deciding factor in your choice between a record changer and a turntable. If you wish to be provided with music played continuously without having to give attention to the machinery which is supplying it, your choice should be a record changer. However, if you wish to obtain the highest in sound quality, you will be best served by a quality turntable.

A record changer is a compromise device wherein, as the number of records on the turntable increases, the angle at which the needle strikes the groove is changed. There may also be introduced an undesirable change in stylus pressure or weight. It can be seen that this is not good for either the records, the needles or the quality of sound produced. With proper tracking force, however, records will give satisfactory performance. The record changer is valued highly by collectors and owners of large libraries of 78-rpm discs, for reasons which need no further discussion.

A turntable is a basically simple device whose one important function is its rotating motion. Since the manufacturer desiring to produce a quality instrument can devote his skill entirely to this single factor, turntables generally have achieved the closest approach to that desired motion with a minimum of rumble and very little wow and flutter. Some have eliminated virtually all forms of mechanical distortion.

There are other important advantages to the turntable. Once the angle at which the stylus touches the groove is properly established, it does not vary as in the case of the record changer. Tracking force also remains constant. A turntable has a spindle which rotates with the table and the record, eliminating the element of wear introduced by the stationary spindle of most changers. The use of a turntable allows the use of a high qualtiy pickup arm; this has a marked effect on the quality of reproduction and on record wear. Some record changer arms are too short for optimum tracking. Some also suffer from inherent resonant characteristics which introduce distortion and undue record wear. Many changers use 2-pole motors, while better quatity ones use the 4-pole variety. Most turntables also use 4-pole induction motors; however, the better units are powered by hysteresis-synchronous motors which provide more speed constancy and regulation since the speed of a hysteresis motor depends upon frequency only.

Your selection of a turntable should be aided by actual physical inspection, by published performance figures and by reputation of the manufacturer. It is important for the turntable to have a heavy mass and to rotate freely in its bearing.

Diodes

Q. *What is a diode? Philip Hartman, Shreveport, Louisiana.*

A. A diode is a vacuum tube having two parts which we call elements: a cathode and a plate, sometimes called an anode. The cathode may be of two general types, a heater-cathode or a filamentary cathode. (See AUDIOCLINIC, July, 1956.) When the cathode reaches operating temperatures, electrons are emitted from it. These electrons form a cloud around the cathode. The old story about unlike charges attracting each other comes into play here. The electrons are negatively charged. If the plate, which immediately surrounds

(*Continued on page 96*)

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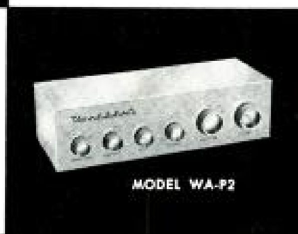

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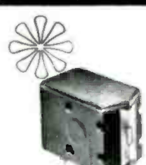

Gold so thin you can't see it . . . but wait till you hear what it does! You'd never know it without a microscope, but the 2 magnetic pole pieces of this DEJUR EMBASSY *recording head are separated by a* GOLDEN SHIM *.0002369 inches thin. This head gap — narrower than any possible before, produces sound that is making audio history.*

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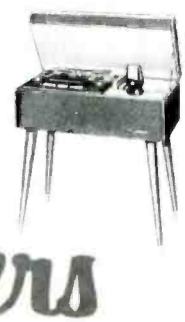

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Equipment Report

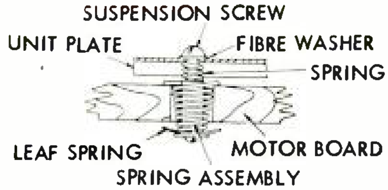

Fig. 3. Detail of the spring suspension which permits the unit to be installed with a minimum of effort, and provides means of leveling from top of changer.

The Garrard Record changers, RC-88, RC-98, and RC-121—Rogers "Oxford" amplifier—Robins Industries' "KLeeNeeDLE" and "Aud-O-File"—"Dual Micro Pianissimo" record cleaner

RECORD CHANGERS have become accepted components in the modern hi-fi system to a degree never thought possible by the serious audiofan as recently as five years ago. The reason for their being in a secondary position in the early days was mainly that the clumsy devices used to provide continuous music from records were a long way from being good enough for the rest of the system—most of them had too much rumble, speed constancy was somewhat less than perfect, and they were not always as gentle in handling the records as the owner of a priceless collection of recorded music would like. But things have changed considerably since then. Modern record changers are so well engineered and built that except for the hypercritical user who practically affects a pair of velvet gloves to handle his records, they are thoroughly satisfactory.

The Garrard RC-80 was the old standby in the record changer field—they were to be found in practically every installation that employed a changer at all. And while the model number did not change for many years, constant improvements were being made in the mechanical linkages and in the individual components, as well as in the precision of manufacture and the care in inspection. This year, however, the changes in the Garrard line were sufficiently extensive to warrant a change in the model number, with the result that the RC-88, RC-98, and RC-121 were announced.

The basic changer mechanism in the first two models remains the same in principle—both use the "dog-leg" spindle and the pusher platform that was so well known in their predecessors, the RC-80 and RC-90. However, the drive mechanism has been changed radically, adjustments have been made more accessible, and countless minor improvements have made the new line attractive to users. In addition, the RC-121 has been added to accommodate the market for a smaller chassis, and to provide a changer of good quality with somewhat lower price. The turntable drive mechanism —motor, idler wheel, and speed-change mechanism—are essentially the same in all three models.

The RC-88

The most popular changer in the line is the RC-88, shown in *Fig.* 1. It mounts in a cabinet space 15½ in. wide by 13¼ in. deep, and requires a clearance of 5¾ in. above the motor board and 3⅞ in. below. It mounts onto the motor board by means of four unique spring suspensions, shown in *Fig.* 3. These suspensions are attached to the top plate by means of long machine screws, and the changer is fixed to the motor board by simply pressing the springs down through the holes (which have previously been cut, along with the large center cutout). The tapered spring is soft and flexible, and provides a suspension which does not transfer vibration to the changer from the cabinet. The cylindrical spring is heavier, and serves to load the mounting screw which is then used to adjust the leveling of the turntable after it is installed in the cabinet. The flat leaf spring at the bottom of the assembly bends to pass through the hole in the motor board, and then returns to its flat position to hold the spring in place.

The motor is dynamically balanced, and is equipped with a stepped shaft. The large solid rubber idler wheel is raised or lowered to contact the proper step on the motor shaft to change speeds, and when the changer is switched off the idler is retracted to avoid the possibility of being "flatted" because of contact with the motor shaft. The motor itself is supported by soft rubber vibration dampeners.

The pickup arm is cast aluminum, and is used with a plug-in shell which will accept practically any cartridge on the market. (An adapter is available for the Audax models.) At the back of the arm there is an adjusting screw which varies the stylus force so that each cartridge may be operated at the optimum condition. When fitted with a G-E cartridge, the stylus force may be varied over a range from 0 to 32 grams, so that regardless of the weight of the cartridge, sufficient range is provided. This adjustment may be done with the fingers, no tools being required.

Another useful adjustment is that of pickup height. This permits the user to set the lowest point to which the stylus may drop, and makes it possible to prevent the stylus from contacting the turntable even if no record happens to be in place.

A third adjustment—one not often requiring any change—is that of pickup dropping point. This allows for any variation in position of the stylus to right or left in the pickup shell, and ensures proper setting down in the outermost groove of the records. Once set for 12-inch records, it is correct for 10- and 7-inch discs.

Figure 5 shows the location of these adjustments, as well as some of the other features of the changer. As to performance, the RC-88 tested showed a flutter and wow content of less than 0.2 per cent, an absolute speed within 2 per cent of normal speed, and rumble approximately 40 db be-

Fig. 1 (left). The Garrard RC-88 "Triumph II" automatic record changer—similar to its predecessor, the RC-80, but improved throughout. Fig. 2 (below). The RC-98, offers several deluxe features—most outstanding being the vernier speed control, actuated by the knob at the left of the turntable.

Fig. 4. The Garrard RC-121 changer—a simpler model with center-drop spindle.

low maximum modulation (20 cm/sec.). However, this figure must be accepted with some caution, because it is extremely hard to make such a measurement without laboratory conditions, which will usually show a better figure. For practical use, it is believed that the measurement should be made with the changer in a standard base, although somewhat better performance would be obtained with a very heavy motor board at least 1 inch in thickness.

The motor switch is equipped with a spark suppressor, and starts and stops introduce no noise in the output even with the gain control turned up well beyond normal playing level. The switch is activated by a feather-touch lever controlled by the pickup arm.

For playing 45-rpm records, an accessory large spindle is interchanged with the dog-leg type, and the records are dropped straight down the spindle. With 12- and 10-inch records, the pusher platform slides the bottom record from the stack placed on the spindle, causing it to pass over the step on the spindle and drop to the turntable, which is covered with a molded rubber mat of special design to give good traction to the bottom record. Before loading the changer, the pusher platform is set for the size of record to be played.

The new model incorporates for the first time a manual position which permits the user to handle the changer as though it were a single-play turntable, with the added advantage that it lifts the arm off and returns it to the rest at the completion of each record. To put the unit into this mode of operation, the lever is moved to the manual position and the operating control is moved to START-REJECT. The changer then goes through one complete cycle and the pickup arm comes to rest, leaving the turntable running. From then on the arm may be moved by hand and records played manually, unless the operating control is moved to STOP. This restores the operation to normal, and if again started, the first change cycle will be repeated.

Cycling time is rapid, requiring only 16 seconds at 33⅓ rpm, 7 seconds at 78, and 9 seconds at 45.

The RC-98

The features of the RC-88 are duplicated in the RC-98, and performance is equal between the two types. However, the RC-98 is equipped with a speed-control knob which permits a small change in the turntable speed—a necessity if the changer is to be used by a musician as an accompaniment to solo activities on an instrument of fixed pitch, or in those instances where the deviation from true pitch may be disconcerting to one with absolute pitch. This control, seen at left side of the panel in *Fig. 2*, gives a variation of approximately ±3 per cent from the true speeds. This control is a resistance network in the motor circuit, and can not introduce any wow or flutter as a governor might. In addition, the RC-98 comes equipped with the 45-rpm spindle. Both, of course, have a short plain spindle for use when the changer is in the manual position, and a plastic center disc to accommodate 45's in manual operation.

The RC-121

Entirely new this year, the RC-121 is slightly smaller than its predecessors, requiring a width of only 13¼ in. and a depth only sufficient to clear the largest record to be played—usually 12 inches. It requires a clearance to 5 in. above the mounting board and 2⅞ in. below.

The main differences between this model and the other two are in the method of handling the records, since all models have the automatic and manual operation control, the same pickup arm and plug-in heads, and essentially the same turntable drive mechanism. With the elimination of the pusher platform, however, and its replacement by the simpler center-drop spindle, the smaller size resulted—with the ability to replace older changers in many existing phonograph cabinets without changes.

Records are stacked on the top of the offset spindle, and the overarm is placed over them to steady the stack of discs. During the change cycle, a lever in the spindle slides the bottom record under the stack and over the main part of the spindle, from where they drop to the turntable. The action of the arm, switch, and cycling mechanism is the same as in the other models. Absolute speed, wow and flutter, and rumble content are closely comparable with the RC-88.

One advantage of the center-drop spindie is its ability to accommodate both 12-and 10-inch records in the same stack, provided the large discs are loaded on first, followed by the 10-inch records. As the last 12-inch disc drops to the turntable, the feeler arm is then able to contact the 10-inch records, causing the pickup arm to set down at the right place for the smaller discs.

After many years of reliable performance with the earlier models, the new Garrard line appears to carry on the tradition of high-quality changer performance. Some of the features of the turntable drive have been taken almost directly from the professional single-play turntable, the 301, which was reported in January, 1956. The method of motor mounting, of direct drive through an idler without rubber belts, and of changing the position of the idler to contact the proper diameter of the motor shaft all are like those in the 301. From a thorough inspection of these three new changers, it seems likely that the line will continue to live up to its reputation.

P-20

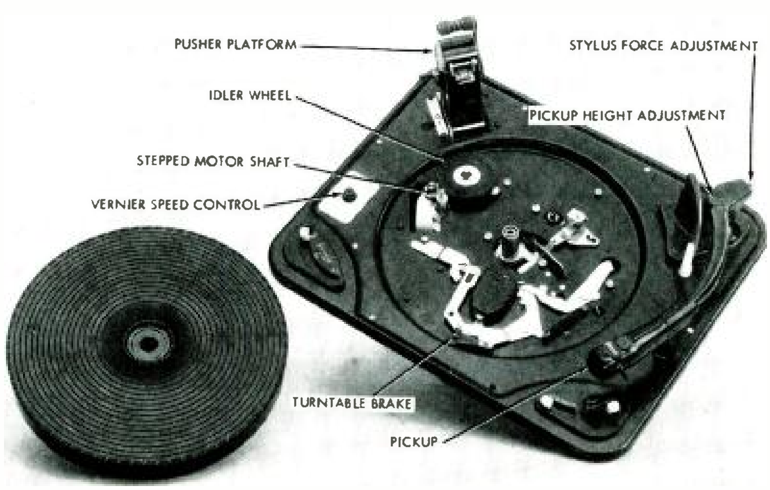

Fig. 5. Top view of the RC-98 with the turntable removed and location of various adjustments shown. The RC-88 is identical in operating mechanism.

