it CAN be ATTRACTIVE - See page 30

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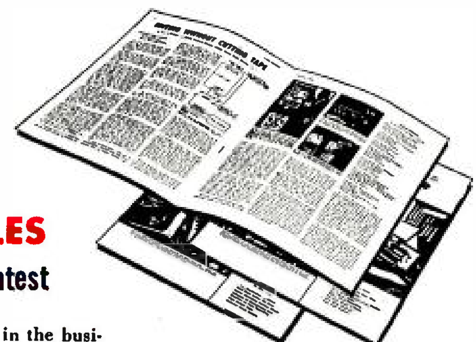

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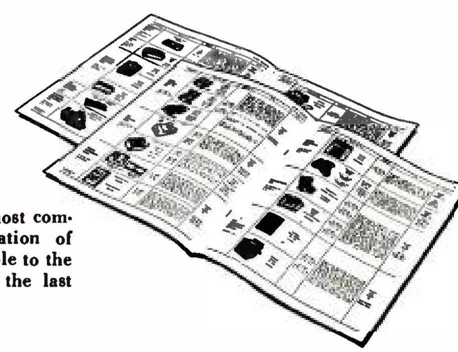
Contest winners include entries from 11 different States, as well as from Canada and Switzerland. The 20 best articles, which were awarded cash prizes totaling $1400, will be published in the pages of Audio Record. The information thus made available to the industry will be of real value to sound recordists everywhere.



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Each year, Audio Record brings you a complete, up-to-date listing of all makes and models of tape recording machines—with conveniently arranged price and performance data. This directory issue, published in September, is the most complete and authoritative compilation of tape recorder information available to the industry. Over 75,000 copies of the last issue were distributed.

. . . plus many other articles of timely interest to the sound recordist

Audio Record keeps you well informed on all the latest trends and technical developments in all phases of tape and disc recording. It is not an advertising publication and its sole purpose is to render a needed and useful service to the industry.

Audio Record, published 8 times a year, is currently distributed free of charge to a request mailing list of about 35,000 sound recordists in broadcasting stations, recording studios, schools and colleges throughout the country.

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CONTENTS

NOVEMBER, 1953 Vol. 37, No. 11

Audio Patents—*Richard H. Dorf* 2
London Letter 8
Audiology—*W. R. Ayres* 12
Editor's Report 16
Make Your Own Woofer—*Curtiss R. Schafer* 19
Housing and Finishing Equipment—*William H. Burke* 20
The Piano—*Part II—Albert Preisman* 22
Handbook of Sound Reproduction—*Chap. 14—Edgar M. Villchur* 25
Audio Fair and AES Convention 29
it CAN be ATTRACTIVE 30
The White Powrtron Amplifier—*Stanley White* 32
Audio ETC—*Edward Tatnall Canby* 34
Record Revue—*Edward Tatnall Canby* 38
New Literature 43
Book Review 49
New Products 50
Technicana 57
Radio's Master Reports 70
Industry Notes and People 71
Advertising Index 72

COVER

This montage picturing installations made by Kierulff Sound Corporation, Los Angeles distributor and custom builder, just goes to show how the home music system—even including television—can be made to fit into the general decor of the home. Note that there are no unsightly wires, and that each of the systems appears to fit into its surroundings. Æ's pages are always open to individuals and professionals who have attractive and novel installations that might lead newcomers into the hi-fi fold without upsetting decoration plans.

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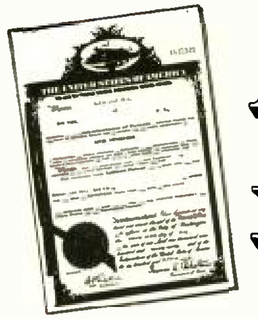

AUDIO PATENTS

RICHARD H. DORF*

As many readers know, the writer has done considerable research in the field of electronic musical instruments. One product of this research has been articles such as the one on the Hammond Chord Organ which appeared in the September issue of Æ.

Another product of the research is a large collection of U. S. Patents covering electronic music. Such patents, whether or not they describe circuits and devices which have reached the commercial market (most have not), serve the researcher-designer with ideas, schemes, germs of solutions, angles of approach. He may pick the brains of a hundred inventors for the kindling which his own match may set afire with a new and brilliant design. Or, if he is not an original designer by skill and temperament, he may use the same hundred inventors' ideas to piece together his own musical instrument with individual circuits lifted bodily from the patents.

A good deal of mail has indicated the interest in electronic music. To serve readers in that category, this month's patent article gives a selected list of patents on the subject. They are arranged in groups, covering the important aspects of electronic music. Almost every patent, however, treats of more than the subject under which it is listed. The patents are listed bv year, to give the reader an idea of their "freshness."

In each category there are listed first what the writer considers the most interesting and useful, with a brief descriptive comment on each; following that others, less important are listed by number only. To conserve space we have not followed standard bibliographic procedure, but give only the information on each patent likely to convey a message to the reader.

A copy of any patent may be obtained for 25¢ from The Commissioner of Patents, Washington 25, D. C. The large public libraries also contain excellent patent files, as well as copies of the Patent Office Gazette, issued weekly and containing a summary of all patents issued.

Tone Generators

1931

1,817,704. Phonograph records contain tones, with pickups keyed to reproduce them.

1,823,716. Charles J. Young, assigned to General Electric. Polyphonic instrument using heterodyne principle.

1,823,724. Wendell L. Carlson, assigned to GE. Heterodyne instrument with r.f. harmonic filters to select tone structure.

1,837,144. French inventor. Heterodyne instrument capable of plucked-string effects.

1932

1,865,428. Same inventor. Damped occillations started by capacitor discharge give piano-harp effect.

1933

1,937,021. John Hays Hammond, a prolific inventor, not connected with Hammond Organ. Photoelectric instrument.

1,937,389. Nicholas Langer, well known primary worker with relaxation-oscillator organs. A gas-tube design.

1,940,093. Bell Labs. Heterodyne instrument with pitch controlled by a "trolley-car motorman's" handle.

1935

1,993,890. Langer. Monophonic neon-lamp instrument.

2,014,741. Photoelectric organ, timbres generated directly.

2,017,542. Langer. Synchronizing octave strings of neon oscillators from a master oscillator.

1936

2,035,238. Langer. Plucked-string effect with neon lamps.

2,039,651. Langer. Improvement on 1,993,890, allows fine tuning of individual notes.

2,044,360. Langer. Another method of syncing neons.

2,046,463. Dr. Winston Kock, assigned to Baldwin, whose organ he mainly designed. Various neon oscillators including inductors.

1937

2,070,344. Harry F. Waters. Neon instrument with continuous-tuning device mounted on replica of a violin neck.

1938

2,128,367. Kock. Thyratron octave strings.

1939

2,148,166. Tones generated by cathode-ray tube.

2,171,936. More of the same by the same inventor.

1940

2,185,635. Kock. Improvement on 2,128,-367.

2,221,097. James A. Koehl, v.p. of Central Commercial Industries, maker of Lowrey Organo. Photo organ using film strips which start moving on keying, then rewind when key is released.

1942

2,276,389. Laurens Hammond. This is the organ man. Octave divider strings using hard (vacuum) tubes as relaxation oscillators.

2,293,499. Western Electric. Instrument using just rather than tempered scale but allowing playing in any key. Interesting discussion of temperament.

1949

2,472,595. J. T. Kunz, Schulmerich (important electronic chime manufacturer). Capacitive pickups for bar chimes.

2,473,897. British inventor. Photo organ.

2,474,847. E. M. Jones, Baldwin. Photo organ with light-interrupter disc. Not similar to present Baldwin photoelectric.

2,476,607. E. L. Kent, Conn. Connsonata oscillator.

2,480,131. Laurens Hammond. Struck coil-springs with magnetic pickups.

2,481,608. Spencer McKellip. Oscillators with two tone qualities.

2,484,914. Photo organ.

2,485,829. Dutch inventors. Photo organ with stationary short film wave tracks scanned by light from cathode-ray tube.

2,486,039. Langer. Aperiodic flip-flop dividers.

2,489,357. Singers' voices recorded optically and pitches played back selectively.

* *255 W. 84th St., New York 24, N. Y.*

2,492,919. Cornell-Dubilier. Vibrating reeds, magnetic pickups.
2,494,943. British inventor. Photo organ.

1950

2,498,367. Laurens Hammond and John M. Hanert, Hammond's Research Chief. Chorus generator for Hammond Organ.
2,500,820. Hanert. Tube generators with chorus effect.
2,509,923. Hanert. Chorus and vibrato effect for generators initially incapable of varying frequency.
2,513,109. Photo organ.
2,522,923. L. E. A. Bourn of British Compton. Electrostatic generator.
2,533,461. Magnetic tone recordings.

1951

2,539,130. Magnetic tone recordings.
2,539,826. Frequency-doubler strings.
2,542,611. V. I. Zuck, Wurlitzer. Capacitive reed pickups.
2,559,276. Photo organ.
2,561,349. Tones from acoustic bass instrument picked up and brought down an octave lower.
2,568,862. Constant Martin, France. Struck strings with magnetic pickups.
2,573,975. Rotating magnetic tone generators.
2,574,577. RCA. Electronic generation of bell tones.
2,576,760. Baldwin. Means for stabilizing speed of rotating photoelectric generator.

1952

2,588,680. Photo organ with single high-speed rotating disc.
2,601,265. Tones generated with cathode-ray tube.

Miscellaneous

1,782,542	1,832,402
1,847,119	2,036,691
2,340,001	2,480,945
2,500,947	2,508,514
2,535,323	2,540,285
2,543,629	2,544,722
2,569,521	2,570,178
2,576,759	2,581,653
2,636,989	

Keying Envelope Control

1936

2,043,828. Coupleux, France. Delay by reducing momentarily the heater voltage in filament-type tube.

1939

2,161,706. Laurens Hammond. Delay suitable for but not used on Hammond Organ.
2,173,888. Gilbert Smiley, Hammond. Grid-bias keying.

1940

2,215,709. Benjamin F. Meissner. Key contacts capacitive so tone transmission varies with key position.
2,216,513. Laurens Hammond. Slow decay with capacitors.
2,224,729. Laurens Hammond. Improved grid-bias keying.

1941

2,266,030. Laurens Hammond. Envelopes affected by rate at which key is pressed.

1942

2,287,105. Walter F. Kannenberg, Bell Labs. Envelope control by d.c. applied to rectifier bridge. See 2,025,158 for more complete theory of rectifier bridge.
2,296,125. Pressure-sensitive keys.

1948

2,452,307. Koehl, Central Commercial. Key contracts unshort several resistors for step-type tone rise.

1949

2,482,548. Dutch inventor. Struck-string envelope keying.
2,483,823. Thomas J. George. Delay circuit with diodes; produces string and flute tones from sine generator.

1950

2,497,331. Several busses, swept by each key contact, give step-type tone onset and decay.
2,500,821. Hanert. Hammond. Pedal generators with slow decay.

1951

2,543,628. Hanert, Hammond. Envelope control for monophonic instrument; legato

playing still retains separate envelope for each note.

2,575,230. Baldwin. Resistive key contacts (not used in present Baldwins).

2,576,758. E. M. Jones, Baldwin. Envelope control for photoelectric instrument; shutters.

2,577,753. Hanert, Hammond. Sustaining means for pedal tones.

Special-Purpose Keying Schemes

1931

1,824,402. Maurice Martenot, France. Pitch determined by amount of wire unwound from spool.

1936

2,045,172. Baldwin. 13 oscillators for entire organ.

2,048,610. Kock, Baldwin. Highest note of any chord struck sounds loudest.

1940

2,203,432. Thomas J. George, Hammond. Use of 6 oscillator strings on premise adjacent notes never used together.

1941

2,241,363. Laurens Hammond. Single pedal provided, sounds note determined by lowest note being played on manual.

1943

2,323,242. Bell Labs. All notes of instrument produced by harmonics filtered from 6 generators tuned below lowest octave.

1949

2,484,930. Black keys eliminated. Selector set at key of composition and white keys automatically provide correct scale.

2,492,320. Bendix Aviation. Practice instrument, with many keyboards connected to single generator system; headphones.