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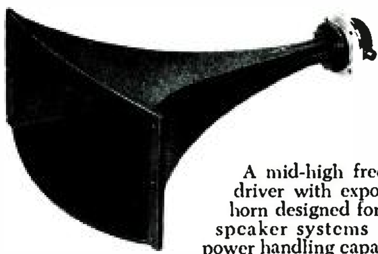

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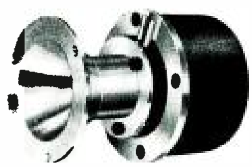

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	(2) Audiom 60 or 70	Midax	11,000	(2) 172	750 cps
	Audiom 80	Midax	9000	280	750 cps
	Audiom 90	Midax	11,700	480	750 cps

	Low Frequency	Mid and High Frequency	Enclosure (cu. inches)	ARU Model	Crossover
3-WAY	Audiom 60 or 70	Midax and Trebax	7800	172	750 & 5000 cps
	(2) Audiom 60 or 70	Midax and Trebax	11,000	(2) 172	750 & 5000 cps
	Audiom 80	Midax and Trebax	9000	280	750 & 5000 cps
	Audiom 90	Midax and Trebax	11,700	480	750 & 5000 cps

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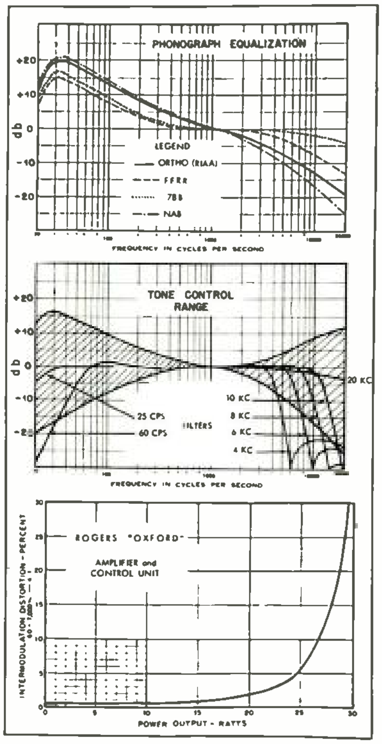


Fig. 6. Performance curves for the "Oxford" amplifier and control unit.

ROGERS "OXFORD" AMPLIFIER AND CONTROL UNIT

Carrying out the British tradition of high-class workmanship, the "Oxford" amplifier and control unit built by Rogers Developments and distributed in the U. S. by Ercona Corporation offer a wide range of control in a two-unit amplifier system.

The power amplifier employs two 6CA7/EL-34's in a conventional Ultra-Linear Williamson circuit with Partridge transformers and adequate filtering. It is a model of wiring neatness, and provides for different speaker impedances by a plug which makes the necessary interconnections between the transformer secondaries. The amplifier is fused, is equipped with plugs to supply power to the preamplifier and to an auxiliary tuner, and has two switched a.c. outlets for additional equipment.

The control unit is furnished with a laminated panel with the letters engraved through the opaque layer, allowing the light to shine through the translucent plastic. The unit is designed to be mounted behind a rectangular cutout, with the panel in front. Six controls are provided—volume (and on-off switch), bass and treble tone controls, low-pass filter, rumble filter, and selector switch. In addition, there are two jacks accessible from the front, one to feed a tape recorder and one into which the tape playback amplifier may be plugged.

The power amplifier is extremely conservative in design, delivering its 20-watt output with ease, although when overworked the same tubes can do somewhat more. The IM distortion curves for the amplifier are shown in the bottom section of *Fig.* 6. The unit is capable of feeding loudspeaker impedances of 2–3 ohms, 6–8 ohms, 12–16 ohms, and 30 ohms, with the measurements being made with a 16-ohm resistive termination. For external equipment, such as a tuner, the amplifier can supply 475 volts at 40 ma (before filtering) for a tuner.

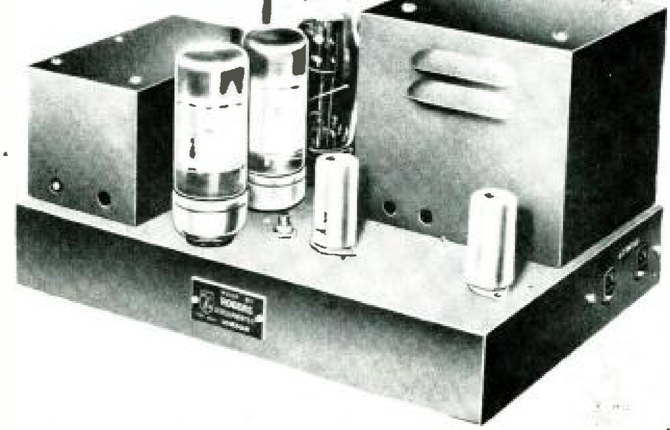
The upper section of *Fig.* 6 shows the curves obtainable from four of the possible curves—the remaining two are of less importance to U. S. users and are not shown, although let it be said that they follow the prescribed curves quite closely. The rumble filter is controllable between 25- and 60-cps cutoffs, with the curves being shown in the center section of *Fig.* 6, along with the various curves for the low-pass filter. The effect of the 25-cps filter is not detrimental to the music at all, but it removes any rumble frequencies that might be encountered from poor turntables—either in the home or at a radio station. The 60-cps position offers some noticeable attenuation of the very low bass, but is helpful in severe cases of rumble. The low-pass filters are also sharp, cutting off at the rate of 30 db per octave, and the points of cutoff are well chosen to reduce hiss or needle scratch from noisy records and to reduce atmospheric noises.

The tone controls employ tapped switches, and provide two cut positions and three boost positions for bass, and three cut and three boost positions for treble. The resulting curves are also shown in the center section of *Fig.* 6. The operation of the control unit is quiet, and click suppressors prevent pops. There are four inputs to the control unit—two for radio, with one having a level-set control, one for phonograph, also equipped with a level-set control, and one for microphone. With the level-set controls at maximum, a 1-watt output is obtained from an input of .015 volts at the radio jacks, 4.2 mv at the phono jack, and 0.52 mv at the microphone jack. With a 10-mv signal fed into the phono jack, the tape-record jack provides a signal of 0.85 volts unaffected by the volume control, but it does follow the tone controls and filters. A radio input signal of .034 v. will give the same output at the tape-record jack with the level-set control at maximum, thus permitting the user to balance the inputs to furnish the same signal at the input to the tape recorder. Plugging into the tape replay jack cuts off all other inputs, and provides the same gain as from the radio input.

Mechanically the two units are well built. The input plugs furnished are not standard with U. S. practice, but we have long deplored the poor quality of the usual phono plug. For equipment of the general high quality encountered in hi-fi components, we believe that a better plug should be made available. And while these plugs are undeniably better, the fact that they are not interchangeable with U. S. phono plugs might be considered a disadvantage, though it shows up principally when one has to test many different units. However, in a permanent installation the non-standard plugs should cause no trouble.

P-21

Fig. 7 (below). The Rogers "Oxford" control unit, which is designed to work with the power amplifier shown in Fig. 8 (right). Both are of excellent appearance and neat construction.



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ROBINS INDUSTRIES' "KLeeNeeDLE"

It is not often that we see any device that gets completely unqualified approval and the recommendation that "this should be in every home." But after using the KLeeNeeDLE for a month, we are of the opinion that no record changer should be without one.

Everyone that has ever used a record changer for any length of time knows that unless the stylus is brushed off at fairly short intervals, it builds up a small felt pad from the dust and lint that accumulates on record surfaces. If left for a sufficiently long time, the pad takes on the dimensions of a carpet—or at least a bath mat—and we have seen them up to a half

Fig. 9. The KLeeNeeDLE in place on a record changer.

an inch long and a quarter of an inch wide. As soon as this pad builds up appreciably, it effectively prevents the stylus from seating itself properly in the groove, and you begin to miss parts of the music and finally the pickup slides across the record without a sound.

Of course, the person who takes good care of his records and does not let any dust or lint accumulate on them will say this shouldn't happen, but there are others who do not take such good care of records, and still others who play records interminably without any precautions for their surfaces.

In any case, the KLeeNeeDLE will eliminate most of this trouble from the start, since it brushes off the stylus every time the arm moves from the rest to the record, or back to the rest again to permit another record to drop. The device consists mainly of a flexible spring in which is mounted a soft brush. The spring is held by the grooves on a threaded rod, which in turn screws into a mounting base. The base has an adhesive disc on its bottom surface, and it is stuck to the changer plate at a point where the stylus will pass over the brush with each movement. The height is adjusted to give the stylus a good "swipe" each time, and the lock nut tightened. Then you can forget the device altogether, and you can stop cleaning the stylus after every three or four plays—the KLeeNeeDLE does it for you after every play.

The device will fit every record changer we have tried it on so far, and it makes life much easier for the person who gets most of his musical pleasure from phonograph records. We cannot recommend this item too strongly.

P-22

ROBINS' AUD-O-FILE

Another item by Robins Industries that takes our fancy is the AUD-O-FILE, an entirely new method of storing records without the excessive handling that is required when they are kept in their regular stiff cardboard jackets. Only 13 x 14 x 14 inches in size, this unit holds 50 records in contoured plastic containers supported by two heavy wires in much the same manner as the Oxford Pendaflex file folders. Since the containers are transparent, the record labels can be seen through them to facilitate selection, and the top of the holder opens enough to make it easy to pick out the desired record without the friction usually required with the regular jackets. After a session of playing, all of the containers are closed at once by pushing them to one end of the rack.

While a single rack full of these plastic containers may not hold all of a person's record collection, it could easily be used for those that are played most often, or more readily, perhaps, for holding a certain

Fig. 10. The AUD-O-FILE keeps records free from dust, avoids scratching.

group of records that one picks out for an evening's home concert.

Another excellent application for this unique record holder is for the demonstration room of a hi-fi dealer, where the records are taken out of their jackets and put back many times a day, with consequent wear. With the AUD-O-FILE they could be departmentalized for different types of music, making it easy for the salesman to select the proper type of record for each customer. Another practical use is in the broadcast station where the programming department sets up a day's records in one of these devices and delivers it to the control room, takes the previous day's program back to the library for refiling, and again fills the containers for the succeeding day. Our only suggestion would be for some means of identifying the records from the top of the holders, coupled with a slide-out carrier like the typical file cabinet. This latter, we understand, is coming soon, so we shall be patient. As it is, however, the AUD-O-FILE is a distinct convenience.

P-23

DUAL "MICRO-PIANISSIMO" RECORD CLEANER

Still in the same vein—that of simplifying the playing, storing, and cleaning of phonograph records—we find that the Dual Micro-Pianissimo cleaner does what it is supposed to do with a minimum of work on the part of the user.

This device consists of two plastic arms hinged at one end, and with a stud on one and a mating hole on the other. Both arms are lined with plastic foam, and in use the foam linings are moistened slightly, a record is placed over the stud, the arms closed, and the record rotated.

At first glance, we were inclined to be skeptical of this cleaner, because when the sponge is dry it feels just a little rough. But once the sponge is moistened it is very soft, and shouldn't damage the record surface in the slightest. We tried it with one record continuously for fifteen minutes just to see what would happen, and all we could see under a strong magnifying glass—not a microscope—was that the record was *very* clean. The plastic foam may be cleaned when necessary by washing with soap and water.

Fig. 11. The Dual Micro-Pianissimo record cleaner.

The principle advantage of this device is that it cleans the record in the direction of the grooves, never across them. For a very thorough washing of records, the whole unit could be used under water, with a few drops of wetting agent, to flush every bit of dirt off of the surface. Remembering the "Dust Bug" of Cecil Watts, and the instructions for its use, we also wonder if a complete and more permanent de-staticizing wouldn't result from the use of a solution of water and ethylene-glycol (permanent anti-freeze solution) for wetting the foam lining. Not having any on hand—these experiments being conducted in August—we continue to conjecture about the advantage of this treatment. However, the ethylene-glycol is a fairly effective anti-static agent, and might reduce the need for cleaning the records at close intervals.