1951

2,549,697. Bendix Aviation. Key switches operated by piano-like hammer action, remain for time depending on player's stroke.

2,577,493. Dutch inventor. Fewer generators than keys, on premise that only limited number of keys can be struck at once.

1952

2,581,680. Maurice Martenot, France. Capacitor varied by movable tape, as used in the Ondes Martenot.

Tone Color

1925

1,530,498. Harmonic outputs of oscillators controlled.

1932

1,877,317. Westinghouse. Each note has fundamental oscillator and also harmonic oscillators as required.

1933

1,933,299. German inventor. Modifying tone qualities of standard instruments.

1934

1,947,020. Richard H. Ranger. Generators provide all harmonics. Filters for each note subtract those not wanted.

1936

2,035,836. Richard H. Ranger. Tones distorted by circuit to provide complex structure.

2,039,201. Friedrich Trautwein, Germany.. Generation of tone accompanied by shock-excitation formants.

1938

2,139,023. Kock, Baldwin. Shock-excitation formants furnished by neons just short of oscillation.

1940

2,227,100. Central Commercial. Harmonic synthesis.

1941

2,251,051. Laurens Hammond. Several generators for each note, each with different tone quality.

1949

2,474,380. Tone-shaping with cathode-ray tube.

(Continued on page 58)

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LETTERS

(Because of the information offered in the following letter from Æ's London correspondent, its publication herein replaces the usual Letters *column—for this month only. Beginning in January a London Letter will be a monthly feature.)*

About this time last year we published our first report on Britain's Annual Radio Show, which is held in September each year at Earls Court, the largest exhibition hall in England.

This is a public exhibition, organised by the Radio Industry Council, and has an annual paid attendance exceeding a quarter of a million. The centre of the hall is occupied by the leading TV and Radio manufacturers, who have large booths often exceeding in cost of space and construction £20,000, on which are displayed the latest models of TV and sound receivers. In addition, many of the leading firms have elaborate demonstration rooms and suites in which the public can see and hear their products under home conditions.

Apart from manufacturers' exhibits, the main feature of interest in this year's Show (which ran from September 2nd through September 12th) was a television studio, built by the Radio Industry Council, to accommodate an audience of 1,000 per session, from which most of the B.B.C.'s National network of programmes were transmitted during the time the Show was open. A novel feature of the auditorium this year was the provision of a cinema sized screen, 21-ft. wide, above the proscenium upon which visitors saw the programme as it went out on the air. The number of performances and rehearsals per day were much increased over last year, and in addition to TV programmes a number of sound programmes were being rehearsed, broadcast, or recorded for subsequent transmission. I noticed, incidentally, that Leak amplifiers are used by the B.B.C. for all their monitoring loudspeakers.

Viscount Montgomery, who opened Britain's Radio Show, with Richard Arbib, Managing Director of Multicore Solders at the Multicore booth, where Philips projection television receivers were assembled and soldered.

A smaller studio, with glass walls, run by the Radio Industry Council staff themselves was used for more intimate TV programmes which did not require the spectacular stage of the B.B.C. studio. The output from either of these studios was transmitted to about 400 television receivers situated either on manufacturers' stands or booths, demonstration rooms, or Television Avenue where 40 different manufacturers' receivers were seen operating side by side. A completely separate camera channel

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was installed in another part of the hall where celebrities visiting the exhibition were interviewed. Besides being able to pick up programmes from these three channels the sets in the exhibition could also receive the B.B.C. National Programme transmitted from Alexandra Palace, or a film programme from a "flying spot" scanner installed in the R.I.C. Control Room. This elaborate suite housing the amplifiers and associated equipment had glass windows so that the public could see the engineers at work.

The trend in television development this year appeared to be the use of larger screens, but the general highest British standard is still only 17 in., and the increased popularity of projection television—the sales of which probably amount to about 15 per cent of the total sales of receivers for the domestic market.

Included in the exhibits in connection with projection television was the installation on the Multicore Solders' stand of a factory production line where projection television receivers were assembled and soldered by factory operatives from the Philips' Works at Mitcham, Surrey. This demonstration was probably the most popular working exhibit in the Show. Crowds twelve feet deep could be seen throughout the day around the line, marvelling at the rapid soldering operations which can now

An all-wave 3-speed radiogram—H.M.V.'s Model 1507—one of the most compact and lightest units of its type ever made.

be undertaken with Multicore Solder.

Practically all the projection sets sold for domestic use employ rear projection, size of screens varying from between 21 and 48 inches in width. Owners of hotels, schools, and clubs were being offered front projection receivers, constructed in two units, the screen and loudspeaker being in a separate cabinet. Practically without exception all these projection outfits were based on the same optical unit which employs a 2½ in. tube.

The most outstanding exhibit of interest to Hi-fi enthusiasts was the new Garrard Model R.C.90 Record Changer. This unit, having the same physical size as earlier models incorporates many additional most useful features. The change cycle is now the same for records of all three speeds, and amounts to only six seconds. A variable speed control is provided so that absolute accuracy of pitch is assured with old records or uneven electricity supplies. An additional lever now enables the user to play records individually, and thus the unit is virtually a single record player and a record changer combined.

Now that E.M.I. are marketing in Britain 45 r.p.m. records, TV manufacturers seem to feel that the American trend of increased

(Continued on page 57)

The Greatest Name in Turntables

REK-O-KUT

designed for Quality in Record Reproduction

Record Reproduction begins with the rotating motion of the record! This motion expresses passage of time. And each rotation is an interval or segment of that time. This important function is entrusted to the turntable.

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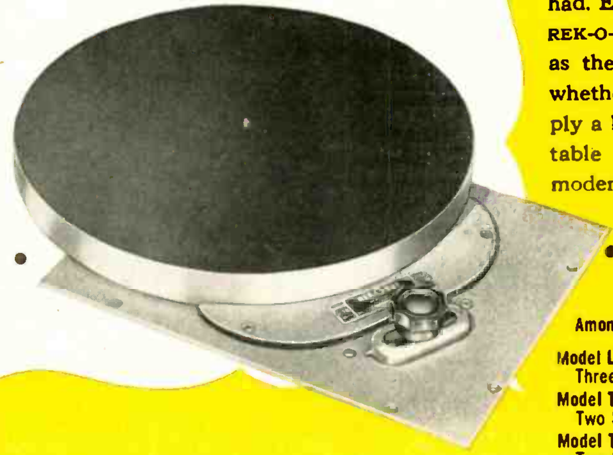

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In Canada: Atlas Radio Corp., Ltd., 560 King Street W., Toronto 28

audiology

W. R. AYRES*

Precision Phase Splitting

THE GRIDS OF PUSH-PULL TUBES require signals of equal amplitude and opposite phase. For generally improved performance, as well as reduction in size, weight, cost and hum-pickup, push-pull input transformers are now almost entirely replaced by vacuum tube phase splitters. Notable exceptions to this rule are cases in which driving power for the following stage is required, and in circuits where very large output voltage requirements are beyond economical realization with R-C coupling.

Many popular splitting arrangements pass one output signal straight through, and divert the other through a phase inverting stage of unity gain. Since unity is an inconveniently low amplification at which to operate common tube types, a signal voltage divider is customarily used in the grid circuit. *Figure* 1 is an example of this plan, grid resistances R_1 and R_2 chosen to cause attenuation complementary to the tube amplification.

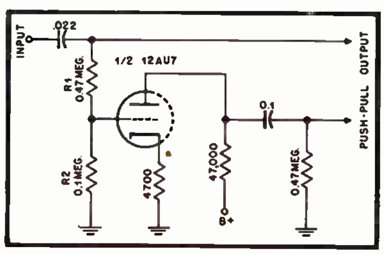

Fig. 1.

Perfection of balance obtained depends upon closeness of these resistances to required values, and constancy of amplification exhibited by the phase inverting tube. Close-tolerance divider resistors are readily obtainable, but fine stabilization of tube amplification is not readily accomplished without added complication and additional close-tolerance components.

Another principle of operation is that of making the grid signal of the inverting tube automatically adjusted by the extent of unbalance. The "floating paraphase" of *Fig.* 2 is example of this technique, grid signal for the inverting tube being proportional to the difference between the opposed output voltages. Obviously with identical grid resistances the output voltages must be unbalanced in order for the circuit to function at all; however, the fractional unbalance is the reciprocal of the inverter tube amplification, and may be made small through use of high amplification.

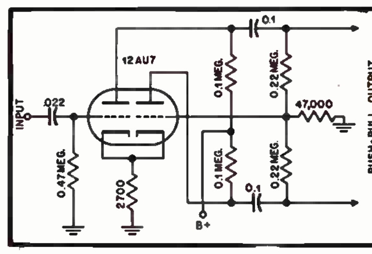

Fig. 2.

While many improved variations on self-balancing phase splitters have been devised, one of the simplest and yet most practical methods is the cathodyne or split-load circuit of *Fig.* 3. Here the tube is equally divided between the plate and cathode circuits. In practice there are additional capacitive loads due to input capacitance of the following tubes, wiring capacitance to ground, etc. If the complex plate and cathode loads are exactly equal, then since they are in series and carry the same current, the voltages across them are exactly equal and in phase (proceeding from ground to B+). Relative to ground, the a.c. plate and cathode voltages are equal in magnitude and opposite in phase to the same degree of exactness that the complex plate and cathode impedances are alike.

It will be seen that this type phase splitter is unique among popular circuits in that precision mid-frequency balancing requires matching of only two components, and is unaffected by tube gain variations. Amplification from input to either output is a little less than unity due to the high cathode-circuit degeneration, but that same degeneration makes nonlinear distortion in the output extremely low. In *Fig.* 3 the load resistances, which may be closely matched, are low enough to permit satisfactory operation with quite high capacitive

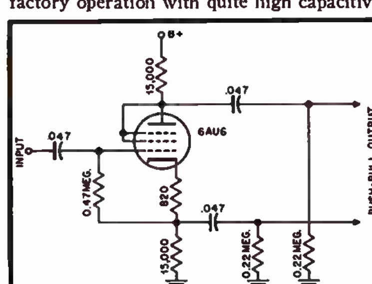

Fig. 3.

* *RCA Victor, Camden, N. J.*

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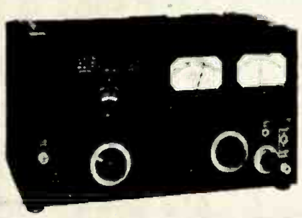

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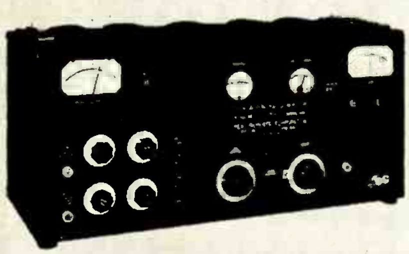

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1939 MODEL 54 STANDARD SIGNAL GENERATOR—Frequency range of 100 Kc. to 20 Mc. The first commercial signal generator with built-in tuning motor.
MODEL 65-B STANDARD SIGNAL GENERATOR—This instrument replaced the Model 54 and incorporated many new features including an extended frequency range of 75 Kc. to 30 Mc

1940 MODEL 58 UHF RADIO NOISE & FIELD STRENGTH METER—With a frequency coverage from 15 Mc. to 150 Mc. This instrument filled a long wanted need for a field strength meter usable above 20 Mc.
MODEL 79-B PULSE GENERATOR—The first commercially-built pulse generator

1941 MODEL 75 STANDARD SIGNAL GENERATOR—The first generator to meet the need for an instrument covering the I.F. and carrier ranges of high frequency receivers. Frequency range, 50 Mc. to 400 Mc.

1942 SPECIALIZED TEST EQUIPMENT FOR THE ARMED SERVICES.

1943 MODEL 84 STANDARD SIGNAL GENERATOR—A precision instrument in the frequency range from 300 Mc. to 1000 Mc. The first UHF signal generator to include a self-contained pulse modulator.

1944 MODEL 80 STANDARD SIGNAL GENERATOR—With an output metering system that was an innovation in the field of measuring equipment. This signal generator, with a frequency range of 2 Mc. to 400 Mc. replaced the Model 75 and has become a standard test instrument for many manufacturers of electronic equipment.