But when used exactly in accordance with the instructions, the Micro Pianissimo cleaner does remove dust and dirt and for a time, at least, the surface is static free. With the two arms opened clear out, the one with the hole in it may be used to clean records while playing on a single-play turntable, and again this cleaning action takes place in the direction of the grooves if the hole is placed over the turntable spindle.

The cleaner is so easy to use and the results are so effective that it remains "in the act" for our own records from now on. We believe a trial would convince anyone.

P-24

BOOK REVIEW

TAPE RECORDERS—HOW THEY WORK, by Charles G. Westcott. 177 pages, illustrated, index. $2.75. Howard W. Sams & Co., Inc.

We have had two or three excellent books on magnetic recording which laid down the engineering basics for the benefit of the serious professional who is concerned with original design work with tape equipment. We have had also a spate of books which hold out hands invitingly to the strictly unwashed newcomer, which avoid discouraging him with anything that has too strong a smell of "engineering," but try to show him how to use his tape machine and what to use it for. Both types are useful and necessary.

All of us in any way concerned with hi-fi know that there is a whole teeming continent falling between these two polar positions. Mr. Westcott has staked out a claim on this great middle continent, and his title to this claim looks good. He is telling "how they work" at a level that will appeal to everybody with some grasp of the fundamentals of sound recording, from the serious amateur to the professional not intimately concerned with magnetic recording.

As far as this reader is concerned, he gives the best account so far in print of the basic design factors in tape machines and in magnetic tape, as these factors are presently embodied in the products of the tape industry. Commercial design is related in every case to the fundamentals of the recording process, and Mr. Westcott does not hesitate to evaluate the various design solutions to be found in available equipment, in terms of their effectiveness for the job in hand. This makes the book highly valuable to anyone who must choose tape equipment for various applications.

His first chapter constitutes a brief history of magnetic recording, which is far more complete than anything the reviewer has previously seen on this subject. Then he gives a non-engineering but completely respectable account of the theory of magnetic recording.

Following this are chapters each of which takes up one of the major functional sections of a magnetic recording and playback system: Transport, drive motors, volume indicators, bias oscillators, equalization, record and playback amplifiers, magnetic heads, and finally the tape itself.

In every case Mr. Westcott gives solid information which the amateur or professional using or buying tape equipment will be grateful to have. For instance, his chapter on the bias oscillator is a thorough survey of the various ways in which bias is handled today, telling which methods are good and bad, and why, and making clear the rather complex relations of bias levels to recording qualities.

The book ends with a chapter on test procedures which covers the major techniques for determining the qualities of magnetic tape equipment, of tape, and of recordings on tape. Anybody concerned with magnetic recording, short of the professional already deeply in the field, should find this book of tremendous value.

—R. S. Lanier

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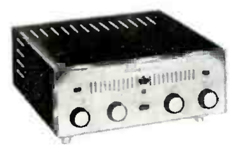
BOGEN R620 AM-FM TUNER. Excellent sensitivity & selectivity, fast tuning. AFC control. Built in line cord for FM, ferrite loopstick for AM generally does not require outdoor antenna. Features generally found in high priced tuners: Balanced ratio detector; Triode RF stage; Triode mixer. Cages available for both tuner and amplifier at slight extra cost.



BOGEN DB115 15 WATT AMPLIFIER. Inputs for tuner, tape, TV and phono with magnetic, ceramic and crystal cartridges. 3 equalizer settings. Continuously variable Baxandall bass and treble controls. 3 position loudness selector. Separate filters for high and low levels. Volume control. Variable damping control. 3 position speaker selector. Frequency response ±.05 15-30,000 cps.

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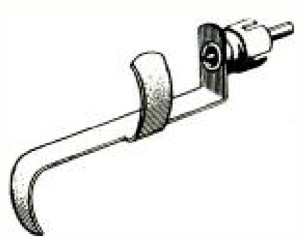
NEW PRODUCTS

• **Changer Drawer Slide.** Record changers, tape recorders and similar devices may be pulled out to their full length for easy access and operation by means of a

new sliding device recently placed on the market by Steel Slides, Inc., 1 Lawton St., Yonkers, N. Y. The steel slide is supplied with newly-developed Neoprene mountings for cushioning the transmission of vibration and shock. Cushion-mounted guides maintain a level position of the phono drawer for its full length of travel. Installation is simplified because only one slide is required for each instrument. **P-5**

• **Solderless Pin Plug.** Absolutely no soldering is necessary for secure attachment of standard single-conductor shielded audio cable to the new Model PP phono plug manufactured by Workman TV, Inc., Teaneck, N. J. A built-in handle, which also functions as the

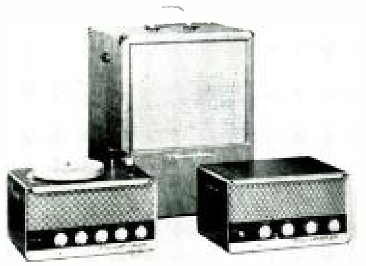


ground connection to braided shielding, removes the possibility of pulling out the center pin when removing the plug from the jack. Permanent connection of audio cable to the plug can be made in one minute. **P-6**

• **Sherwood Crossover Networks.** As an expansion to its line of high-fidelity components, Sherwood Electronic Laboratories, Inc., 2802 W. Cullom Ave., Chicago 18, Ill., is now manufacturing a series of crossover networks which combine economical construction with precision-wound coils. Although the units are unusually compact, they afford 12-db-per-octave attenuation to permit construction of speaker systems with remarkably low intermodulation. Included in the series are six-element networks for 300/5000 cps and

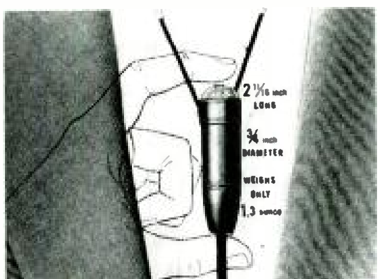
500/5000 cps crossover, and four-element models for 200, 600, 800 and 3500 cps. All units are for 16-ohm speakers. Complete details will be mailed on request. **P-7**

• **Bell "Pacemaker" Amplifiers.** An entire new line of commercial amplifiers designed for the "budget" market has just been placed on the market by Bell Sound Systems, Inc., Columbus, Ohio. Eight models and a variety of accessories make up the Pacemaker line. Included are a 10-watt a.c. amplifier, a complete 10-watt system including speaker, a 20-watt a.c. amplifier, a 33-watt a.c. amplifier, two 6-volt 20-watt mobile amplifiers, one with single-speed and one with three-speed phono top, and two 12-volt 20-watt mobile amplifiers, also with a choice of single-speed or three-speed phono top. Accessories include a systems case which will fit most models, and which carries two 12-in. speakers and 25 feet of cable.



Control panels are recessed and illuminated. All units in the Pacemaker line are finished with a special material which is scratch-resistant. **P-8**

• **Tiny E-V "Lavalier" Microphone.** Created primarily for TV, the new Electro-Voice Model 649 miniature dynamic microphone is only 2-11/16 ins. long and ¾ in. in diameter, yet provides sufficient signal strength for many applications demanding high output. It is ideal wherever microphone concealment or free movement of the hands is desired. No closely associated auxiliary equipment is required. The unit is equipped with a pop-proof wire-mesh grill which minimizes wind and breath blasts. Frequency response is uniform from 70 to 13,000 cps. While connected for 50 ohms impedance when shipped, convenient impedance changes can be made in the transformer housing for 150



and 250 ohms. Case is high-tensile lathe-turned aluminum finished in non-reflecting TV gray. Weight is only 1.3 ounces less cable. Electro-Voice, Inc., Buchanan, Mich. **P-9**

• **Pilot Integrated Hi-Fi Chassis.** A new "3-in-1" high fidelity system featuring an FM-AM tuner, preamplifier and a 20-watt power amplifier on a single chassis has recently been introduced by Pilot Radio Corporation, 37-06 36th St., Long Island City 1, N. Y. Identified as Model HF-41, the new unit is furnished complete in a handsome streamlined enclosure. The color combination is deep burgundy and brushed brass. Simplicity of installation and interconnection with speaker and record player have been emphasized in the HF-41 to enhance its appeal to non-technical high fidelity listeners. The unit complies with the FCC's new regulations governing spurious radiation. Among numerous performance features are built-in rumble filter, variable loudness control, tape-head playback, tape output,

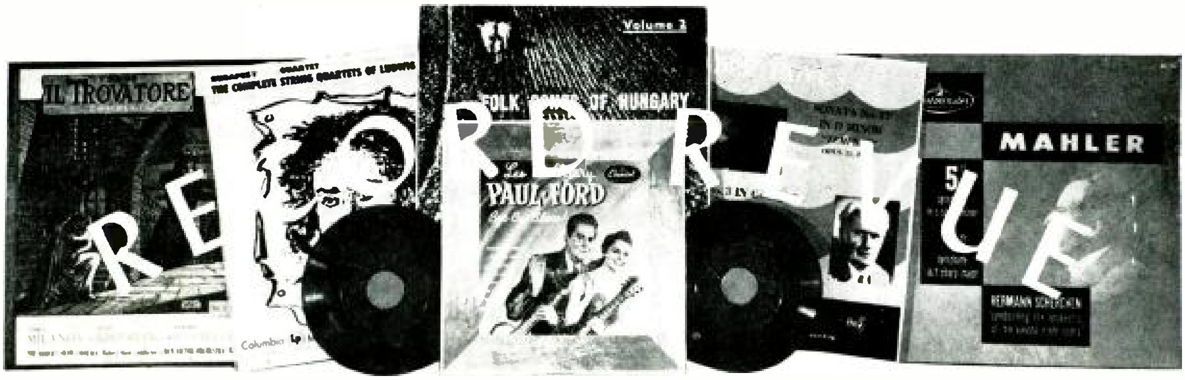
tape equalizer, 4-position record equalizer, afc and afc defeat, variable phono load, d.c. on filaments of preamp tubes, and Williamson-type power amplifier. Dimensions are 4¾"h x 14-9/16"w x 12⅛"d. **P-10**

• **Transistor Tester.** Maintenance and servicing of transistorized electronic devices will be expedited by means of this new instrument recently introduced by Sonex, Inc., Upper Darby, Pa. Readings are taken on a 4-in. meter. The tester is self-calibrating and the transistor under test is operated in a temperature-stabilized circuit which insures that all tests are made under identical biasing conditions. The tester employs three transistors, one as a stable local oscillator having a nominal frequency of 1000 cps, the other

two as a special-purpose low-level synchronous detector. Power is supplied by a single battery with very low current drain. **P-11**

• **Bulk Tape Eraser.** A new, small-sized "Noiseraser", intended specifically for the hi-fi market, has recently been put on the market by Librascope, Inc., 133 E. Santa Anita St., Burbank, Calif. Known as the N-HF, the unit contains a powerful magnetic circuit which removes recorded and undesirable signals from entire reels of tape in a matter of seconds, 4 to 6 db below standard erase head levels of demagnetization. It is recommended for

standard quarter-inch magnetic tape on reels up to 10½ in. diameter. The N-HF operates from an ordinary a.c. convenience outlet. **P-12**



EDWARD TATNALL CANBY*

More Stereo Tapes

> *Stereo Rating.* Mr. Canby has rated these tapes on a scale from 1 to 5 (5 being the highest value) as to specific stereo effectiveness, over and above the general values of recording and performance as heard in comparable monaural reproduction.
>
> The rating is personal, includes both musical and technical factors that contribute to stereo value, and represents a fair measure of the stereo worth of the tape in terms of the extra cost of stereo recordings and playback equipment.
>
> All tapes were reviewed in the stacked (in-line) head form. Tapes marked with an asterisk are listed as also available in staggered head form.

Tchaikovsky: Serenade for Strings, Op. 48. Bolzoni: Minuet. Sorkin Symphonette.

(Concertape (Webcor) Stereo 2923 3B

Stereo Rating: 3

This is a fine recording and very well played by the small string orchestra, but it doesn't have much stereo value. The one-track version is just as satisfactory musically, though both make good listening.

There's nothing wrong with the recording technique. The balance is good, the instruments more or less where they ought to be in space. But the stereo result is very mild for two good reasons. First, the recording hall is fairly dead and the mikes quite close—as befits this kind of semi-chamber music. This minimizes the stereo room-sound that is so persuasive in the big orchestra stereos on RCA Victor. The over-all effect here is hardly different from that of the one-channel version; the right-left orientation is present but not particularly noticeable nor compelling.

Secondly, this music doesn't really need much spatial differentiation. It is already so clearly and transparently scored that the stereo separation of the elements adds nothing musically significant. This is true, I begin to realize, for most chamber music. It is usually played as a lump in space, its sound coming, as with a solo, more or less from one spot. Spatial perspective just doesn't count for much.