1945 MODEL 78-FM STANDARD SIGNAL GENERATOR—The first instrument to meet the demand for a moderately priced frequency modulated signal generator to cover the range of 86 Mc. to 108 Mc.

1946 MODEL 67 PEAK VOLTMETER—The first electronic peak voltmeter to be produced commercially. This new voltmeter overcame the limitations of copper oxide meters and electronic voltmeters of the r.m.s. type

1947 MODEL 90 TELEVISION SIGNAL GENERATOR—The first commercial wide-band, wide-range standard signal generator ever developed to meet the most exacting standards required for high definition television use.

1948 MODEL 59 MEGACYCLE METER—The familiar grid-dip meter, but its new design, wide frequency coverage of 2.2 Mc. to 400 Mc. and many other important features make it the first commercial instrument of its type to be suitable for laboratory use.

1949 MODEL 82 STANDARD SIGNAL GENERATOR—Providing the extremely wide frequency coverage of 20 cycles to 50 megacycles. An improved mutual inductance type attenuator used in conjunction with the 80 Kc. to 50 Mc. oscillator is one of the many new features.
MODEL 112 U.H.F. OSCILLATOR—Designed for the many applications in ultra-high frequency engineering that require a signal source having a high degree of frequency accuracy and stability. Range: 300 Mc. to 1000 Mc.

1950 MODEL 111 CRYSTAL CALIBRATOR—A calibrator that not only provides a test signal of crystal-controlled frequency but also has a self-contained receiver of 2 microwatts sensitivity.

1951 MODEL 31 INTERMODULATION METER—With completely self-contained test signal generator, analyzer, voltmeter and power supply. Model 31 aids in obtaining peak performance from audio systems, AM and FM receivers and transmitters.

1952 MODEL 84 TV STANDARD SIGNAL GENERATOR—With a frequency range of 300-1000 Mc., this versatile new instrument is the first of its kind designed for the UHF television field.

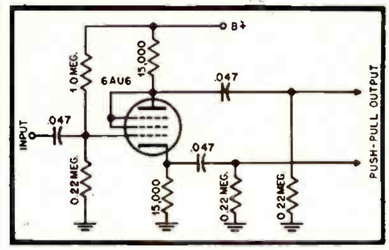


Fig. 4.

loading, yet with 270 supply volts the harmonic distortion at 30 peak volts output (per side) is only one-quarter per cent. When phase splitting or cross-coupling is accomplished within a feedback loop, there is rarely need for balance closer than one per cent, particularly since the following power amplifier tubes probably have power sensitivities differing by ten per cent or more.

Due to negative feedback in the cathode circuit, the output impedance is low at the cathode and high at the plate. Therefore, the stage amplification is less affected by changed cathode loading than by changed plate loading. Nevertheless, the two output voltages still *differ* only to the extent that the cathode and plate load impedances differ, since they are series elements carrying the same alternating current. Balance, of course, is the greatest single requirement of a phase splitter. If necessary to preserve it with loads of widely different capacitance on the two outputs, one simply uses suitably low plate and cathode resistances.

Cathode potential at no-signal in a phase splitter is commonly one-fifth to one-third of B+. Bias may be obtained with a series bias resistance, and cathode signal output may be taken directly at the cathode, with the total resistance from cathode to ground arranged to equal the plate-load resistance. But this would appear to be a relatively fruitless complication, besides not being adaptable to the use of matched pairs for plate and cathode load resistances.

An arrangement requiring no additional resistances, yet avoiding need for a tie-point in construction, is that of *Fig.* 4. Here the grid potential is elevated adequately by voltage-divider action, and suitable tube operating conditions prevail.

Usually at some expense of large-signal handling capability, the preceding amplifier stage may be direct-coupled to the phase-inverter grid. There is the basic objection of operating conditions in one stage being subject to component tolerances and tube variations in another stage. However, aside from the advantage of saved components, direct coupling here simplifies the application of overall feedback by avoiding troublesome phase shift at sub-audio frequencies.

With relative simplicity, the cathodyne phase-splitter offers low harmonic distortion and a known high standard of balance. One per cent matched resistance pairs now available at nominal cost permit preciseness of balance not always realizable with even elaborate self-balancing splitter circuits. Further, since the degree of balance is set only by the ratio of two circuit impedances, precision performance continues throughout useful tube life.






EDITOR'S REPORT

THE AUDIO FAIR

Every year about this time, this page devotes some space to comments about the Fair just closed, with orchids where deserved, and an occasional thorn to another deservee. Fortunately very few of the latter await distribution this year. On the whole, the Audio Fair has appeared to settle down for a long stay—exhibitors have learned quite successfully what will attract the public and keep them interested. But a few comments may touch a responsive chord among those who were fortunate enough to attend—or may cause a shudder, depending upon how the Fair affected the individual.

One fact has been observed from the beginning—if you want people in your exhibit room, you must make noise of some sort. Even Æ itself—never before with any type of sound creator (except subscription and Anthology hawkers) burst forth this year with a hill and dale phonograph, circa 1905, of the Edison cylinder variety. While this observer well remembers such devices while a youth—"The Preacher and the Bear" being most outstanding in his memory—dozens of visitors came and stared and listened to hi-fi of half-a-century ago, and then told us that this was the first instrument of that type they had ever heard. Paraphrasing an early Latin expression, they came, they heard, and they bought (subscriptions). But the lesson was well learned. Next year we shall have a collection of cylinders and we shall reproduce them electrically. This will probably surprise lots of people, including ourselves. But we'll wager it will attract visitors.

The opposite side of the picture is that when one exhibitor makes *too much* sound—the Hotel New Yorker not being thoroughly treated acoustically—it often offends adjacent exhibitors, even making it difficult for them to demonstrate their own equipment adequately.

It is beginning to look as though *no* hotel is going to be big enough to hold Audio Fairs of the future. When the third largest hotel in the country has to use the service elevators to handle the crowds, one thing is certain—Audio has arrived. And to think that in 1949 exhibitors were elated at an attendance of 3022! Four years later we had at least 25,000. Some exhibitors have been known to claim that all of them were in their rooms at one time.

The old-timers in the hi-fi field have been concerned about the entry of the commercial set manufacturers into the competition. We cannot agree that this represents any sort of threat to the present hi-fi manufacturers. Let us compare audio with auto for a moment: In this country there is a well developed cult of sport car fans—enough that publications covering this field have circulations of around half a million—and these people wouldn't be caught driving a standard commercial-type automobile such as Ford, Dodge, or Cadillac. They'd be much more likely to have a Ford chassis with a Cadillac engine and a home-made body. Undoubtedly there are many who would be completely satisfied with a factory-assembled "package" hi-fi set—chances are such a set would be greatly superior to the present sound reproducing equipment in their homes. There are probably many who would be satisfied by adding a simple change—perhaps by adding feedback or controllable phono equalization. But the real music lover will undoubtedly continue to prefer his personal selection of components, put together by an expert or by the owner himself. And so long as these music lovers continue to increase in numbers, our hi-fi manufacturers have no worry.

We have been amused the past few days by endorsements by famous persons for certain types of factory-assembled sets. The biggest smile comes when one of the more famous names in the music-broadcasting business claims to have heard realistic reproduction for the first time. Where can this man have been not to have attended an Audio Fair or even to have investigated some of the finer equipment demonstrated by the Audio Salons all over the country? No, we're not bitter—it's just funny, that's all.

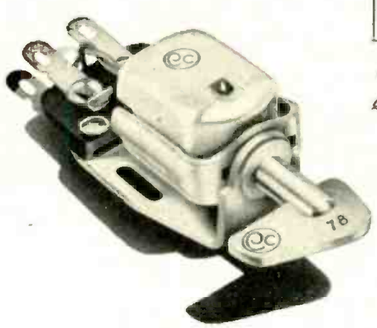
MAGNETIC RECORDING INDUSTRY ASSOCIATION

We welcome the formation of the Magnetic Recording Industry Association, another event coincident with the 1953 Audio Fair. Joseph R. Hards, vice president of A-V Tape Libraries, New York, was elected president of MRIA at its organization meeting on October 15. Nineteen members met to vote in the constitution and by-laws of the new group and to elect officers and board members.

"With magnetic recording now a $100 million industry, there is a need for a representative and lasting group to exchange ideas and information among its members and with the public, and to promote good relations between the industry, government, the public, and business concerned with magnetic recording," said Mr. Hards, who is largely responsible for organizing the group. Other officers elected were Russell Tinkham of Ampex Corporation as vice president; Herman Kornbrodt of Audio Devices, Inc. as secretary; and Victor Machin of Shure Brothers, Chicago, as treasurer. The Board of Directors will include two members—Paul Jansen of Minnesota Mining and Manufacturing Company, and Everett Olson of Webster-Chicago Corporation, in addition to the four officers. Membership is expected to double within the next month. We wish them all success in their avowed aims.

NEW MAGAZINE

In a welcoming mood, we also take pleasure in greeting *Tape and Film Recording,* a new bi-monthly magazine devoted to all aspects of magnetic recording. The first issue should be out by now, and judging from the past performance of its editor, Mark Mooney, Jr., formerly with *Camera* magazine in the same capacity, the new book should have the right slant for the movie maker who wants to add sound, in addition to the amateur tape recordist. Best of luck, *T & F R.*



Make Your Own Woofer

CURTISS R. SCHAFER*

For a minimum expenditure of money and a modest expenditure of time, anyone can easily convert an old-model speaker into a modern 18-inch woofer.

Excellent design data for several types of loudspeaker enclosures have recently appeared in technical publications. Most of these designs—whether for corner horns or four-way bass-reflex cabinets, will give their best performance when used with a good, heavy-duty theatre-type woofer. The actual use of such woofers has been restricted because most of them carry a list price tag reading around $250. It is the purpose of this paper to enable anyone really interested in obtaining such a speaker to assemble it himself for a net cost of between $30 and $35, depending on whether or not he has a friend who can operate a lathe.

Most of us like to know exactly what we are going to get out of a construction project before we start it. Therefore *Fig.* 1 shows the free-field response of the unit when mounted in a true infinite baffle, at a 20-watt electrical input level. *Figure* 2 shows the impedance characteristic at various frequencies. *Figure* 3 shows the completed speaker, ready for installation.

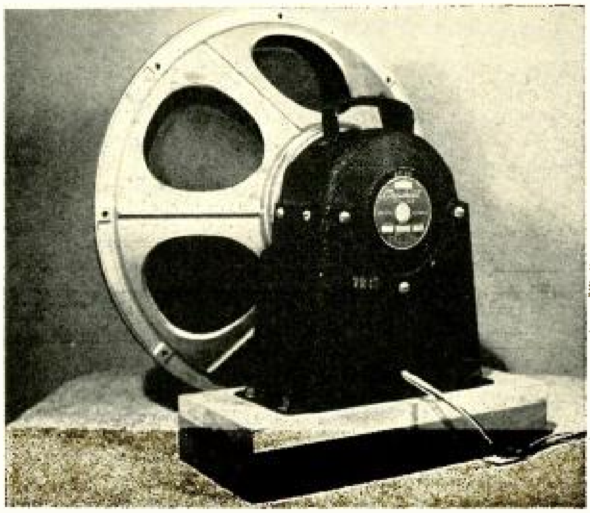


Fig. 3. Early model of 14-inch Jensen speaker modified by substituting new 18-in. basket and cone to make modern high-quality woofer.

Capehart used a 14-inch Jensen "Auditorium" speaker in many of their larger models, from 1933 to about 1942. These may be purchased from many radio and phonograph repair shops at a nominal price. The aluminum basket and cone for the current models of 18-inch theatre woofers (Jensen PMJ-18 and PLJ-18 will, with a very little bit of lathe work, fit the magnetic structure of the old 14-inch unit, and it is this conversion that is the basis of the speaker described here.

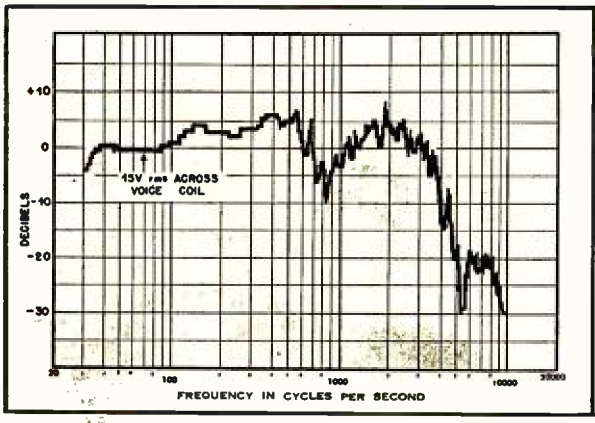
There are also many 18-inch Jensen speakers, of the electromagnetic type with built-in field exciters, available at theatre supply houses, and these may be converted by changing only the cone and adding the spider clamping ring shown in *Fig.* 4.

This is the procedure, starting with disassembly of the 14-inch unit:

1. With a 7/16-in. open end wrench, remove the four ¼-in. bolts that secure the basket to the magnetic structure.
2. Separate the basket and cone assembly from the magnetic structure.
3. Tear out the old cone, voice coil, and centering spider.
4. Remove the three heavy screws that fasten the iron ring to the aluminum basket, and separate the ring from the basket.
5. Drill out the riveted brass studs that supported the spider.
6. Chuck the iron ring in a good lathe and turn down the outside diameter of the ring so that it will fit snugly into the new basket; the new outside diam-

(*Continued on page 69*)

* *Route 4, Ridgefield, Conn.*



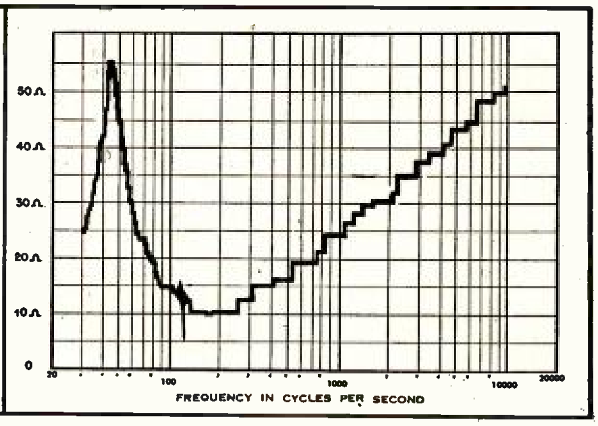


Fig. 1 (left). Free-field response of modified 18-inch woofer mounted in a true infinite baffle. Fig. 2 (right). Impedance characteristic of the woofer—nominal value being 10 ohms.

Making a "Front End" Handsome

WILLIAM H. BURKE*

Most articles discussing the preamplifier and control unit are concerned principally with electronic circuitry, with very little attention being paid to construction, or to making it look "professional." This author takes the other slant.

Fig. 1. The "Front end" unit in place in the author's phono-radio cabinet. Note the neat appearance of the decal labels.

In an article on converting their Musician's Amplifier to Ultra-Linear operation, the authors[1] explained that they had not described a "front end" for their amplifier for several reasons, a major one being "the almost unsurmountable obstacle to the amateur constructor in achieving the appearance of a factory-built unit." With all due respect to those eminent gentlemen, I wish to dissent. That obstacle is nowhere near insurmountable. I am an amateur constructor—as amateur as they come—but I built a front end that is handsome and professional in appearance. And so can you, if you have the equipment and know-how to build a Williamson in the first place. I had never tried anything like it before. I have no unusual talent for that sort of thing; neither am I all thumbs. In short, I am just like you.

There was a time when, exhibiting a normal degree of timorousness, I agreed with Messrs. Sarser and Sprinkle. When I began to plan for the construction of the Ultra-Linear version of the Williamson.[2] I decided that for the sake of appearance I had better buy a manufactured front end. I priced the adequate ones; I consulted the budget; the bubble burst. If I was to have a good front end I was going to have to build one. So I resolved to have my cake and eat it too, or to perish in the attempt. Having picked a design that seemed to offer everything that I could want in a front end,[3] I lit my pipe and curled up with a good catalogue. What I learned then and in the subsequent construction of my front end unit is applicable to the housing of any unit, and this article will be concerned primarily with the problem of attractively housing whatever circuit the constructor prefers to build. *Figures* 1 and 2 show the resulting equipment.

As a housing for my unit I chose a two-section aluminum case, accurately formed and attractively finished in gray hammertone. To achieve a pleasing color combination, I chose red bar-knobs for the controls. Anyone whose interior-decoration requirements are more chaste and austere will find that black bar-knobs will also make a handsome job. In any event, the gray hammertone of the case will harmonize with any color scheme. The solution to the labeling problem was provided by the "audio" series of "Tekni-Cals," easily applied water-transfer decals available only in white. Another type—"Tekni-Labels"—is also available in black, gold, and red. The combination of gray, red, and white proved to be a most attractive one.

The complexity of the front end which I built dictated the choice of the 4 × 5 × 17 in. case; smaller sizes are available to fit other requirements. The materials once acquired, the procedure for completing the control panel is as follows. Lay out symmetrically the holes through which the control shafts will protrude, using a soft lead pencil whose marks can be easily rubbed off later. Drill holes comfortably larger than the diameter of the shafts, for a reason which will be stated later. Then rule guide lines for the labels, after careful consideration, of course.

Procedure

Now apply the decals. Read the directions over several times before doing anything, and follow them carefully. If you do, you will have no difficulty, even though you have never applied a decal before. Once you have applied a decal to the panel, you can move it around to your heart's content with a wet camel's hair brush. When it is in exact position,

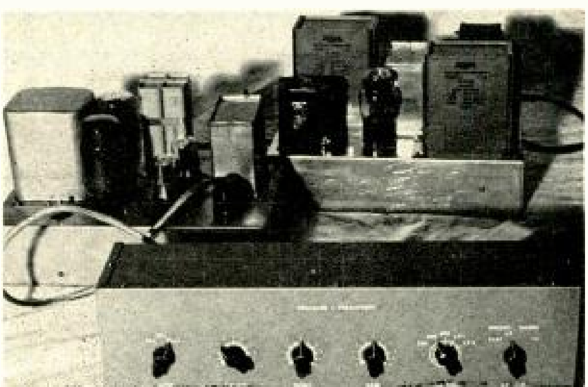


Fig. 2. The completed control unit together with the Ultra-Linear amplifier used with it. Heater current for the control-unit tubes is drawn from the cathode circuit of the KT-66's.

* *611 Stuart Ave., Kalamazoo 48, Mich.*

[1] Sarser and Sprinkle, "Gilding the lily," Audio Engineering, July 1952.

[2] Hafler and Keroes, "Ultra-linear operation of the Williamson amplifier," Audio Engineering, June 1952.

[3] Arthur J. Rose, "Front-end control unit for Williamson amplifier." *Radio and Television News,* June 1952.

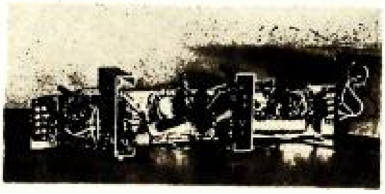


Fig. 5. Chassis of front-end unit further disassembled to show construction.

fix it there in the following manner: place over the decal one thickness of soft, dry cloth (soft thin cotton is best; a piece of an old T shirt is ideal) and press your forefinger gently but firmly upon the decal. If you inadvertently move the decal in the process, work water under the edges with the wet brush, push the decal back into exact position, place the cloth over it again, and once more apply even, gentle pressure. Do this as many times as you have to; whatever you do, don't lose patience and don't be satisfied with *almost* good enough. Once the decal is fixed in exact position, wrap a single thickness of the cloth around the tip of your forefinger and go over the entire decal, flattening out any small wrinkles. Dials are available in a separate Tekni-Cals booklet, which offers a good variety of attractive dials. Choose the ones you wish to use, trim them closely and carefully, and center them around the shaft holes with care. Take all the time you need, and you will wind up with a professional-looking job. It took the writer an entire evening, and it was an evening well spent. One further step remains, and a word of caution concerning it must be added. After the decals have dried for twenty-four hours, the directions tell you to brush over them lightly with a camel's hair brush moistened with lacquer solvent. When they say "moistened," they mean "*barely* moistened." Dip the brush into the lacquer solvent (available at any paint store) and then dab the brush repeatedly upon a piece of absorbent paper until you can see that the brush *is* barely moist. Then brush over one label or dial and repeat the process.

You will find that the audio series of "Tekni-Cals" contains just about every label you could want, and what isn't available can easily be made from what is. TURNOVER, ROLLOFF, FLAT—they're all there (but be sure to get the *fifth* edition of the audio series; the fourth edition, which I had to use for the first unit I built, lacked many useful labels and made much patching together necessary). If you want to label the top of your panel with EQUALIZER-PREAMPLIFIER—and it does add a professional touch—the legend can be made up of EQUALIZER, a minus sign, and PREAMPLIFIERS, cutting off the final s. If you prefer CONTROL UNIT, CONTROL is available and UNIT can be taken from VOLUME UNITS. Neither RADIO nor TUNER is available, oddly enough, for both AM and FM are on hand; and, if desired, RADIO can be made from AUDIO and GENERATOR. Incidentally, *Figs.* 1 and 2 show the first unit; *Fig.* 3 shows the second unit with different dials.

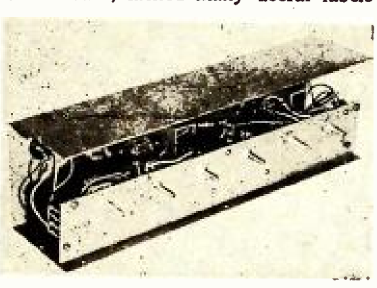


Fig. 4. Front section of case removed to show method of mounting sub-assembly.

Protection

An important question which now arises is: How do I keep that handsome control panel from getting marred while I have it on the bench mounting parts on it? The answer is inescapable: mount nothing on it. I mounted everything except the input and output sockets and jacks on the sub-assembly shown in *Figs.* 4 and 5. Not only did this procedure spare the finish of the control panel; it also made wiring simple because everything is in the open and easy to get at. While the details of a sub-assembly may vary widely in accordance with the circuit being built, some basic principles might be applied to any. The first requisite is an aluminum strip about three inches wide and about as long as the case is. If such a strip cannot be bought or liberated, other materials than aluminum will do. One-eighth-inch Masonite could even be used, with the ground bus connected then to one of the brackets mounting the strip to the case. First lay out the holes for the controls by placing the strip against the back of the control panel in the appropriate position and marking the centers of the holes through the holes in the panel. Then drill the holes, making them slightly larger than the threaded bushings of the controls—a 7/16-in. hole is fine for 3/8-in. bushing. The reason for this is that it will probably prove desirable, when the final touches are being put on the unit, to move one or more of the shafts sidewise slightly in order to center the pointer of the knob on the top center index line of a dial. A matter of neatness.

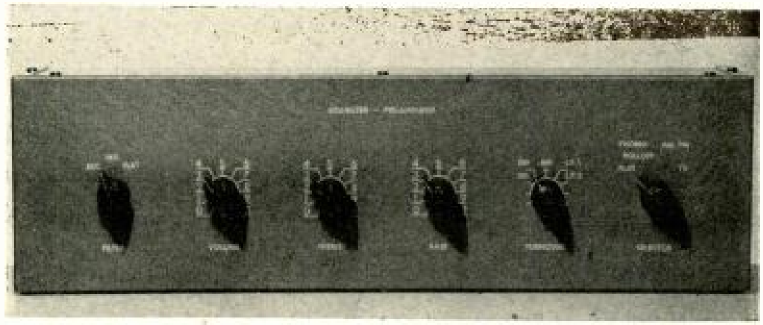


Fig. 3. Second model of the author's unit to show new type of dials used on the panel.