A big room liveness might well add a more noticeable stereo realism to this kind of sound, since then you would be immediately aware of the stereo room-space, as you are not in this recording. But that would be musically quite out of style.

Best thing, I'd say, is to go out and try another piece, another kind of music.

Mozart: Horn Concertos. #3, K.447, #2, K.417. James Stagliano; Zimbler Sinfoniets. Mozart: Horn Concertos #4, K.495, #1, K.412. (Same)

Boston (Livingston) Stereo BO 7-4 BN, BO 7-5 BN.

Stereo Rating: 5

These tapes will prove unexpectedly pleasant for the Mozart lover, as stereos, though I had expected to find them so-so, after hearing the LP disc on which the same performances are recorded in standard fashion. They are remarkably improved via stereo.

The playing, as I heard it on LP, ranks well below the top among the several LP versions of these four concertos. Good, straightforward, with many lovely moments; but there is a hardness and inflexibility (no conductor?) that will not endear them to those who have heard more sensitively played versions. Still. . . .

The stereo version has such an unexpectedly lovely sense of orchestral and solo presence that at once Mozart comes through and the effect is delightful! Interesting especially since I found that in the LP versions the acoustics of the new modern hall at M.I.T. distinctly poor for the music. The LP sound was cold, dry, undistinguished. Here, in the very same hall, probably at the same moment, the sound is beautifully alive, wholly natural and convincing! Shows what microphoning (including stereo miking) can do. Extraordinary.

I almost thought I must be wrong—until I switched back to monaural, one-track playing. There was the poor, undistinguished sound again.

A good part of the value of this as stereo lies in the perfect rendering of the horn solo, which has that peculiar hollow, all-embracing sound, not too precisely located, off in the distance but filling all the space, that is its true "live" beauty. That effect is immeasurably strengthened by the sense of hall reverberation, from all sides, that accompanies the horn in the stereo version. Any musician will hear at once, I think, that here is really a new effect of realism in recording reproduction.

Incidentally, these two tapes sell, as of this writing, at $10 apiece, $20 for all four concertos. The monaural taping, all four on one tape, is $12. The same sells on LP disc for $5 list—minus, sometimes, a healthy discount. Oof! But I suspect stereo will come down some, at least, within the next year.

Brahms: Violin Concerto. Heifetz; Chicago Symphony, Reiner.

RCA Victor Stereo Tape ECS-4'*

Stereo Rating: 4½

Another in the monumentally successful RCA Chicago series of stereos with Reiner, and this would rate tops, score of 5, except that the solo violin here poses a problem in stereo technique that has not been entirely solved—and may not ever be, until we simply get used to the sound as here presented.

The orchestra here spreads out wonderfully wide with that same vast, concert hall expanse and the same solidity and realness that is in all these Chicago tapes. The soloist was perhaps recorded *au naturel*, that is, just as he stood on the stage, without special miking. He definitely is less loud in the tonal balance than the conventional solo violin sound of monaural recording. This is as it should be—for the nearer we approach literal realism, the more literal we must be and soloists simply do not play like tonal giants, as loud as the whole orchestra, in real life. Still, there is an odd wandering quality about Mr. Heifetz. One isn't quite sure where he is, nor how far away in space—and since the rest of the orchestra is so very positively placed, this gives him a curiously disembodied and ghostlike quality at times! He flits about.

Not too serious a criticism and the fiddling is generally well balanced with the orchestra, for fine musical projection of the high-powered performance. But it will be interesting to watch future concerto stereos, to see what other possibilities there are for natural miking of the solo artist.

Bartok: Concerto for Orchestra. Chicago Symphony, Reiner.

RCA Victor Stereo Tape ECS- †*

Stereo Rating: 5

Aha! What a pleasure this one is. The stereo recording technique is probably the same as that in others of the series, notably the Strauss. But this is a texture piece, a concerto for all the instruments of the orchestra, singly, in pairs, groups, blocks, backed by the larger sound of the whole ensemble—and this is the ideal situation for big-orchestra stereo. The musical gain over non-stereo playing is most gratifying, in proportion to this musical importance of the solo groupings and the complex texture of the work itself.

I found the LP disc (monaural) version of this performance rather too live and distant, not bringing out sharply enough the solo instrumental sounds that come out of the orchestral texture. The stereo version remedies this to perfection. The solos aren't actually any louder or nearer than in the LP recording but the stereo space-sense gives them a new pin-point presence and direction that does them full justice. Wonderful.

Liebermann: Concerto for Jazz Band and Symphony Orchestra. Chicago Symphony, Souter-Finegon Orchestra, Reiner.

Stereo Rating: 5

R. Strauss: Don Juan. Chicago Symphony, Reiner.

Stereo Rating: 3

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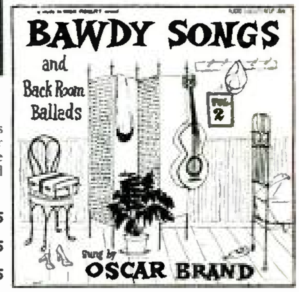

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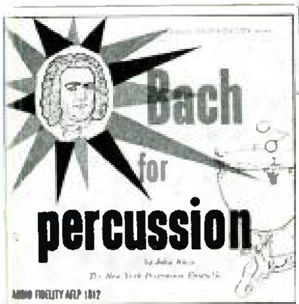

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combining Twelve-Tone composition with Mambo and Boogie, is a natural for stereo and this tape is a whiz. Big. broad, over-all sound in a huge hall; quantities of piquant, pin-point solo effects within the whole, running the gamut straight through the resources of both bands. Marvellously natural piano, drums, rhythm.

I am less crazy about this music as I hear it more, though my admiration for its fabulous technical organization remains profound. But the stereo version put it back into my listening area again, for a while longer. The opening portions, ominous and low in volume, drag along unmercifully. But the later, more intense parts, from blues and boogie to the mambo (this was a year or so ago) pack a huge punch.

The Strauss Don Juan which follows with hardly a pause is an anticlimax. Part of that is the rather ghastly contrast in musical style and content—a very poor pairing. But the Don Juan stereo recording seems to be less effective by a good deal than the others of the series. It lacks the huge, wide sound, and it has less definition and presence. I had to pull the two speakers closer together to make it sound right. I have a feeling that this was recorded earlier than any of the others. If not, then it's just a lemon.

Strauss: Also Sprach Zarathustra. Chicago Symphony, Reiner.
RCA Victor Stereo Tape ES-1 †*

Stereo Rating: 5

This, RCA's first tape numerically, is one of the finest to date, from the stereo standpoint. Like others in this Chicago series (but not "Don Juan") it has a huge, wide, impressive sound, the orchestra seeming perfectly enormous, the hall-sound uncannily natural, the instruments beautifully spaced out, not too far away for good definition, not too close for a natural sense of liveness and space. (If they're too far, there is no clear sense of side-to-side separation; if they are too near, they lose their sense of being in the hall, at a natural distance from you.)

It's clear, as one listens to this, that the large-scale orchestral works of the modern period make first-rate stereo material. Stereo thrives on a big ensemble, on a huge space that reflects and reverberates through the two speakers. Stereo thrives on "concert hall sound." But it also desperately needs solo definition, within that big sound, to help pin-point the presence of the orchestra, to give it size and place in front of your ears.

Not close-up solos, but solos that to the ear are within the orchestra, part of it, solos that are at full orchestral distance. They give a sharpness and definition to the orchestra that helps it to stand out as a body in front of you; they shape it up, as the sharp lines in a drawing shape the space they enclose.

A well scored modern orchestral work, notably Strauss (also Bartok and plenty of others) is full of these solo sounds—individual solos, the clarinets, oboes, drums, celesta, and the rest, plus group solos such as the trumpet and trombone chords, the horn ensemble, groups which are compactly bunched together on the stage and so are easily located in space. It is largely these solo effects, within the orchestra, that create the full orchestral body as an almost visible whole, spread out in front of you.

Earlier orchestral music of the Romantic school isn't as good. It depends more on massed doublings, many instruments playing together, and in such music the pin-point perspective sense is not nearly as pronounced. When, as in Brahms or Tchaikowsky, all the strings play together in octaves, there is virtually no directional sense at all; the orchestra simply emits sound as a whole. Fine—but it doesn't particularly help the special stereo effect of separation-within-a-whole.

Tchaikovsky: Symphony #6 ("Pathétique"). Boston Symphony, Monteux.
RCA Victor Stereo Tape GCS-5†*

Stereo Rating: 3½

From the stereo point of view this recording seems less effective by a good lead than the recent RCA Chicago Symphony tapes under Reiner. That is, the specific stereo advantage, over the same sound in conventional reproduction, is less. Hence the lower rating.

The reasons are not simple, but probably can be assigned to two circumstances, the hall itself and the music. If this is Boston's Symphony Hall, then it is not as good a place for stereo as Chicago's. Not, at least, with this particular miking. The sound seems deader, the "size" of the imagined orchestra is smaller, the immediacy and room-space less convincing. But also to be taken into account is Tchaikovsky's music, which abounds in big, over-all instrumental doublings, has relatively few sharp-etched solo sounds as in more modern-slanted music such as Straus and Bartok.

There are few places in the first movement, for example, where the stereo listener can get a really clear grasp on a slice of the orchestra definitely *within* the larger whole. Most of the music spreads over the entire space and so gives the ear little to work on in the way of pin-point stereo space-makers. The later movements are more effective, notably those parts with heavy percussion and/or brass, where one can grasp more easily at the spatial definition.

This is not to say that this tape is poor, or even ineffective. It's fine—but the RCA Chicago tapes are demonstrably finer still.

(Musically speaking, this is a sharply tailored, very French performance, minus all slush and sentiment, the brass rather heavily weighted, sometimes to an orchestral unbalance. Might be the mike set-up—but I think it's Monteux, too. For those who dislike too much Tchaikovskian weeping and wailing, this makes an excellent performance. For my ear, wailing or no, it is too aseptic, the climaxes not free enough. After all, it *is* Tchaikovsky. . . .)

"Sound in the Round."

Concertape (5").

Stereo Rating: 3

This sounds interesting as a demonstration tape but it turns out to be mainly one of those idiotic (pardon the word) potpourris of railroad trains, jet planes, ping-pong, and what-not that have graced the hi-fi shows for years, fascinating the gadgeteers and systematically driving people away from the more serious and useful values of stereo sound.

An announcer, of course, and he tries hard to be cute. Real salesmanship. The trains and the planes and what-not are supposed to roar across the front of your room, practically blowing you out of it. What they actually do is to make a preposterous U-turn. They roar straight at you in one speaker for seconds and seconds, then just before they hit you head-on, they turn right-angles, roar across four or five or six feet of space between the speakers (not very far for a jet plane)—and then roar, at another sharp right-angle, straight away out of the other speaker. U-turn, indeed!

Best recording here: Outdoor fireworks, Fourth of July. There's a mountain or a hill or something off a ways to the left. Each explosion reverberates marvellously from that hill, and you can literally feel its presence, just as you feel the walls of the hall in the best stereo symphonic tapes. Reverberation is a terrifically effective thing in stereo.

Westminster Wind Library: Beethoven. (Octet Op.103; Octet Rondino in E Flat; Sextet Op.71; Vars. on "La ci darem la mano." Vienna Philharmonic Wind Group.

Westminster XWN 18189

Westminster has a priceless collection of wind music tapes on hand of Viennese music as played by this leading Viennese group. Here are the Beethoven items, played with that soft, sweet, lively Austrian quality that is so unlike the sharper brilliance of French woodwind playing. Only a wind player could tell you what makes the difference—and he would probably deny that there is one. All the same, if you want the best Beethoven, Haydn, Mozart, in this medium, go to Vienna, as did Westminster.

This is early Beethoven, the sort that is superficially "Mozart-like" but in all truth of a craftsmanship that is strictly Beethoven, beneath the sophisticated and humorous exterior. The recording suffers a bit from occasional muddiness, notably when the horns play. Nothing serious for musical ears.

Mozart: Haffner Serenade (#7, K.250). American Chamber Orch. Schalz.
Westminster WN 18164

Not to be confused with the Haffner Symphony, this is an informal serenade of many movements that happens to have been associated with the same Haffner family. The suite is unusually long, and no doubt was good for a good part of an evening or long dinner's worth of background music, in the manner of that day. Background it may have been, commissioned it certainly was, but it's evident enough from the music itself that it must have been listened to, and intended for listening. There are too many neat turns, subtle tricks, lovely melodies, unobtrusive but showy cadenzas, for any sort of background music in our modern sense.

The hallmark of the serenade style in Mozart is a certain looseness of harmonic tension, a tell tale absence of strong harmonic pulls and contrast, and the same in the melodic material. You would never take this music for a symphony, though the idiom is outwardly more or less the same. It is too easy-going, too redundant, relaxed. Deliberately so.

The playing is generally accommodating and the recording is excellent, with plenty of liveness.

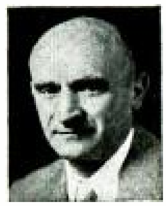
Michael Haydn: Symphony in C. Jos. Haydn: Overture in D. Karl Stamitz: Concerto for Clarinet and Bassoon. R. Schanhofer, clar., Leo Cermak, bassoon, Vienna Orch. Society, F. Charles Adler.
Unicorn UNLP 1020
Michael Haydn: Concerto for Obbligato Viola, Keyboard and Orchestra. P. Angera, vla., Marjarie Mitchell, pf. **Jos. Haydn: Symphony in B Flat.** Vienna Orch. Society, Adler.
Unicorn UNLP 1019

Michael Haydn, the famous Haydn's younger brother, remains an interesting listening enigma to me. The last few works of his to appear on records were dull and almost inept sounding; he surely seemed a small talent (and no real rival of Mozart, who also worked at Salzburg). But these two works, Symphony and Double Concerto, are both graceful and expressive, if far less taut and concise than Mozart's music. Michael matured early, was more brilliant and successful at first than his brother Joseph, who developed very slowly and reached his highest ability only in his sixties.

The Concerto, at least, dates from Michael's early and brilliant years—about the same time, 1760, that the newly restored symphony in B Flat by Joseph was composed. And the Concerto by Michael is more expressive, more varied, though less intense harmonically, than the early symphony of Joseph, and on a somewhat larger scale as well. (But the Symphony, more stereotyped in expression, already shows the latent talent for higher musical organization that was to make Joseph Haydn the greatest musician of his day, some thirty years later. This one antedates the first of his hitherto official 104 symphonies.)

Viola and piano are both nicely played and superbly recorded in the Michael Haydn Concerto—I have never heard a finer viola sound on records. The same chamber music big liveness applies to the other works and is wholly appropriate, except that in the Stamitz work the bassoon and clarinet are perhaps too close and big, even for a chamber-style concerto.

Stamitz was one of the famous family at Mannheim that, with others of the school of Mannheim, was responsible for the major aspects of the "Mozart" or "Haydn" style that we know today. But Karl Stamitz, a fine musician, composed music that now seems extraordinarily aimless and anticlimactic in its melody, harmony and organization. There is a steady series of melodic clichés, grace-



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TRANSISTOR ACTION

(from page 22)

have gathered the following information: (1) The hook transistor uses hook multiplication to multiply the collector current of an otherwise-normal transistor. In this manner an over-all current gain greater than 1 results. (2) In time a hook photocell may be developed which affords greater amplification of light-generated current than even the photo-transistor.

Summary

If the reader has been able to follow the arguments leading to an explanation of transistor action, and has followed the explanation of the various devices, he now has an intuitive feeling for the physical behavior of junction devices, which will help in designing circuitry to use these junction devices in. Described in this article were: Germanium photo-resistor, Junction diode, Junction photo-diode, Junction transistor, Junction photo-transistor, Junction hook transistor, and Hook photocell.

Various semiconductor devices were not described at all, both because of the lack of space, and because in some of these devices the exact theory of operation is not very well known. Not described at all include the following: Point-contact diode, Point-contact photocell, Point-contact transistor, Coaxial transistor, Point-junction transistor (in which one element is a point-contact and the other is a junction), Surface-barrier transistor, Field-effect transistor, Semiconductor relay, Intrinsic region junction transistor, Double-base diode, Junction tetrode, Photo-voltaic cell, Fieldistor, Symmetrical transistor, Zener reference diode, Thermistor, Photo-conductive cell, or Analog transistor.

If the reader wants to do further reading in the very interesting field of transistor action and the physical foundation of semiconductor devices, he is referred to any one of the many fine books on transistors now available, or to the three references given here, which in the author's eyes cover the field quite well. The first is now a classic explanation of transistor action.

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TAPE DISTORTION

(from page 31)

It would seem that a reduction of only 3 db in signal-to-noise ratio is little enough to exchange for frequency response good to 15,000 instead of 7,500 cps. However, there are two counter views: (1) Few if any tape recorders have decibels to spare in the matter of signal-to-noise ratio. Whereas ratios of 70 db, 80 db, and better are commonly found in preamplifiers and power amplifiers, a tape recorder is doing extremely well if it gets up to 55 db. The designer of such a tape recorder fights hard for every last decibel or two in striving for a figure of 55 db, and a sacrifice of 3 db is consequently not unimportant. (2) Operating at -3.6 db bias puts the tape recording process into a region where a slight miscalculation as to input level produces a large difference in IM distortion. On the basis of *Fig.* 2 (or 3) at 0 db bias a 3 db miscalculation in level increases IM distortion only 1.5 per cent, but at -3.6 db bias the same miscalculation raises distortion by 5.5 per cent.

In view of the above two considerations, a recordist or tape machine designer equipped with the necessary test instruments might decide that at 7.5 ips he cannot afford, in terms of distortion and/or noise, the luxury of response more or less flat to 15,000 cps. Instead he may decide on a compromise course, shifting to a bias current intermediate between 0 and -3.6 db. Thus, for example, his choice might cost him only a 1 db reduction in signal-to-noise ratio and a reduction in flat response from 15,000 cps to 10,000 or 12,000 cps. At the same time he would have better protection against the consequences of overrecording than if he used -3.6 db bias.

In order to find this optimum bias point, it would be necessary to draw a number of curves similar to Curve 5 in Figure 3, showing the effect of bias current variations on several frequencies such as 9,000, 10,000, 12,000 cps, and so on. Input level should be kept 20 to 30 db below maximum recording level to avoid saturation. Then for each frequency curve one can evaluate, along the lines indicated in Fig. 3, what flat response out to this frequency signifies in terms of increase in distortion and/or reduction in signal-to-noise ratio because of departure from 0 db current. Based on these evaluations, the bias current can be selected which reflects the individual's concept of the optimum combination of frequency response, distortion, and signal-to-noise ratio within the capacities of a particular machine.

Conclusions

It has been pointed out that IM distortion can be a serious problem in tape recording, especially if one attempts to cut close to the line in maximizing signal-to-noise ratio; that adjustment of bias current can be quite critical if distortion is to be kept to a minimum at high recording levels; that departures from this critical bias point can exaggerate the consequences of excessive recording levels; and that, if the necessary test equipment is available, a definite procedure can be followed to determine first the bias current for minimum distortion and secondly the bias current which at speeds below 15 ips provides the most satisfactory compromise among the requirements of low distortion, wide frequency response, and high signal-to-noise ratio.

A number of judgments are required in determining maximum recording level and optimum bias current. How wide need frequency range be in order to give essentially satisfactory results? How much IM distortion is tolerable? How much for a split second? How much for a few seconds? How much for half an hour?

These of course are subjective judgments. Consequently the determination of maximum recording level and optimum bias current is not a hard and fast procedure.

The writers have heard a number of professional master tapes, one or two generations removed from the original, which, according to indications of a properly calibrated VU meter in playback, were recorded at excessively high levels; the VU pointer frequently kicked to full scale instead of staying below 0. Yet many of these seemingly over-recorded tapes nevertheless sounded clean to the ear. Although IM distortion was undoubtedly present in substantial degree, perhaps it was occurring in such short bursts as not to be disturbing; or perhaps the nature of the musical selection was such as to mask the effects of distortion. On the other hand, the writers have listened to master tapes seemingly recorded at conservative levels, yet less clean-sounding than desirable. Possibly other factors than recording level and bias setting intervened between the original source and good reproduction. At still other times the writers have listened to recordings velvety smooth except for a relatively high background of hum, noise, and tape hiss. They would gladly have accepted more distortion for less background distraction.

The above observations point up the

fact that top quality tape recording is both a technique and a craft. It is advisable to have a technical grasp which enables one to adjust a tape recorder, if feasible, so as to make the most of its capabilities with respect to distortion, frequency range, and signal-to-noise ratio. At the same time, one must have the craftsman's touch, which is based on experience, qualitative judgment, and—the best instrument of all in audio work—an acute ear.

PORTED LOUDSPEAKER CABINETS

(from page 25)

mined almost entirely by the pipe length, the volume V and the port area A having second order effects only. In practice cabinets do not stray too far from a cubical shape for which Planer and Boswell equation for f_r is quite adequate when the inevitable drift in the speaker resonant frequency is taken into account.

Experience suggests that almost any addition to the cabinet interior affects the measured resonant frequency, such apparently minor factors as the relative position of port and speaker or the provision of an isolating shelf between port and speaker shifting the resonant frequency by a few cps. If it is desired to build a cabinet having an accurately determined resonant frequency some final adjustment to enclosure volume or port area must be made after the unit is completed.

The gain in power output at the lower end of the frequency range is determined by, amongst other things, the Q of the enclosure, a factor that it is impossible to calculate with any pretensions to accuracy (Q for a cabinet has the same meaning as the Q for an electrical circuit, being the ratio of stored energy to dissipated energy per cycle). Energy is stored in the enclosed air volume and dissipated as sound or in frictional or viscosity losses in the cabinet and lining structure. The fraction dissipated as sound power is small, structural dissipation accounting for the majority of the losses. Structural losses in an airtight enclosure are largely due to flexion of the chamber walls and are therefore affected by the material used in the construction, but over a fair range of woods experience seems to indicate that the Q falls between 3 and 6. A high value of Q leads to "cabinet hangover" any low-frequency transient having a low-frequency tail oscillation added to the original, giving a soft and rather flabby character to the reproduction. The enclosure Q cannot be reduced to unity or there would be no advantage in using an enclosure, and so the final value must be a compromise to suit personal tastes of the user.

Acoustic Damping

Damping may be added in many ways, the most popular being the use of hair felt, fibreglass or some similar absorbent attached to the walls, though more recently it has been realized that the absorbent material is largely ineffective if mounted on the walls where the air particle velocity normal to the surface is substantially zero. Some consideration of the reason for including the damping will indicate the best position for mounting it in the enclosure.

The added damping really has two duties to perform, it decreases the Q at the resonant frequency to the desired value and it provides sufficient absorption at frequencies above twice the resonant frequency to attenuate the sound output from the port. This is essential if severe interference between sound from the front of the cone and the sound from the port is not to occur. Maximum attenuation to sound energy in the maximum number of modes of enclosure oscillation is provided by a single sheet of absorbent material suspended from the front left and rear right top corners and fastened down to the rear left and front right bottom corners. Maximum attenuation at the basic resonant frequency is given by a sheet of absorbent material across the port for at this point the velocity of the air particles is a maximum.

The thickness and character of the absorbent used across the port is considerably more critical than when it is suspended inside the cabinet. Absorbent material suspended inside the cabinet is effective as a high resistance shunted across the parallel resonant system formed by the box volume and port volume whereas an absorbent diaphragm across the port is effective as a low resistance in series with the effective inductance of the port. Thus an enclosure requiring 15 sq. ft. of half-inch felt attached to the walls will be damped to the same degree as the basic resonant frequency will be by a single thickness of calico across the port.

Both methods of damping may be employed usefully, a length of felt or fibreglass sheet being suspended in the cabinet to deal with the higher frequency modes of resonance, while the basic resonance is dealt with by absorbent material inserted in the port. Provision of a shelf having a depth of one-half that of the cabinet immediately adjacent to the port between port and loudspeaker considerably attenuates the high-frequency output from the rear of the cone, and is generally to be recommended.

A primary requirement for any loudspeaker enclosure is that it should not add too much coloration of its own creation to the outgoing signal. Some idealists might even suggest that it should add no coloration to the signal but this may be misdirected effort. Every room surface, including the floor, door panels, furniture, each hollow vase, and even the brick walls contribute their own quota of coloration to every sound reproduced in the room. Thus it would appear more reasonable to consider the amount of coloration added by the speaker cabinet against the background of coloration added by the room and its contents. If this is done it will usually be unnecessary to worry about a speaker enclosure of normal construction until the piano is removed from the room.

Adequate freedom from cabinet vibration can usually be secured by the use of half-inch plywood or one of the reconstructed wood boards for the body, stiffened either by a triangular corner block of 4-inch side, or half a dozen one-inch square struts across from wall to wall. As a third alternative half a dozen 3 × ¾ stiffening strips screwed "edge on" across the walls in a random pattern can be recommended. Cross bracing strips or 3-inch deep stiffeners both serve as an excellent support for absorbent material, spacing it well away from the walls.

If the ultimate in vibration-free housings is required, a double walled construction of ⅜-inch plywood spaced ½ inch apart and having the space packed with dry sand is excellent. An enclosure built from ½-inch plywood with half-inch insulation board glued to the plywood under pressure is less troublesome to construct in some ways, but gives excellent results.