For the tubes and the can electrolytic, I used two 1 × 3⅛ × 4-in. open-end aluminum chassis, each fastened to the aluminum strip with two small right-angle brackets and metal screws. Suitable brackets might be purchasable; I made mine. Whether you use miniature chassis or just metal or Masonite squares for the tube mountings, it is a good idea to mount them about a quarter of an inch out from the aluminum strip, so that wiring may be passed between tube mount and strip. Mount at each end of the aluminum strip a screw-type terminal strip, such as the Jones barrier-type strips. All leads into and out of the unit can be connected to these terminals with solder lugs; this will simplify removing the sub-assembly for servicing. With reference to *Fig.* 4, the terminal strip on the left end of my assembly handles the three inputs and their common ground; the terminal strip on the right end handles B-plus, filament supply, output, and ground (the output and filament-supply conductors can be cablefellows, because the filaments are operated from d.c. drawn from the cathodes of the Williamson output stage via the arm of the balance pot. This also accounts for the relatively informal wiring: since there is no a.c. in the unit, there is no need to worry about lead dress. There is no hum whatsoever, either). After you have mounted the terminal strips, connect the lower terminals with a ground bus, which is grounded to the chassis at one point only. The rest of the construction is *ad lib.* When the sub-assembly is completed, mount it in the rear section of the case with three right-angle brackets and metal screws. Machine screws and nuts will not do here, for obvious reasons.

When you have finished, you will have a unit which really has that "factory-built" appearance about which Messrs. S. and S. were so bearish. In fact, this very evening an audio engineer walked into my living room, saw my unit, and said: "Who makes that front end? I thought I'd seen all the ones on the market." Of course, if your taste will settle for nothing less than hand-rubbed hardwood, you probably ounght to spend your eighty or ninety dollars and be done with it. But many readers will be interested to know that my unit, which involves about as complex and expensive a circuit as one could want to build, cost me about thirty-two dollars. I might add that its performance is magnificent. All this and handsome appearance, too. It can be done.

The Piano

ALBERT PREISMAN*

In Two Parts—Part 2

Continuing the description of the most universal of the musical instruments with a presentation of the technical considerations in the production of tones and their related harmonics.

IN THE FIRST PART of this paper the piano was described from its constructional standpoint. This section is devoted to a discussion of the technical characteristics of tone production and the elements which contribute to the quality of tone obtained from the instrument.

The String as a Transmission Line

Mention was made that the vibrating string behaves like an electrical transmission line. Besides the pioneer work of Rayleigh, Helmholtz and many others, Winston E. Kock[3] has analyzed the behavior of the vibrating string according to this analogy, and has taken the displacement of the string, rather than its velocity, as analogous to current in the line. In this manner he obtains similar boundary conditions: at the ends of the open-circuited line the current is zero, and at the ends of the rigidly held string (nodal points) the displacement is zero.

Suppose the hammer strikes the string. The result is an impulse force, similar to an impulse voltage, and it can be analyzed into a series of sinusoidal or pendular components. The string, like the line, will respond to a maximum degree to those components for which it is resonant, which means to frequencies for which it is a half wave length, whole wave length, one and one-half wave lengths, etc. Some of the different types of vibration are illustrated in *Fig.* 12; we say that the string generates a fundamental tone plus various harmonic overtones, such as the second, third, and so on.

All this is on the assumption that there is no dissipation in the string. So far as internal friction is concerned, this is generally very small. It can be reduced very markedly by increasing the string tension. In the electrical transmission line the analogous effect is to reduce the unit shunt capacitance, and thus raise the Q of the line with respect to the *series resistance* of the line.

What is intended to be brought out here is that the effect of resistance is to raise the velocity of propagation along the line as one goes up in frequency. Since the length of the segments in which the string can vibrate, as illustrated in *Fig.* 12, is fixed, and each segment represents a half wave-length at the frequency in question, then if the velocity is greater, the frequency must be higher, because frequency is equal to the velocity divided by the wave-length.

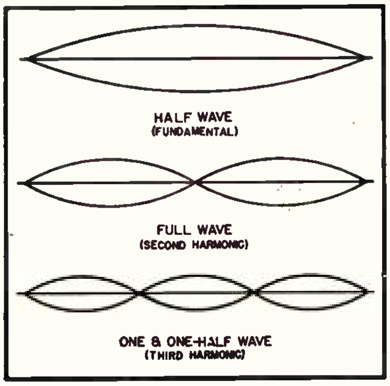


Fig. 12. Different modes of vibration of a string.

As a result of all this, resistive or frictional damping makes the overtones slightly higher in frequency than true harmonic values (integer values); i.e., the overtones are somewhat sharped. This effect is known as inharmonicity, and is deemed undesirable, particularly in the bass strings. Here it is found that the soundboard can radiate the fundamental tone only feebly as compared to the overtones. The ear, owing to its nonlinearity, can take the overtones—such as, for example, the fourth and fifth—and obtain a difference beat frequency. If the fourth and fifth and all other overtones are true harmonics, the difference beat between adjacent overtones will in every case be the fundamental frequency, and the difference beats will all blend harmoniously.

But if the overtones are not harmonic, the difference beats will not be all of exactly the same frequency as the fundamental nor of each other, and a jangling sound will result. It is for this reason that the bass strings of a concert grand yield more pleasant tones; the strings are longer and consequently under greater tension for a given pitch and mass, and hence the inharmonicity is less. Furthermore, if a string is under greater tension, its amplitude of vibration for a given output is less. This in itself reduces the inharmonicity, as will be shown.

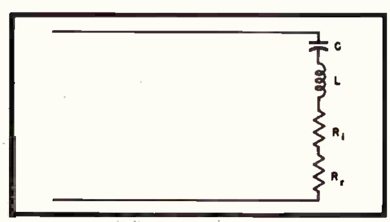


Fig. 13. Equivalent terminating impedance of a piano string.

The ends of the vibrating portion of the string, particularly the bridge, are not absolutely rigid. Indeed, it is by virtue of the "give" in the bridge and connected soundboard that vibrational energy is transferred to the soundboard and thence radiated into the air. Such "give" is equivalent, in the electrical line, to a finite rather than infinite impedance termination. The elasticity C and mass L of the bridge and soundboard, and the radiation resistance R_r of the system and internal friction R_i, may all be represented electrically as illustrated in *Fig.* 13. Such a termination tends to limit useful radiation of the low bass frequencies, because of the high reactance of C, although the step extension on the bass bridge (*Fig.* 8) tends to increase C (reduce the stiffness) by coupling the bridge to the more compliant central section of the soundboard.

At the higher frequencies the impedance of L (mass of bridge and associated portion of the soundboard) limit the amount of radiated energy. This is perhaps an even more serious limitation than the lack of radiation of the bass tones; the highest notes of a piano are particularly undistinguished in character. Although people, even artists, accept the tone of the top strings, they are more nearly a thud than a tone. More will be said about this later.

Effect of Stiffness

There is another effect that can be ascribed to damping, and that is the lack of suppression of certain harmonics. Piano strings are struck at approximately one-seventh of their vibrating length. This is therefore a point of maximum displacement or a loop rather than a node. For the seventh harmonic, every seventh interval of the string should be a node.

Hence, it can be expected—and it was, so argued by Helmholtz—that if the hammer strikes the string at one-seventh of its length, the seventh harmonic will be suppressed. It has even been argued that this is an undesirable harmonic!

However, actual tests show that there is a very appreciable amount of seventh harmonic present in the output of the

* *Capitol Radio Engineering Institute, Washington, D. C.*

[3] W. E. Kock, "Vibrating string considered as an electrical transmission line," *J. Acous. Soc. Am.*, Vol. 8, p. 227, 1937.

piano. This can be explained on the basis of dissipation. If the string has losses or damping, then there are no true nodal points along the string, but rather points of rapid change in phase; from transmission-line theory it can be shown that the impedance at such points is finite rather than infinite, and that therefore some seventh harmonic will be generated.

Piano manufacturers make a great point of choosing the point at which a string or tri-chord is struck, and undoubtedly it affects the tone quality. The highest treble strings are generally struck nearer to the end, in an apparent effort to augment the harmonic output of these strings. The usual striking distance for a string varies from about one-seventh to perhaps one-ninth of its length.[4]

Although frictional damping in a string can cause inharmonicity, apparently at the tensions employed today, this is not a serious factor. There is, however, another factor that is definitely appreciable, and that is the stiffness of the string.

The elementary theory of the vibrating string involves a linear differential equation; one obtains such an equation by assuming only first-order effects, such as no change in tension of the string with amplitude (because the amplitude is small), and no internal stiffness in the string. This means that if the tension is removed, the string hangs limply; i.e., in its unstressed state it can be bent without any effort.

Actual strings, however, do have some internal stiffness, especially if they are relatively short and thick. They then begin to behave like bars, which can resist bending stress just like a beam. For example, a beam anchored firmly at both ends, vibrates in modes, some of which are shown in *Fig.* 14. They are not harmonically related to the fundamental vibration, but are appreciably higher.

In *Fig.* 14 the restoring force is due solely to the internal stiffness of the members; the tension is assumed zero. In an actual string, the tension is the main restoring force, but in a short, thick string the stiffness may be an appreciable contributing factor. In this case the inharmonicity may be appreciable, and the overtones will be definitely sharp compared to the true harmonics.

Even in the ordinary middle register the inharmonicity may be measured quite readily with a sensitive frequency meter known as a Conn Stroboscope.

Tests made by O. H. Schuck and R. W. Young,[5] as well as more recently by R. W. Young,[6] indicate that the increased frequency of the overtones, or inharmonicity, can be entirely explained on the basis of stiffness of the strings, rather than frictional damping. The measured results agree very satisfactorily with the more advanced theory of the vibrating strings that takes stiffness as well as tension into account.

Most pianos have the same length of strings in the middle and upper registers, hence most exhibit about the same amount of inharmonicity in that range. This is most pronounced for the highest and shortest strings, and this is to be expected, since these strings approach short stiff bars in their properties.

It is in the extreme bass strings that inharmonicity becomes prominent once again, and moreover, is more pronounced for small pianos of the spinet type than for large grand pianos, particularly concert grands, which in addition radiate appreciable sound at fundamental frequencies. R. W. Young suggests that the lack of inharmonicity may well indicate what is considered a desirable tone quality, and that furthermore a uniform change in inharmonicity from string to string may be more desirable than an abrupt change at any point in the scale.

There is another fact that may be explained in terms of inharmonicity. Piano tuners tune a piano so that it becomes progressively sharper than the equally tempered scale as one goes up the scale. Lack of space precludes any discussion of piano tuning, or of the equally tempered scale, for that matter, but mention will be made of the fact that a tuner tunes two strings by measuring and adjusting the beats between the harmonic of the one note with the appropriate harmonic of the other.

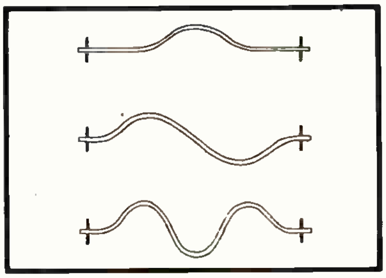


Fig. 14. Different modes of vibration of a bar clamped at both ends.

For example, to tune one string so that it is four whole tones above that of another (fifths), it is necessary to tune to zero beat the third harmonic of the lower tone with the second harmonic of the upper tone. The two tones will then be five whole tones apart.

But if there is inharmonicity, the overtones will be inherently more sharped, the higher they are. Thus, the third overtone of the lower note will be relatively higher compared to the third harmonic than the second overtone of the higher note is compared to the second harmonic. Hence, when the two are tuned to zero beat,[7] the second harmonic *and also the fundamental of the higher note* will both be somewhat sharped.

The opposite result occurs when the lower strings are tuned to the standard A, 440 cps. Thus the piano is tuned so that it becomes progressively flatter than the equally tempered scale A–440 and progressively sharper above A–440. Such "stretching" of the scale actually occurs; inharmonicity may wholly account for it, and a small spinet may be flatted more in the low register than a concert grand.

Steinway once tuned one piano exactly right to the equally tempered scale by means of a Conn Stroboscope, and another with a stretching of the pitch. The former piano sounded dead and lifeless in comparison with the latter; no one failed to detect the difference.