Shape of Cabinet

Enclosure shape is important, though that importance is not revealed by any design equation. Shapes in which one dimension exceeds the others by a large factor are generally to be avoided. Thus, pipes with or without adequate internal damping have always proved disappointing. Irregular-shaped interiors appear to have some acoustical advantage that is not revealed by current practice in measurement, an advantage that is possessed by the triangular corner cabinet. Corner mounting is generally to be preferred both from the acoustical and domestic points of view, for no other shape permits such a large number of cubic feet to be so inconspicuously concealed.

While internal irregularity has its advantages the opposite is true of the exterior. Each external edge and corner produces irregularities in the primary high-frequency response due to diffraction at the surface discontinuity, and though these irregularities are masked to some extent by the generally reverberant sound they should be borne in mind when considering alternative enclosure designs.

The position of the port with respect to the speaker is not highly critical but there is some slight theoretical advantage in placing the port near to the speaker opening. Klapman has shown that the effective radiation resistance presented to a diaphragm is directly proportional to the number of diaphragms if they are all closely associated in space. Close spacing has the disadvantage of increasing the high-frequency radiation from the port unless precautions are taken to prevent it, but if such precautions are taken the balance of advantage is marginally in favor of close spacing of port and speaker openings.

The subject of loudspeaker housings is one of considerable complexity, but it is of such importance as to justify extended consideration. The present contribution is taken from the chapter on Loudspeakers in a book "High Quality Sound Reproduction" shortly to be published by Chapman & Hall of London, in which the subject of ported cabinets and other forms of speaker mounting are considered in greater detail. All of the illustrations in this article are from the same book.

INTERACTION IN FEEDBACK DESIGN

(from page 42)

the same for all amounts of feedback. This is shown by the dot and dash construction line in *Fig.* 6.

Figure 7 shows the same family of curves normalized to the same level. This gives a better idea how the addition of feedback over a two stage amplifier will vary the response. The curves in *Fig.* 6 and *Fig.* 7 are for the special case where n is unity, or the rolloff point of the two networks identical.

In cases where they are divergent to begin with, some feedback is necessary to bring the 6-db-slope point up to a level of 6 db attenuation. This follows the same general pattern shown in *Fig.* 6

and a relatively simple abac, shown in *Fig.* 8, tells the whole story of interaction for the two-stage case. For this particular case the variation in response shaping can be shown quite simply by using the 6-db-slope point as a reference frequency. It follows a family of curves given at 1 db intervals in the chart of *Fig.* 9.

This is the variation of response shape for the case where both rolloffs are in the

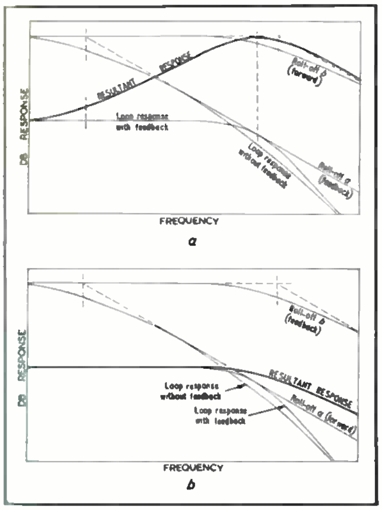

Fig. 10. How to compute the response when one of the rolloffs is in the feedback path. Both cases illustrate the rolloff ratio and amount of feedback, but at (A) the early rolloff is the feedback one, while at (B) it is the remote rolloff.

forward part of the circuit, as represented in *Fig.* 5. In some circuits however, one of the rolloffs may be in the return or feedback path. This means that the over-all loop response can be obtained from the family shown in *Fig.* 9, but the resultant forward gain must be further deduced by subtracting the rolloff in the feedback path from this curve. The method of doing this is illustrated for two cases in *Fig.* 10.

IMPROVED CIRCUIT

(from page 36)

high as 50 μμf for medium-mu and 150 μμf. for high-mu triodes, can cause trouble in some circuits, especially with volume controls, where these capacitances could result in considerable treble attentuation when the volume control is turned down. Thus, for maximum benefit from the tweeter, the set should be carefully checked for such bottlenecks.

Long cables in high-impedance circuits can also be troublesome.

If sensibly utilized, then, the electrostatic tweeter can add the treble end to a hi-fi set at very little cost. Now, if some way could be found to add the bass end at similarly small expense, everything would be fine!

COMING EVENTS

Oct. 1–3—National Electronic Conference, Hotel Sherman, Chicago. For information write J. S. Powers, Executive Secretary, 84 E. Randolph St., Chicago 1, Ill.

Oct. 7–12—80th Convention, Society of Motion Picture and Television Engineers, Ambassador Hotel, Los Angeles, Calif.

Oct. 9—Hartford Symphony in High Fidelity, Bushnell Memorial, Hartford, Conn. Sponsored by Audio Workshop of West Hartford and Gray Research & Development Co., Inc., Manchester, Conn.

Oct. 14–16—New England High Fidelity Music Show, Hotel Touraine, Boston, Mass.

Oct. 15–17—IRE-RETMA Radio Fall Meeting, Hotel Syracuse, Syracuse, N. Y.

Oct. 18–21—Second Mexican High Fidelity Fair, Hotel Regis, Mexico, D.F. For information, write Mario Aguilar, Lopez 43-301, Mexico 1, D.F.

Nov. 8–9—IRE Technical Conference, Town House Hotel, Kansas City, Kansas.

Feb. 7–10, 1957—Los Angeles High Fidelity Show, presented by the Institute of High Fidelity Manufacturers, Los Angeles, California.

Feb. 15–18, 1957—San Francisco High Fidelity Show, presented by the Institute of High Fidelity Manufacturers, Hotel Whitcomb, San Francisco, California.

March 18–21, 1957—IRE Annual Convention and Radio Engineering Show, The Colisseum, New York City.

Apr. 9–11, 1957—Fourteenth Annual British Radio Component Show, Great Hall, Grosvenor House, Park Lane, London, W.1, England. Admission by ticket only, obtainable from the Radio and Electronic Component Manufacturers' Federation, 21, Tothill Street, London, SW. 1.

Apr. 12–15, 1957—The London Audio Fair, 1957, Waldorf Hotel, Aldwych, London, W.C. 2.

ELECTRONIC ORGAN

(*from page 56*)

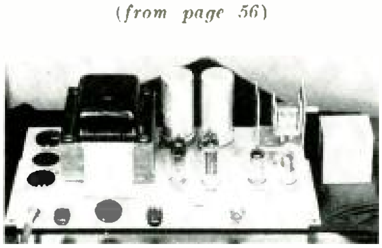

Fig. 18. Electronically regulated power supply and the preamplifier occupy the same chassis and provide interconnection between components.

eventual difficulty with noise which is found with almost every type of pedal-operated potentiometer. The chassis which holds the preamplifier and the electronically regulated power supply for the entire console may be seen on the floor of the console shell in *Fig.* 6 and in a close-up in *Fig.* 18. The expresson control is the radio-type variable capacitor seen on the right end of the chassis in the latter figure; the swell shoe is connected to it mechanically so that operation of the shoe rotates the rotor.

The variable capacitor is part of a capacitive voltage divider. The shunt leg of the capacitive divider is the capacitive input of the 6AU6 stage with capacitive feedback. The 150-μμf fixed capacitor feeds signal of opposite phase from the 6BF6 cathode circuit so that at minimum setting of the variable capacitor a bucking or bridge balance condition is approached. This bucking gives the circuit a greater range of control than the ratio of minimum to maximum capacitance that the variable capacitor would otherwise provide. The 6AU6 feedback

Fig. 19. "Tone Cabinet"—loudspeaker system with self-contained power amplifier—suitable for home use.

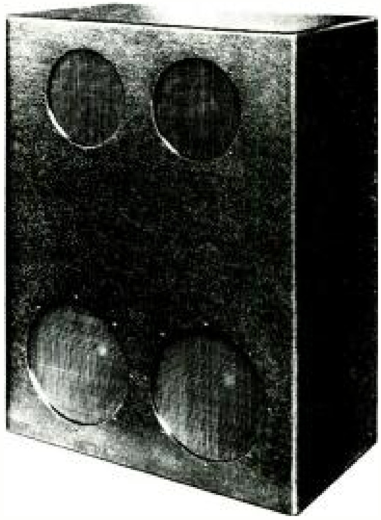

Fig. 20. Designed for installation in concealed location, this utility tone cabinet is equipped with a 40-watt amplifier.

capacitor is multiplied in value by the gain of the stage and this lowers the grid-circuit impedance so that a recommended value of grid resistor may be used without loss of 32-cps signal. Output of this stage is fed through cables to the speaker units.

Three loudspeaker units or tone cabinets are available for use with the Artist model, though qualified people can sometimes make installations with nonstandard speakers. The Model 110 unit, shown in *Fig.* 19 contains a 15-inch woofer and a 10-inch "tweeter," with a 20-watt power amplifier. Sound radiates upward. Model 119 has the same specifications but has a utility finish for concealed locations and propagates sound horizontally. The Model 159 unit, shown in *Fig.* 20, also in utility finish for concealed locations, has two 15-inch and two 10-inch speakers, with a 40-watt amplifier. Any number or combination of speaker units can be used, depending on the location, since each contains its own power supply and its signal input is simply bridged across the output line from the console.

SEMICIRCULAR HORN

(from page 29)

Rigidity sufficient to completely eliminate horn wall sound absorption (i.e., zero vibration and 100 per cent reflection is hard to achieve. Costs, ease of assembly, volume, and final weight dictate the use of reasonably priced and readily worked, semi-light materials, usually ¾-in. plywoods. Concrete or sand-filled walls have been recommended but are hardly attractive. Phelps[14] found attenuation of several db in wood walls partly reducible by heavy shellacing.

Definitely rigid, non-vibrating, non-absorbent material, could only consist of metal of appreciable thickness,[4,5] with smooth, gently curved walls as exemplified in brass instruments. Perhaps there will be adoption of the light-weight moldable fiber-glass laminates with low inherent resonance such as is used in small boat construction. This might allow construction of a more accurate continuous curved flare of true exponential form. Thick-walled, massive, one-piece plastic material, heavily braced, as used for radio consoles or auto fenders, is another possibility. At the New York 1955 audio show, massive rigidity using a 1½-in. plywood mounting baffle 4 × 8 feet across was installed for binaural demonstrations by one record maker.

The Semicircular Exponential Horn

In an attempt to have a back-loaded horn which is a reasonable facsimile of a smoothly curved, rigid-walled, musical horn, the semicircular back-loaded exponential horn was designed to eliminate or minimize some of these difficulties.

Referring to photographs, one notes a smoother air-column path in the gently curved horn than in other designs in use. There is less chance of standing waves from reflections. Since sound tends to follow an arced surface without undue loss of energy, the simulated semicircle should cause minimal horn wall absorption and inhibition of harmonics.

We are familiar with the whispering galleries or arches of churches where the soft voice is clearly carried across the width of the nave to an opposite wall. Similarly, a semicircular horn induces circumferential travel. In this design the outer arc of sound travel is an ample 8 feet within an over-all 3½ × 4 foot plane.

A true exponential flare is incompletely attained. The five component sections in the horn (see photos) are straight-sided with 45-deg. turns instead of 90 to 170 deg. conventional turns. For part of the cross-section the horn acts as a cone. Advantage of the cone flare lies in the absence of a sharp cutoff and a gradual rolloff below the equivalent cutoff of an exponential flare.

The standard exponential horn formula was used in constructing our model.

$$S_x = S_1 \varepsilon^{mx}$$

where S_x = cross-sectional area at point x
S_1 = " " " " throat
ε = 2.72 (Naperian base)
m = flare constant that determines cutoff
x = distance from throat to S_x or cross-sectional area

4 W. D. Phelps, "Vibration and absorption of sound in horn walls." *J. Acous. Soc. Am.*, 12: 68, 1940.

5 Sound energy of 20-40 watts passing through a French Horn, as usually blown, would induce tremendous vibration of its thin brass wall.

The horn has a 32-cps cutoff, below the speaker cone resonance of 35. A tapered "mouthpiece"[16] (or speaker chamber) leads into a roughly square throat of 100 square inches to minimize harmonic breakup of low fundamental tones (see Table II). With a constant exponential flare and mouth, increasing the throat area will help smooth out bass response by separation of successive maxima obtained in bass response curves. The cross-sectional area of this horn doubles every 24 inches and has flare rate of .028.

The mouth area had to conform to a reasonable (for me) size and this was determined as 22 inches square (480 s.t.) in the plane of the speaker baffle mount. If truly exponential, this mouth represents a cutoff at 125 cps, but since the horn has some acoustic qualities of a cone, rolloff to 30 to 40 cps is present.

The axial sound path is 5½ feet long and corresponds to a half wavelength at 100 cps. Consideration is due to the 8-foot path length along the outer arch which should permit propagation at frequencies of 60 cps and lower.

Some experimental geometry was needed in "bending" this horn in a semicircle to prevent inside-curve compression of the air column. The square cross-section for the throat had to be modified in favor of a trapezoidal pattern. Only in this fashion could a final mouth outline avoid a triangular pattern which would restrict the mouth circumference.

For the horn walls, over 60 square feet of plywood was used. It was constructed of ¾-in. 5-ply, heavily braced at joints, splined, and glued. All interior joints were spackled to smooth out the curves. The interior received three generous coats of shellac to further decrease sound absorption in the gently curved horn path. The speaker baffle board was air-sealed with caulking compound to the speaker chamber. It will be seen that the finished cabinet envelope (see Fig. 3) enclosed an air space between its walls and the enclosed horn. It was decided not to fill this dead space since no additional absorption was necessary to deaden the horn walls.

A corresponding alteration of the junction between speaker chamber and throat was made. It will be noted that beginning with the baffle mount, there is gradual taper up to the throat to avoid breakup of tones below 50 cps.

From another viewpoint, the five conjoined truncated sections simulate a manifold exponential horn. For example, the throat area of one section matches the mouth plane of the preceding section. Such a manifold horn will accept a wider frequency range.

The finished horn is a compromise as are most others in use. It deviates from the ideal smoothly-flared circular exponential horn as follows:

1. It is roughly square in cross-section (trapezoidal in many planes) instead of circular.
2. It is conical in each of five major sections, short-cutting the minimal increments that would effect a smoother exponential curve.
3. It is a series of roughly square pyramidal sections.
4. It is a finite horn angulated at 45 deg.
5. It approximates specifications for a 125 cps cutoff.

To feed one's vanity these compromises could be vigorously defended as less drastic deviations from true horn dimensions than most existing designs—corner type, folded design, and so on.

In actual practice the theoretical considerations are amply substantiated. With an audio signal generator our semicircular exponential horn has beautiful bass response down to 40 cps. Below this, distinct wave pressure causing palpable pants-leg flutters, was experienced. The rumble in this bottom range, with a good changer and pickup combination, is distinctly perceptible.

The audio components terminating in the back-loaded horn consist of the highly sensitive Craftsmen C-1000 with phono, television and professional tape deck feeding a Fisher 30-watt amplifier, with a damping factor of 29 and a Stephens 15-in. coaxial 206AXA speaker with further damping from a 7½-lb. magnet. This bass-restricting effect was offset by the large air-mass loading of the woofer. Originally housed in a bass reflex cabinet of recommended dimensions, the speaker's bass response had been discouragingly weak. After installation in the new enclosure, with back loading of the woofer, we noted:

1. Flat to slightly enhanced bass response audibly smooth down to 40 cps (in spite of combined amplifier-speaker magnet damping).
2. Undistorted reproduction of tympani, bass viol, tuba and trombone tones. Turntable rumble was clearly audible though not exaggerated.
3. Some attenuation around 300 cps, possibly from phase cancellation.
4. Mild reinforcement at frequencies from 500 to woofer crossover at 1200.
5. Non-directional radiation up to 200 cps, from the horn mouth—22 in. square.

Repeated compliments by critical listeners, musicians, engineers, and rabid hi-fi enthusiasts on the clean, low tones, have happily confirmed the value of this type of back-loaded low-frequency horn. In floor space requirements and coaxial propagation of the audible range it satisfied conventional standards. All sounds come from the front speaker plane with no divided-presence effect.

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[16] The lower range brass instruments use tapered mouthpieces while trumpets use a cup mouthpiece to induce propagation of harmonics.

AUDIO ETC

(*from page 78*)

itself, in every country. Elgin discovered the Parthenon, falling to pieces after having been used to store ammunition, and handily carted off a considerable hunk of its outer decorations for the British Museum, where they still repose. The Greeks haven't asked for them back—yet. Suddenly, people stopped taking apart the French cathedrals and began, slowly, to put them back together again—an unheard-of proposition.

And because they put them together, or shored them up, with the express idea of *bringing back the past*, whereas previously, all construction had been strictly to add new to the old, to rebuild, in new styles, because of this utterly changed attitude, we have today a fabulous collection of monuments, instead of a lot of useless and crumbling real estate. And let me tell you, whereas in earlier times a useless, old-fashioned Gothic cathedral might bring X dollars in local money as a stone quarry (no small sum and definitely worth it under the circumstances) the same Gothic cathedral today, restored and publicized as a tourist and artistic attraction, subjected to nightly "Son et Lumière" shows, early show and late show every evening, easily brings in a far larger fortune in plain cash, at least 100X dollars a year shall we say, and this in addition to the pride and patriotism that the restoration of these superbly beautiful monuments generates, and the pleasure and awe produced in pilgrims from all over the world.

So there we are. Junk heaps until the recent past, now objects of marveling and wonder to every visitor. How could such incredible changes in *thought* ever take place? *How long will it last?* Will another hundred years bring us around to where the Mona Lisa is just a smudged piece of canvas and the cathedral of Chartres an encumbrance to helicopter traffic? Could be. Has happened often enough before. Indeed, if you will look at it in the long view, our present enlightened historical interest, dating back only a hundred-odd years, is a tiny segment of our whole known past history. Five per cent of the time since Christ, less than two per cent of the time since our history is known continuously in writing. Anyhow, the new and unexpected art of restoration, of returning the old where it once was, has developed mightily in these years and has profited from huge outlays of cash, both private and governmental. The French State has bought up dozens and dozens of estates it once got rid of for petty cash; the huge forests that were cut down for more petty cash are now built up again—as historical monuments and as parks. The whole process of decay and change has been reversed; cunning and clever Gothic rebuilders have put back together again the fallen arches and the crumbling towers, patient scholarship has traced every bit of information to pin down the exact shape and size and decoration of destroyed art work; whole slices of church, hunks of chateau, acres of Roman arena, have been painstakingly rebuilt according to the original—or what is now thought as the "best" period when, as in many cases, the buildings are a composite and harmonious hodge-podge of construction, from many times. And so—to "Son et Lumière."

Son et Lumière

These Sound and Light spectacles are the newest wrinkle in historical entertainment and they represent some of the finest—and the worst—stereophonic reproduction I've heard, in a new dimension, the vast spaces of the out-of-doors. The technique of the shows is basically simple enough, and, it would seem, once one has seen and heard it, the obvious and inevitable thing to do. Take a bit of the movies, some of the art of stage lighting, add to these the technique of radio drama and TV presentation, using a narrator, or many, assigning character roles, dialog and all the rest as per a standard modern script. For a stage set, visually, take your audience right to the Subject itself, whether church, chateau, or even an island in the ocean as is done nightly at Cannes on the Riviera. Take advantage of the whole modern technique of outdoor floodlighting, but make it dynamic. Instead of a static, motionless, continuous lighting, apply the theatrical lighting principle of constant change, of mood-lighting, spotlighting, of lighting for dramatic effect —wars, fires, mysteries—and all of this on a vast scale, outdoors. Spot the countryside around with mammoth search lights, hidden in trees, on the roadsides, in niches, on rooftops, inside rooms and outside on battlements. That is the "Lumière" part, and it is truly spectacular at its best.

And for the "Son"—fill the countryside with loudspeakers of enormous power. String your power lines into steeples, towers, dungeons, run them a half mile or so down a hillside, up to a mountain peak, spot your huge transducers in the distant corners of vast chateaux, so far apart that the time-lag is far too great to run more than one speaker at a time on a given audio circuit. (One show I heard had the two towers at opposite ends of a huge cathedral spouting the same recorded dialog, from the same channel; the two together are unintelligible, so great was the time-lag.) Bring all your far-flung audio lines together at some unimaginably great powerplant of sound (or so I imagined it) at Headquarters, where the audio signals—many of them at once—originate. A battery of switching facilities and a multitude of recorded tracks does the rest. Combine with the Lumière, the lighting, and you have your show.

It's not easy to figure out how many tracks are in operation in one of these enormous outdoor presentations, for there is much switching from tower to tower, from ground to sky, from a half-mile to the right to a half-mile to the left. I'm not exaggerating by much. I counted five tracks at one show, or so I decided at the time; but quick switching might have accounted for a few of them. I didn't ask. I was too engrossed in the fascinating drama unfolding in Light and Sound before my eyes and ears.

The programs are a sort of cross between radio, where all the background and action is in terms of sound, and TV, where real people and changing backgrounds are used together with sound. Here, we had only the buildings themselves, in all their complexity and in all their acres of ramification, plus the gardens and parks and rivers and forests surrounding them. But by means of lighting and radio-style sound-suggestion, the story of each great establishment was told. King So-and-So was foully murdered in a small room at the top of this castle—and that very room suddenly lights up from inside in horrid red light. Marie de Medici, mother of a whole family of French kings, added this beautifully lit-up gallery of two stories, poised above a reflecting river on stone arches. Chenonceaux. On the famous hilltop of Vezelay, where for centuries upon centuries vast armies of pilgrims came to worship the remains of

Mary Magdalene, the great cathedral once caught fire inside, and something like a thousand people were burnt alive in the ensuing panic. We see the church itself, gory in pulsing, red flames of light—and we hear the ghastly sounds of panic. That's Son et Lumière.

At this same Vezelay, built on top of a high, round hill, I heard the most impressive of all the Son et Lumière moments, the preaching of the Crusades by Saint Bernard, who spoke from that very spot—lit up for us on the side of the hill—to an enormous mass of hundreds of thousands of people swarming about the lower slopes. Now, as then, the place makes a natural amphitheatre; we can imagine easily enough that the great crowd could actually hear Saint Bernard, without benefit of amplification. And as we hung over the high terrace railing, looking downhill into the beautiful valley below in the moonlight, the voice of Saint Bernard came to us from over to the left, around the corner of the mountain, from exactly the same spot it had boomed once before, in the year 1146, the 31st of March. More than 800 years back.

And as he spoke, we suddenly began to hear the crowd, down below us. In the distance, in the background far down the valley, and then, startlingly, suddenly, right below us in the near trees. We could not spot the loudspeakers nor could we form the slightest conception as to how near or how far away they were. A nearby woman's voice, close-up style, complained to her husband about all this fuss over a Crusade—Jerusalem, when she'd had to get up at the crack of dawn and now they hadn't a thing to eat and you couldn't move an inch for the crowd and when were they going to get out of this mess and home to a warm dinner. . . . You heard other voices, mumbling further away, from no particular place; but gradually there was created the most perfect and truly stereophonic effect of the vast crowd of people, lodged down below us, stretching far back to the little town whose church we could see, lit up, a mile or so away below us, lapping up the hill almost to our feet.

And as Saint Bernard preached on the need to save Jerusalem from the frightful infidel, the crowd below began to respond, to take fire, to excite itself. Gradually the shouts of approval, the subdued cheers, the murmurings grew louder, and finally, my hair simply stood on end; for there below us, invisible in the night but appallingly audible, were all those thousands of people, shouting and yelling their heads off, spread out for thousands of yards on each side and below and ahead. It was one of the most exciting bits of drama I'll ever hope to experience and, of course, the final poignancy was, as in all of these Son et Lumière shows, that it actually happened and *right there*, on that very spot, in 1146.

So you can imagine the possibilities in this new dramatic medium, when well used. I saw a few clinkers, and the shows tend to be a bit wordy and too patriotic; the music is mostly nil, or as at Vezelay, a sort of pretentious modern stuff that leaves me with a bad taste in my ears, so to speak. Nevertheless, the good far outweighs the bad, the sense of history in film-TV-radio format with a new twist is too good to miss, in spite of such excursions into bad taste as the invasion of the great Vezelay cathedral by a monstrous and hideously loud recorded choir and orchestra, that desecrated the sanctity and quiet of a sacred place even for me, who am not a Catholic. The artisans of "Son" in stereo form are very good at outdoor work but they miscalculated horribly in the special

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indoor double liveness to cope with rather than an occasional echo from a nearby mountainside.

It remains to tell what little I know of the technical side. (Editor: write in yr. best French to the French authorities and see if you can get a technical article on the subject. It would be interesting. I'll help with my French, such as it is.) As I say, the sound was on many tracks, and for the best of me I couldn't decide just how many—that was a sign of very good dramatic technique. Chimneys, towers, windows, hillsides spouted sound, and the volume, with no indoor containment to reinforce it, was positively enormous. It's a well known phenomenon, at least to me, that sound reproduction out of doors shows up the weaknesses in sound equipment (the "loudspeaker" sound) far more than indoor reproduction. Knowing this, I can report that the French sound was on the whole remarkably good. The sibilants shook whole hillsides, the basso profundo should have knocked down more than one ancient tower, and probably will. Wide range sound, in kilowatts.