In passing, it is to be noted that if the amplitude of vibration is large, the tension will vary periodically, and thus in itself produce inharmonicity. However, this is apparently not appreciable for strings under the tension used today in a piano. Thus, the inharmonicity does not appear to vary with the loudness of the tone.

A solution to the inharmonicity of strings owing to their stiffness has been suggested by Franklin Miller.[8] The idea is to attach a small mass, of the order of 0.1 gram, within a few centimeters of the end of the string. This is sufficient to correct for the first eight overtones to within a few hundredths of a semitone. Theoretically, a large mass near one end of the string would correct for a large number of overtones.

A small mass, when attached to a string, lowers each nodal frequency except those for which the mass is located at a node. A mass distributed in sinusoidal manner along the string would correct for ten or twenty partials, but is much too complicated. A practical mathematical solution is possible for one mass used to make the first overtone harmonic with the fundamental, but other overtones remain inharmonic. Hence, a somewhat larger mass closer to the end of the string is preferred; this more nearly harmonizes a greater number of overtones.

Although a two-mass correction renders the first four overtones exactly harmonic, it does not improve the higher overtones, and does not appear to warrant the extra complication. It is pointed out that for a string 120 cm. long and a mass of 7.2 g., a mass of 0.133 g. placed 3.33 cm. from one end of the string, or half the mass placed that distance from *each* end of the string, would be sufficient. Gold plating might be a solution to the problem, but it would be better to have an adjustable mass. since the string stretches when tuned. However, so far

[4] Steinway strikes at less than one-seventh throughout, more so in the treble.

[5] O. H. Schuck and R. W. Young, "Observations on the vibrations of piano strings," *J. Acous. Soc. Am.*, Vol. 15, No. 1, p. 1, 1943.

[6] R. W. Young, "Inharmonicity of plain wire piano strings," *J. Acous. Soc. Am.*, Vol. 24, No. 3, p. 267, 1952.

[7] Actually, owing to the equally-tempered scale, the two are tuned to a certain number of beats per second rather than to zero beat, except in the case of octaves. However, starting about 1½ octaves from the top of the scale, a tuner may sometimes even deliberately sharpen the octaves to a slight extent.

[8] Franklin Miller, Jr., "A proposed loading of piano strings for improved tone," *J. Acous. Soc. Am.*, Vol. 21, No. 4, p. 318, 1949.

this solution still awaits adoption by a manufacturer.

Effect of the Hammer

The effect of the impact of the hammer on the string has been investigated by many, starting perhaps with Helmholtz. Recently R. N. Ghosh[9, 10] has written two articles on this subject which are interest and significance.

For a hammer that has certain amount of elastic "give," such as in the case of a felt hammer, there is first a tiny interval of time (investigated by Helmholtz) in which the hammer felt becomes compressed, but the string does not as yet move. Then follows a period of time during which the string begins to move and two waves travel in opposite directions along the line from the point of contact between the hammer and the wire.

These pulses, upon reaching their respective ends, are reflected therefrom in opposite phase, and return to the hammer. Upon reaching the hammer, at least some of the energy of each pulse is reflected back to the end it came from, and the action is repeated.

Since the hammer in a piano is about 1/8 of the distance from one end, it turns out that the pulse from that near end reaches the hammer, is reflected from it back to the end, undergoes another reflection, and so on several times before the other pulse reaches the farther end and finally comes back to the hammer. By that time the hammer has received enough energy from the near end to rebound from the string and permit standing waves to be set up in it.

Hence, the analysis concerns itself with the reflections from the near end, only, and is therefore considerably simplified. Nevertheless the mathematics (Heaviside's Operational Calculus) is fairly involved, but indicates that there is built up by the string against the hammer a pressure that varies, for certain constants, as shown in *Fig.* 15. Here the ordinates represent pressure and the abscissa represent (vt/α), where v is the velocity of propagation along the string, t is the time measured from the instant the standing waves are formed, and α is the distance of the hammer from the near end. Also, $\chi = T_o/\mu\alpha$, where T_o is the tension in the string and μ is the coefficient of elasticity of the felt; and $\beta = \rho\alpha/M$, where ρ is the mass of the string per cm. and M is the mass of the felt hammer. The values for χ and β shown are typical for a piano for α lying between 1/7 and 1/9.

The interesting thing about this curve is that it is continuous. If the hammer were perfectly hard and inelastic, the pressure curve would be discontinuous in shape. Owing to the elastic quality of the felt and even that of the hammer shank, the curve is smooth albeit undulating, as in *Fig.* 15.

[9] R. N. Ghosh, "Elastic impact of a pianoforte hammer," *J. Acous. Soc. Am.*, Vol. 7, No. 4, p. 254, 1936.

[10] R. N. Ghosh, "Elastic impact of pianoforte hammer," *J. Acous. Soc. Am.*, Vol 20, No. 3, p. 324, 1948.

The tone quality of the string depends upon the pressure curve. From Ghosh's analysis, only α and β are involved in the time-variable terms of the formula for the pressure, and the initial velocity with which the hammer strikes the string merely determines the amplitude but not the shape of the curve.

Hence it would appear that assuming the elastic limit, μ, of the felt is not exceeded, the tone quality of the string should not change with amplitude. Yet tests by White[11] and Hart, Fuller and Lusby[12] indicate that the tone quality or wave shape does change with the loudness.

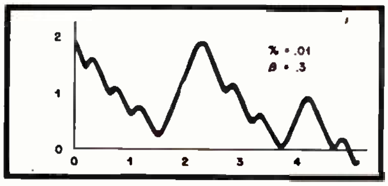


Fig. 15. Variation in pressure on a pianoforte hammer by the reaction of the struck string.

One possibility is that nonlinearities in the soundboard may change the wave shape with amplitude. Another possibility mentioned by Hart, Fuller, and Lusby and taken up by Ghosh is that of vibratory motion set up in the hammer. If the hammer is given a high velocity, appreciable energy from the key may be stored in elastic deformation of the hammer shank, weighted as it is with the large mass of the hammer it is driving. This may set up a vibratory motion in the hammer owing perhaps to air friction as it comes in contact with the string, and thus alter the pressure characteristic from that shown in *Fig.* 15. This may in turn explain the difference in wave shape with amplitude.

Touch vs. Tone Quality

We now come to a rather old but still controversial question, namely, can the tone quality of a piano note be altered by the manner in which the key is depressed, without the loudness being changed?

The answer, in the form of scientific tests or experiments, [11, 12, 13] is in the negative. William Braid White tested many artists with regard to this theory, and in every case where the tone color was different, the amplitude of the wave was different, too, as revealed on an oscillograph.

Ortmann obtained the same results after an elaborate series of tests that form the basis of an entire book.[13] Thus, he attached a stylus to the hammer and moved a piece of smoked paper past it so as to trace out a line on the paper. From this the hammer velocity as a function of time could be ascertained. Ortmann believes that the chief difference between two types of tones is the amount of noise that accompanies the sound. Thus, a "good", "sympathetic", or "beautiful" tone means, in part, a sound-complex with a maximum of tonal elements and a minimum of noise elements. Conversely "poor", "shallow", or "dry" tone means a minimum of tonal elements and a maximum of noise elements. The noise comes from the key striking its stop, and the clicks and thuds of the other parts of the action. The most characteristic difference in touch, when measured in terms of the noise element, is that between percussive and non-percussive touch.

[11] W. B. White, "The human element in piano tone production," *J. Acous. Soc. Am.*, Vol. 1, No. 3, p. 357, 1930.

[12] Hart, Fuller, and Lusby, "A precision study of piano touch and tone," *J. Acous. Soc. Am.*, Vol. 6, No. 2, p. 80, 1934.

[13] Otto Ortmann, *"The Physical Basis of Piano Touch and Tone,"* a book.

Hart, Fuller, and Lusby constructed a device that could strike the string in a variety of ways. An oscillograph revealed the wave shape picked up by a microphone, and the hammer motion was recorded optically. The object of these tests was to see if the possible whipping or vibratory action of the hammer, when its shank is elastically deformed, could possibly have an effect on the tone. Owing to the bulk of the equipment, 50 hammers had to be removed, and middle C was the only tone checked.

It was found that only when the hammer velocity was changed by 35 per cent could a difference in loudness and quality of the tone be perceived. In all cases where the hammer velocity, as it left the fly, was the same, the wave shape was identical, regardless of whether the striking mechanism struck the key with increasing, constant, or decreasing force.

Apparently there was no whipping or vibratory action of the hammer ordinarily to alter the nature of the contact of the hammer with the string, at least for a given hammer velocity. However, the striking mechanism could be adjusted so that when the key was struck once, the hammer would strike the string twice in very rapid succession—within 0.035 second—something quite impossible for a human performer to accomplish ("ricochet"). This is called a "repetition," and the second impact produces a marked jangling effect in the tone. However, this is an effect that every action builder carefully seeks to avoid; as proof is the fact that a performer never produces a repetition in normal playing.[14]

In view of this, it is somewhat ludicrous to see a piano player impart a vibrato motion to the key, *after* the hammer has struck the string and produced the tone. Furthermore, as Ortmann says, "— so far as effect on the tone is concerned, it is useless to write 'religioso,' 'pietoso,' or 'mesto' for a piano passage since the keyboard cannot be influenced thereby." To which the major piano builders add a fervent "Amen."

(Continued on page 64)

[14] Top speed for a human being is about 600 to 700 notes per minute. Action makers and regulators aim for ability to handle this speed, and succeed in obtaining it. No greater speed is necessary.

Handbook of Sound Reproduction

EDGAR M. VILLCHUR*

Chapter 14. Tone Control and Equalization.

A description of the simpler methods of obtaining frequency response equalization by the use of resistors and capacitors. The author also touches on expander circuits.

THE AMPLIFIER CIRCUITS that have so far been discussed are designed for a "flat" frequency characteristic within the signal band—the output signal voltages are ideally independent of frequency. Certain stages of an amplifier are purposely designed to introduce frequency discrimination, in compensation for conditions that exist elsewhere. These frequency discrimination circuits are either fixed or variable; the fixed circuit is usually referred to as an equalizer, and the variable circuit is called a tone control. Automatically variable circuits may be considered a special case of the variable circuit.

Fixed equalizers are used to compensate for:

1. Treble pre-emphasis in FM broadcasting. This is a standard and uniform broadcast practice required by the Federal Communications Commission, for the purpose of improving the signal-to-noise ratio of the FM signal. A 75-microsecond[1] de-emphasis network is inserted at the audio output of the tuner detector.
2. Constant-amplitude bass recording (bass attenuation) and treble pre-emphasis in records. Several circuits may be provided for the various recording curves, or a single compromise circuit may be used, and its corrective action augumented by variable tone controls.
3. Non-uniform frequency characteristics of a pickup cartridge, especially of the piezo-electric type. A circuit used for this function is a bridge between the characteristics of the pickup and those of the record being played.

Tone controls are used to compensate for:

1. Frequency irregularities of associated reproducing equipment.
2. Acoustical conditions of the listening room, including the masking effects of background noise and the frequency *vs.* absorption characteristics of the room surfaces.
3. Tonal imbalance caused by a generally weak treble or weak bass.
4. Reduced hearing sensitivity at bass frequencies when the intensity level of the program material is reduced. (Compensation may be accomplished by an automatic bass boost circuit synchronized with the volume control.)

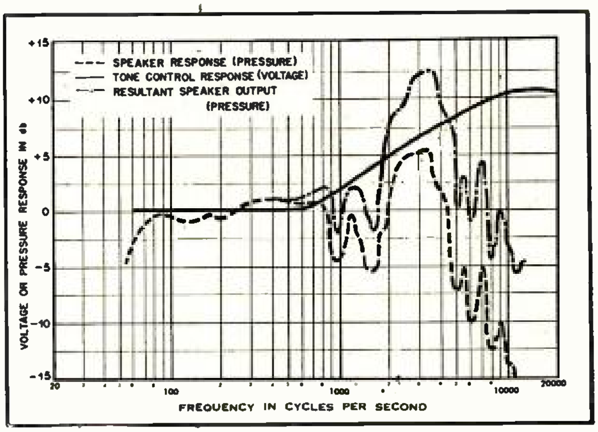


Fig. 14—1. Combined effect of the response of a high-quality speaker and of a treble-boost control with a transition frequency which is too low.

Tone Control Curves

The type of frequency discrimination required of fixed equalizers is normally exactly determined by the problem; the transition frequency and rate of boost or cut corresponds to the particular condition for which equalization is introduced. Variable tone controls, on the other hand, must furnish the means for correction, by the same circuit, of all sorts of signal aberrations. The designer of such controls can create a complex circuit which furnishes the means for any and all types of frequency variation, or he can limit circuit flexibility, and furnish the means for approximate correction of those conditions most likely to be encountered. The latter is the practical procedure.

Most modern tone-control systems in high-quality amplifiers consist of two controls, allowing independent, variable, and progressive boost or cut of either bass or treble from relatively fixed transition frequencies. This scheme is largely based upon design convenience, but also corresponds fairly well to the needs of the situation. The transition frequencies must be chosen as a suitable compromise between the requirements of the various types of correction that will probably be called for.

The geometric mean of the audible frequency spectrum—about 800 cps—is also its perceptive mid-point. (There are about 4½ octaves of useful frequencies on each side of 800 cps.) This frequency region is commonly selected as the transition hub of all tone control correction. The writer. however, holds the view that the selection of the psychological mid-point of the spectrum as a transition point is arbitrary, and does not fulfill the needs of a properly designed tone control. The function of such a control, it is felt, is to make the perceived frequency distribution of the reproduced music correspond as closely as possible to the perceived distribution at the original source. Tone control then becomes tone compensation, and the problem of response-curve characteristics revolves about the question of what the controller must be equipped to compensate for. The following transition frequency regions are recommended on the basis of a survey[2] of the purposes for which tone control is most likely to be used:

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[1] A resistor-capacitor network may be described quantitatively by its "time constant," in seconds which is equal to the product of the resistance in megohms and the capacitance in microfarads.

[2] E. M. Villchur, "The selection of tone control parameters," AUDIO ENGINEERING, March, 1953, p. 22.

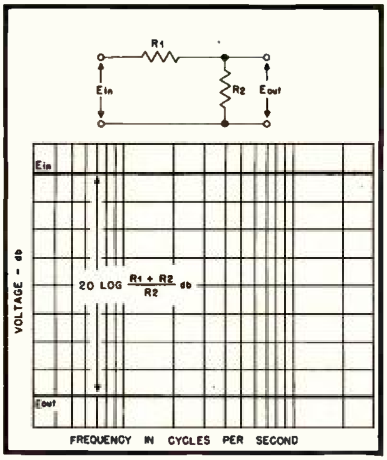


Fig. 14—2. Uniform attenuation over the frequency spectrum produced by purely resistive voltage divider.

Treble boost—3,200 cps
Treble cut—2,000 cps
Bass boost—400 cps
Bass cut—500 cps

The high treble-boost transition frequency is chosen not only on the basis of predicted compensatory functions, but because most speakers introduce treble accentuation in the first few octaves above 800 cps, due to cone break-up resonances. The unhappy effect of using too low a treble-boost transition frequency in conjunction with such a speaker is illustrated in *Fig.* 14—1. The two curves in this graph are taken from manufacturers' published data for high-quality equipment currently on the market, and are by no means atypical.

The Frequency Discriminative Circuit

The basis of the common frequency discriminative circuit is the voltage divider. There are three types in use: the resistive-capacitive, or R-C circuit, the resistive-inductive, or R-L circuit, and the resistive-inductive-capacitive, or R-L-C circuit. R-L-C circuits have an advantage in that they can provide steeper rates of boost or cut and a disadvantage in that they have a resonant peak. Coils also increase the danger of inductive hum pick-up, and are not as readily available in the required values as capacitors. In any case the R-C circuit is by far the most common, being smooth, simple, inexpensive, and entirely satisfactory. Although the maximum rate of boost or cut can at best approach 6 db per octave, steeper rates can be achieved by using more than one R-C stage of frequency correction, cascaded.

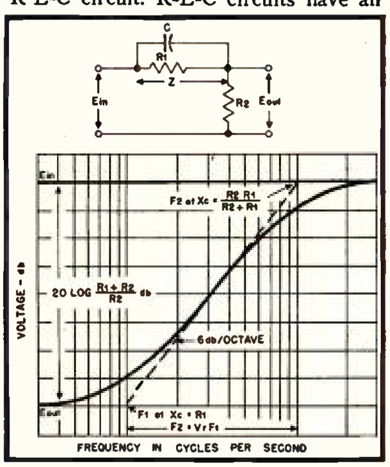


Fig. 14—3. Frequency discrimination of voltage divider with reactive element for one arm. This circuit may be used for treble boost or bass cut.

In *Fig.* 14—2 the input signal is attenuated uniformly over the entire frequency spectrum. If one of the arms of this voltage divider is now made reactive instead of purely resistive, however, the attenuation will no longer be uniform. Consider the circuit of *Fig.* 14—3. The reactance of Z varies radically with frequency: at the upper end of the spectrum C furnishes an effective short circuit across R_1, and at the lower end C is effectively open. The result is that at the uper end of the spectrum there is very little attenuation through the circuit, and at the lower end almost the full attenuation of the resistive voltage divider, $R_2/(R_1+R_2)$, is applied.

All tone control networks are basically attenuating circuits. Their effect, however, may be an apparent boost. This is so because the attenuation on one side of the transition frequency is almost uniform up to the end of the spectrum, while attenuation on the other side of the transition frequency can become progressively less. The process may be thought of as a uniform depression of the entire band of frequencies, followed by a progressive re-opening of the attenuator gate to one part of the band only.

The circuit of *Fig.* 14—3 will be analyzed descriptively in order to provide a physical picture of how equalizers work. The reader may wish to use the same type of analysis for the circuit of *Fig.* 14—2.

At low frequencies the reactance of C is so high that the capacitor may be considered open. Transmission through the circuit is therefore attenuated by the factor $R_2/(R_1+R_2)$, as represented by the lower horizontal line in the graph. Since C is never actually open the true transmission curve does not join the horizontal line, but approaches it asymptotically.

As the frequency is raised, a point will be reached at which the reactance of C is numerically equal to the resistance of R_1. C now becomes a significant element in the network. If C were not a vector quantity the impedance of the upper arm of the voltage divider would be halved, but as it is the impedance is reduced by a considerably smaller factor, and voltage transmission through the network is increased by a maximum of about 3 db. (The exact amount of increase depends upon the ratio between the values of R_1 and R_2) The total transmission increase over all the lower octaves has thus been only 3 db at most.

Above the transition frequency f_1 the net impedance of the upper arm of the voltage divider undergoes large changes. X_c is halved with each octave, and the impedance of the parallel combination of R_1 and C is correspondingly reduced, by a larger factor with each octave, although never at as great a rate as the change in X_c. Transmission through the network therefore increases with each octave, at a rapidly increasing rate which can approach the unobtainable limit of 6 db/octave.

The greater the attenuation of the resistive part of the network the closer the rate of boost can come to this ideal. The curve of voltage output *vs.* frequency cannot continue to increase its slope toward the 6 db/octave line indefinitely, however, because as the frequency continues to be raised we approach maximum or complete transmission. The output curve must therefore undergo a change from increasing slope to decreasing slope (at its point of inflection), and then flatten out again as ceiling transmission is approached. When the reactance of C, now the main element of Z, is approximately equal to the resistance of R_2 the output voltage is, at most, 3 db from maximum. (A more rigorous determination of f_2 appears in the following indented section.) At higher frequencies the curve, which has only 3 db to go, is raised very gradually.

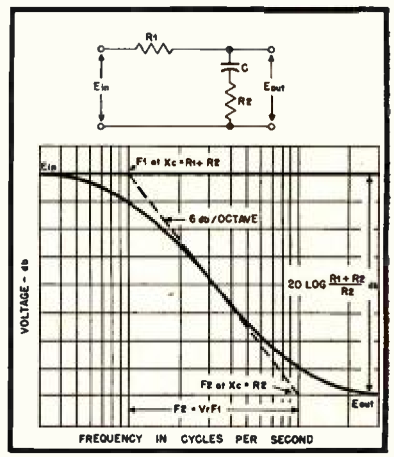


Fig. 14—4. Frequency response of circuit suitable for treble attenuation or bass boost.

The circuit of *Fig.* 14—3 is thus suitable for either treble boost or bass cut, depending upon what part of the frequency band it is applied to. As a treble boost circuit the transition frequency is considered to be f_1; as a bass attenuator the transition frequency is f_2.

> The following expressions concerning circuit characteristics neglect the effect of vacuum-tube plate resistance, but are sufficiently accurate.[3, 4] Units are ohms and farads, or megohms and microfarads.

[3] Holger Marcus Dahl, "R-C circuits as equalizers," AUDIO ENGINEERING, June 1948, p. 16.

[4] Charles J. Merchant, "Simple RC equalizer networks," *Electronics*, Feb., 1944, p. 146.

The transition frequencies for the circuit of *Fig.* 14—3 are determined as follows:

$$f_t = \frac{1}{2\pi R_1 C} \quad \text{(The frequency at which } X_c = R_1)$$

$$f_b = \frac{1}{2\pi R_T C} \quad \left(\text{The frequency at which } X_c = \frac{R_1 R_2}{R_1 + R_2}\right)$$

where f_t = Transition frequency for treble boost

f_b = Transition frequency for bass cut

$$R_T = \frac{R_1 R_2}{R_1 + R_2}$$

The total amount of boost or cut is equal to:

$$20 \log V_R = 20 \log \frac{R_1 + R_2}{R_2} \quad \text{db}$$

where V_R = Ratio between maximum voltage transmission (C shorted) and minimum voltage transmission (C open)

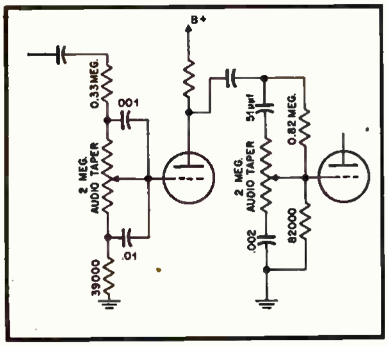


Fig. 14—5. Variable bass and treble tone control with values assigned for approximate transition frequencies recommended in text.

The maximum slope of the curve (at the point of inflection) is equal to:

$$6 \frac{V_R - 1}{V_R + 1} \quad \text{db/octave}$$

Thus when V_R becomes very large the slope of the equalization curve is almost 6 db/octave.

The frequency spread of the curve may be expressed as the ratio between f_t and f_b as:

$$f_t = V_R f_b$$

If a resistor R is inserted in series with C the effect is to reduce the total boost or cut, and the slope.

In *Fig.* 14—4 the transition frequencies are determined as follows:

$$f_t = \frac{1}{2\pi R_2 C} \quad \text{(The frequency at which } X_c = R_1 + R_2)$$

$$f_b = \frac{1}{2\pi R_2 C} \quad \text{(The frequency at which } X_c = R_2)$$

where f_t = Transition frequency for treble cut

f_b = Transition frequency for bass boost

$R_2 = R_1 + R_2$

The total amount of boost or cut is equal to:

$$20 \log V_R = 20 \log \frac{R_1 + R_2}{R_2} \quad \text{db}$$

The maximum slope (at the inflection point) is equal to:

$$6 \frac{V_R - 1}{V_R + 1} \quad \text{db/octave}$$

The frequency spread of the equalization curve is expressed as:

$$f_t = V_R f_b$$

If a resistor R is added in parallel with C the effect is to reduce the total boost or cut and the slope.

Frequency discriminative circuits may be inserted directly into interstage coupling networks of the signal channel, in which case they act as simple attenuators. They may also be used in feedback return loops. In the latter case the effect of the circuit on the signal is reversed—for example, a bass-boost circuit increases the relative amount of bass fed back degeneratively and takes on a bass cut function. In both cases the *insertion loss* refers to the number of db of attenuation at minimum transmission.