The Platypus's Puss

The Loudspeakers? That's the big thing! There is a strange speaker device, used everywhere in France, that has me, to put it aptly, quite baffled. It comes in many different sizes, all relatively small, and it looks like a duck's bill. Or better, a duck-billed platypus, with a hole or port at the place where that strange egg-laying mammal has his little mouth.

How it operates I do not know, nor can imagine, except that inside this weird, bill-shaped affair, which points up and outward like the Platypus's puss, is evidently a small but highly potent driver. I could see one, in a small and close-to restaurant version, but couldn't figure out whether it was a standard cone speaker or not. In the smaller size, for restaurant background music, the whole platypus affair wasn't more than a foot or so long, bill-shaped. You'd never guess it was a loudspeaker. In the huge and potent outdoor size, installed on the tops of towers, in trees, on cliffs and islands in lakes, the platypus bill was still relatively small considering the volume of sound that was produced. At a distance, these speakers looked to be about three feet high or maybe four, and perhaps a foot and a half wide at the most. On cathedral tops they stuck out into space like so many extra gargoyles and indeed, it took me a long while to locate them, so nicely do they fit in with their fantastic surroundings.

After the Saint Bernard performance at Vezelay I couldn't resist a search, the next morning in broad daylight, to see whether I could find where that incredible stereophonic crowd had actually come from. The illusion was so good that at night it was utterly useless to try to estimate distances. I did spot the only structures in the landscape that could conceivably be loudspeakers—they had to be *somewhere* on that bushy, green hillside—but these were more baffling than ever. All I could see were several perpendicular, beam-like structures, like upright wooden planks but in metal; they couldn't have been more than a foot wide and maybe seven or eight feet high, as seen from the rear or downhill side. (They were utterly inaccessible for a closer look.) They didn't look in the slightest like a loudspeaker, not even a platypus one. But there was nothing else on that hillside that by any stretch of imagination could have reproduced sound, and there were the proper sort of cables running to them, down from above. They were, in fact, spaced apart at huge distances, though not exactly measured in miles; I suspect, too, that they were directional to some extent, for such a huge volume of sound could not have been spread out evenly in all directions. (But more of that in a moment.)

Mystery. I had at least seen a similar kind of speaker installation in many French churches, a thin, vertical beam-like enclosure fastened inconspicuously on columns as part of the sound reinforcing system. These were simply four or five small cone speakers mounted one above the other, without much baffling. Good enough for speech reproduction. But I could not explain the larger outdoor "column" enclosures with their apparently enormous bass.

In all the outdoor Son et Lumière shows I didn't spot one single speaker *box*, nor any indoors either, and I saw only a few of the old-fashioned flared exponential horn type of installation. The platypus enclosure and the tall, thin beam type reigned supreme, wherever there was sound. I might add that, though I got to see and hear five complete Son et Lumière shows, there are many others now, all over France, and more are being produced—like so many movie or TV productions—every day. It's a brilliant idea, both in sound and light. The programs I heard were recorded by Philips of the Netherlands (Epic Records in the U. S. A.) and to Philips a batch of congrats for a good job.

And so, an afternote, illuminating an aspect of Son et Lumière that struck me rather forcibly as I thought of the local inhabitants of these happy regions where, every night, Reproduced Sound thunders away over the countryside for mile after mile! Here is a clipping that caught my eye in a French paper. Translation by ETC.

> (Headline:) "Bruit . . . et Lumière" a Vezelay. ("Noise . . . and Light" at Vezelay.)
>
> "A certain number of the inhabitants of Vezelay have presented a petition to the President of the Council of the region. After having rendered homage to the intentions of those who wished to add value to this magnificent historic site, they deplore the manner in which the enterprise "Son et Lumière" at Vezelay has installed certain highly potent loudspeakers in the immediate neighborhood of numerous inhabitants, of hotels, a hospital and a boarding house. They add that the function, every evening from 9:30 until well after midnight, of these loudspeakers troubles the repose and the sleep of the population in an insupportable manner, at an unseemly hour; that it should be easy to allay the trouble by removing certain parts of the outdoor program, notably cries, excess of loud music, noises of cheering and shouting; that the departure of the audience, especially after midnight, in a long series of headlighted automobiles, adds an extra unpleasantness and extra noise most prejudicial to the peace of mind of the inhabitants . . . and the petitioners suggest that at least, instead of the present two shows per evening, seven days a week for four months, the program be reduced to a single nightly show and perhaps only two or three times a week."

And so, 800 years later, Saint Bernard and his thousands of the Second Crusade carry on stereophonically, night after night, to the distress of many a present-day Frenchman who merely wants his sleep, as of 1956. History? To these people it's just an awful lot of noise. A wonderful show, though, if you're not trying to sleep.

AUDIO CLINIC

(from page 59)

the cathode, has a positive voltage applied to it, electrons will be attracted to it. They will flow off the plate, through the power supply which is used to put this positive voltage on the plate of the diode, and back to the cathode whence they started.

The diode has a very useful property. Let us assume that a.c. is applied to the plate of the diode. During one half of the cycle the voltage will be positive with respect to the cathode, and the tube will conduct as outlined above. When the cycle reverses, however, the plate will be made more negative with respect to the cathode and so the tube does not conduct during this second half of the cycle. Although the tube is conducting only half the time, it has converted the a.c. into d.c., something necessary in power supplies where d.c. must be supplied to a piece of equipment.

Fuses Blow

Q. The line fuse in my amplifier is constantly burning out. What can I do to service the amplifier myself? H. Carleton, Brooklyn, N. Y.

A. This condition indicates one of two things: either the fuses you are using to replace the original one are the wrong size or the primary of the power transformer is for some reason drawing too much current. The current rating of the fuse must be greater than that of the average current the amplifier draws, since the amplifier's transformer, when the switch is first thrown, must build up a backvoltage. During that instant, a very large current will flow, large enough to burn a fuse out if sufficient compensation in its size is not made. One type of fuse is available which will pass a momentary overload but if the overload continues it will blow out. This fuse is called "Slo-Blo." For the exact size of the fuse, consult the instruction manual.

Having made sure that the size of the fuse used is correct, we can then proceed to the problem of why the transformer is drawing too much current. First, remove the rectifier tube and place a new fuse in the circuit. Turn on the equipment and see whether the fuse blows again. If it does, then it may well indicate that the transformer is no longer usable or that something has happened to the filament supply or to the high-voltage connections on the rectifier socket. In one instance, someone had spilled some liquid into the amplifier, which arced across the rectifier plate terminals of the socket. We scraped it away with a knife and the unit functioned normally. If the fuse does not blow, it may indicate that the rectifier has shorted internally. Replace it and try again. If the fuse goes, it probably indicates that one of the filters has shorted or, in certain types of amplifiers, the plate bypass capacitor in the output stage has shorted. Remove one side of each of the various capacitors, one at a time, and try again to see if the fuse still goes. If all of this is done and the trouble still persists, then it may be that the primary of the output transformer has shorted to its core. To test for this, disconnect the B plus lead (red) and try again. Another trouble, though far less common, is for the coupling capacitor or capacitors which feed the output tubes to short. This will cause the output tubes to draw too much current, which can then cause the primary to draw excessive current, possibly enough to blow the fuse.

Industry People...

Jay Carver, whose background in audio runs the gamut from retailing to manufacturing, has been promoted to manager of advertising and sales promotion for Electro-Voice, Inc. . . . **Thomas O. Moore,** formerly engaged in experimental and research work on recording systems for Naval Research Laboratory, has joined the staff of ORRadio Industries, Inc., as chief electronic engineer . . . **John Hilliard,** chief engineer of systems for Altec Lansing Corporation, recently visited a number of aviation installations; purpose of the visits was to assist in the development of high-intensity sound instrumentation when microphones are operated at extremely high temperatures or high altitudes . . . **Gail S. Carter** has been appointed sales manager of Pentron Corporation; **Irving Rossman,** Pentron president, will retain the post of director of sales . . . **Charles S. Stodter** is the newly named executive secretary of the Society of Motion Picture and Television Engineers. He succeeds **Boyce Nemec** who recently resigned to open a management consultation service . . . **Robert Reiss,** sales manager for Eastern Electronic Sales Corporation, announces that due to increased business the firm has opened new offices and showroom facilities at 288 Grand Ave., New Haven, Conn. . . . **Russell J. Tinkham,** with Ampex since 1952, has been named manager of the company's audio custom engineering department . . . **Milton D. Thalberg,** president of Audiogersh Corporation, recently announced the opening of the firm's new executive and sales offices at 514 Broadway, New York 12, N. Y. . . . **John S. Boyers,** one of the founders of Magnecord, Inc., and most recently associated with National Company, Inc., as chief engineer for magnetic memory and audio devices, has been appointed manager of engineering for Bell Sound Systems, Inc. . . . **Frank H. Slaymaker,** formerly chief engineer of the special products division, is the newly named manager of electroacoustical research for Stromberg Carlson; his former spot is being filled by **Rudolph G. Miller** . . . **George Silber,** president of the Institute of High Fidelity Manufacturers, announces the appointment of **Walter Stanton,** president of Pickering & Company, Inc., and **Charles Fenton,** head of the company bearing his name, as secretary and treasurer of the Institute. They are succeeding **Vinton Ulrich** who recently resigned the dual post of secretary-treasurer . . . **Jack Gilbert,** head of Jack Gilbert Associates advertising agency, announces the appointment of **Richard Felix** as account executive, specializing in electronic and high-fidelity accounts. For the past three years Felix has been advertising manager of Radio and Television Weekly . . . **Benjamin H. Ballard, Jr.,** was recently named to the post of sales manager for consumer products by National Company, Inc.

ADVERTISING INDEX

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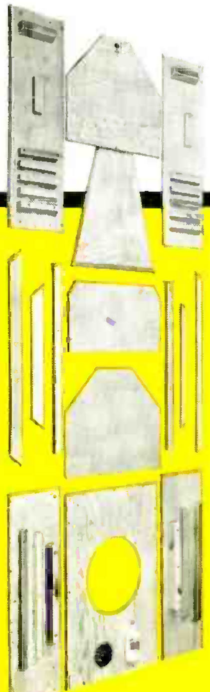

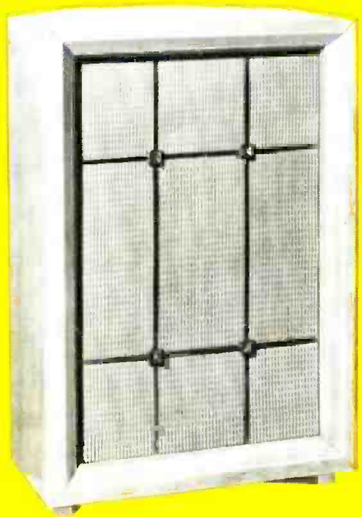

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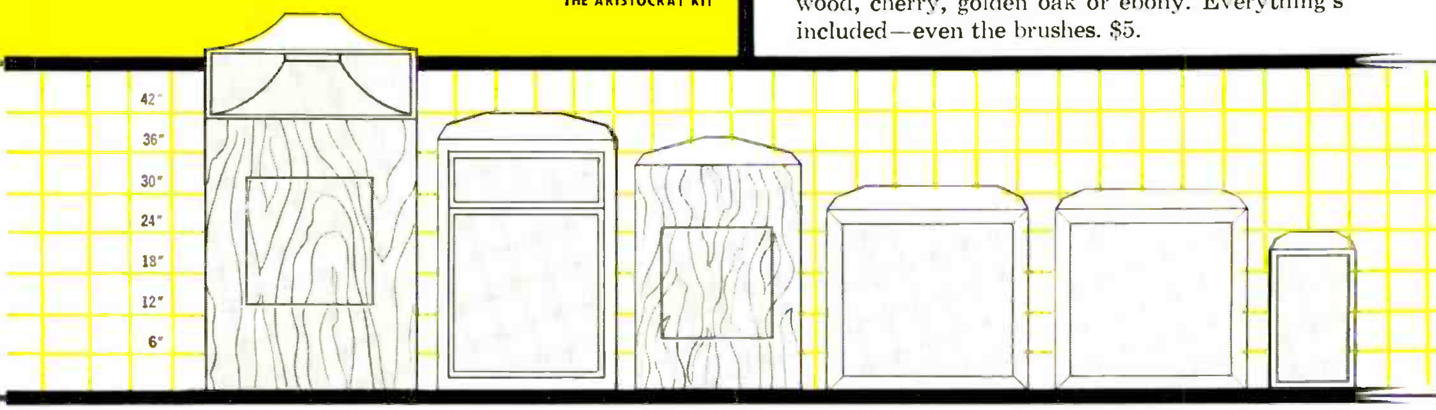

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