The basic principles of R-C circuits described above may be applied to various types of tone controls. One popular circuit configuration[5] is illustrated in *Fig.* 14—5, with values assigned to approximate the transition frequencies recommended earlier in the chapter. Varying the potentiometer sliders changes the rate of boost or cut and to a lesser extent shifts the transition frequencies (towards the ends of the band for shallower slopes).

Another circuit has been described[6,7] in which the R-C networks are part of a negative feedback loop, and where the transition frequencies are varied with only minor changes of slope. The compromise involved here is the relinquishing of control over the rate of boost or cut.

The phase shifts introduced by R-C tone equalization networks are very large. The graph of *Fig.* 14—6 shows that 6 db of attenuation through the circuit of the inset diagram introduces approximately 60 deg. of phase shift. To the knowledge of the writer, such phase shift has not, up to the present, been demonstrated to have significant undesirable effects in monaural reproduction, whether the conditions which are being compensated involve an opposite phase shift, no phase shift, or phase shift in the same direction.

[5] Howard T. Sterling, "Flexible dual control circuit," AUDIO ENGINEERING, Feb., 1949, p. 11.

[6] P. J. Baxandall, "Negative-feedback tone control," *Wireless World*, Oct., 1952, p. 402.

[7] Basil T. Barber, "Flexible tone control circuit," AUDIO ENGINEERING, Sept., 1953, p. 29.

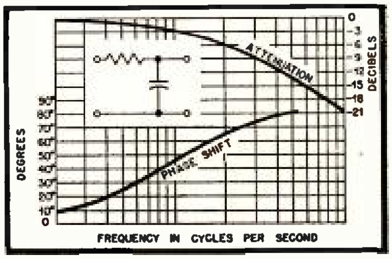


Fig. 14—6. Phase shift in relation to attenuation of an R-C network. (*After F. Langford Smith.*)

Loudness Controls

A "loudness" control is a tone-compensated volume control which varies the average intensity of program material without appreciably changing the perceived frequency distribution. To keep the loudness, or apparent intensity, of the different frequency elements in the same proportion, it is necessary to compensate for normal perceptive illusions that occur when the over-all intensity level of the sound is raised or lowered. The need for such compensation is probably almost universally agreed upon; the type of compensation which is most desirable, and the question of whether to make the compensation automatic, semi-automatic, or manual, is sometimes a subject of contention.

Certain facts relative to the problem have been experimentally established, and may be stated without the qualification of presenting them as a point of view. The Fletcher-Munson curves of equal loudness over the frequency spectrum, at different over-all loudness levels (see Chapter 6), may be used to calculate the required compensation for the Fletcher-Munson effect. *Figure* 14—7 plots the difference in perceptive sensitivity, over the frequency band, for the

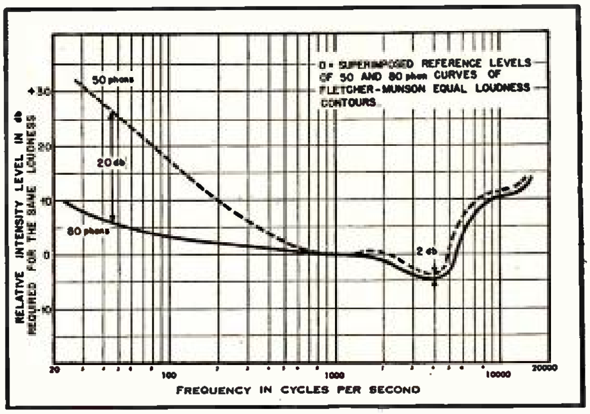


Fig. 14—7. Differences in hearing sensitivity over the frequency spectrum. The 50-phon and 80-phon equal loudness contours (*from Fletcher and Munson*) superimposed.

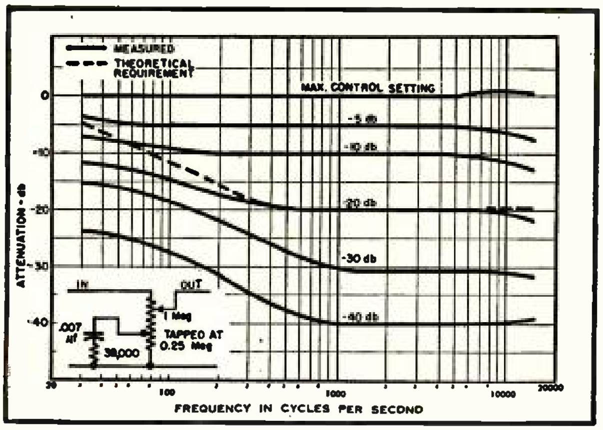


Fig. 14—8. Simple loudness control. The potentiometer uses a logarithmic taper. (*After Toth.*)

80 phon and 50 phon loudness contours.[8] The maximun boost required for the Fletcher-Munson effect will be seen to be about 20 db at 50 cps, and 2 db from about 1500 cps and up. The treble boost is, even at maximum, insignificant, since the curves are essentially identical above about 1000 cps.

The bass boost may be applied automatically by a circuit such as appears in *Fig.* 14—8. The difficulties in using this circuit are that the degree of bass boost is tied only indirectly to the intensity level of the program material, through the physical position of the volume control slider. Different program sources may require entirely different settings of the slider for the same average signal intensity. One solution to this problem is to provide an additional potentiometer before the loudness control. This is used for initial adjustment of the input signal (with the loudness control all the way up), to an intensity level judged to be approximately equal to the original level of sound at the point of origin. The loudness control will then be more or less properly calibrated and will provide approximately correct tone compensation when varied. The complexity involved, however, may be considered an argument for completely manual compensation—that is, the use of bass control until the program timbres sound natural.

It has been suggested that since the Fletcher-Munson curves have been plotted on the basis of pure tones they do not accurately predict the compensation required for the complex sounds of normal program material, and that specifically, when the intensity of sound is reduced, a significant treble boost is required by such effects as masking. In the absence of quantitative data paralleling that of the Fletcher-Munson study, however, this writer knows no accurate basis for designing an automatically variable treble boost circuit. The effects of room noise on masking higher frequency sound will of course vary in different locations.

[8] As pointed out in Chapter 6, 80 db above threshold is the order of average sound intensity of a 75-piece orchestra heard from a front row seat, and 50 db is the minimum intensity level at which this music is likely to be reproduced with a legitimate interest in quality.

Phonograph Preamplifiers and Compensating Networks

The circuits immediately following the pickup are used to compensate for recording characteristics and for any frequency discrimination in the pickup itself, if such exists. The compensation is applied at these low-level stages so that the required bass boost does not accentuate hum introduced by previous voltage amplifiers.

Piezo-electric pickups have relatively high signal outputs, usually between one-half volt and several volts. Compensation must be based upon the characteristics of the pickup unit itself, and designed to correct the curve of pickup output *vs.* frequency towards the reciprocal of the desired recording curve (not towards "flat" output). Certain crystal pickups have been specifically designed to match a particular recording characteristic when connected to the proper load resistance. Any crystal pickup, however, provides bass boost and treble droop automatically, so that the use of an uncompensated crystal cartridge tends to be fairly acceptable.

Figure 14—9 illustrates a circuit that can be used for semi-variable crystal pickup equalization. The load resistor across the pickup has the effect of reducing bass response—the lower the resistance the less the response—while the parallel R-C network corrects treble droop.

The magnetic pickup has a much lower output than the piezo-electric—for some types the signal voltage is no greater than 10 millivolts or so—and additional voltage amplification is required. Frequency compensation for recording characteristics are included in the added amplifier stages; these stages make up the *preamplifier*. The compensation may be introduced by an attenuating network, as in *Fig.* 14—10, or by a feedback network, as in *Fig.* 14—11.[9] The latter circuit includes alternative equalization circuits which provide approximate compensation for most recording curves. The circuit may be simplified by limiting the number of choices and by combining the treble and bass switch controls, as in *Fig.* 14—12.

Exact compensation cannot be expected in any case, because the published recording characteristic of a manufacturer does not take into account addi-

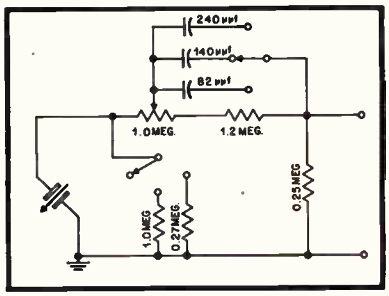


Fig. 14—9. Crystal pickup amplifier (*After McProud.*)

tional factors such as microphoning and recording studio acoustics. The variable tone control can be used to supplement the preamplifier switch control.

The use of feedback methods for preamplifier equalization has the advantage of decreasing distortion, especially in the unequalized portions of the band, but it does not improve the signal-to-noise ratio over that obtained with an attenuating network. This is because the noise and signal are both attenuated by the same factor, and the input signal to the preamplifier cannot be increased to improve the ratio between the two, as with other feedback amplifiers.

The load resistor across a magnetic pickup may serve the purpose of high-frequency equalization, since the lower the value of this resistor the greater the high-frequency roll-off. Such a method of high-frequency equalization has the disadvantage of attenuating the high-frequency signal from the pickup (as a matter of fact the over-all pickup output is also reduced) while leaving the high-frequency noise output of the pre-

(*Continued on page 61*)

[9] George Ellis Jones, Jr., "Two preamplifiers for magnetic pickups," AUDIO ENGINEERING, Jan., 1952, p. 24.

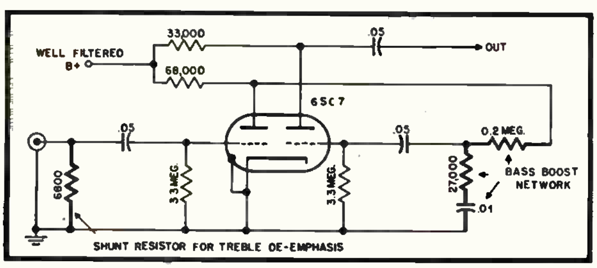


Fig. 14—10. GE-type preamplifier. Equalizing circuit elements are shown in heavy line.

Audio Fair and AES Convention Reach New Heights

Record attendance at New York event fulfills pre-Fair estimates—four floors of exhibits crowded throughout entire four-day period indicate full acceptance of hi-fi by the "man on the street."

WITH OVER 24,000 registered visitors and Friday night influx delivered by service elevators direct to the eighth floor where no registration facilities were available, there can be no doubt that the total attendance at the 1953 Audio Fair exceeded the 25,000 figure estimated by both exhibitors and Fair management. Exhibits were open for a total of 37 hours, and allowing each visitor a minimum of three hours—little enough to see the 117 rooms—it would figure out to indicate that at least 20 people were in each exhibit all the time. And that makes no allowance for the repeaters—those who came two, three, or even all four days. Those who have been around the previous Audio Fairs will remember many of the same faces that have attended every day of every Fair in New York. But this year there was a considerable change in the character of the crowds. While heretofore most of those in evidence were the dyed-in-the-wool hobbyists, this year's crowd was augmented by those who had no previous experience with hi-fi, but who were looking and learning for the first time. Particularly notable were the many young couples—new homemakers who were looking for something better in the way of music in the home. They found it in abundance at this year's show. Because of the dates of the 1953 Fair, a full description of the exhibits must be delayed until the December issue.

Dr. Edward W. Kellogg, left, receives the John H. Potts Memorial Award from Arthur W. Schneider at AES Banquet. Incoming president Jerry B. Minter, lower left, looks on, while Col. Richard H. Ranger studies notes.

AES Convention

The Convention papers of the Audio Engineering Society were well attended, and many new members were enrolled during the event. Full texts of all the papers presented will appear in the coming issues of the *Journal of the A. E. S.*, but are not readily available for prior publication by other media.

The Fifth Annual Banquet, held on Thursday evening in the Grand Ballroom, was also well attended—many coming to witness the presentation of the Awards which are given annually. The first of these—the John H. Potts Memorial Award for outstanding achievement in the field of audio engineering, and given by Æ—was received by Dr. Edward W. Kellogg, who retired from RCA in 1947. His work began with telephone engineering, continued with submarine detection during the first World War, veered into antenna design, and then settled for audio. Among other important contributions to the field, Dr. Kellogg, with Chester W. Rice, developed the dynamic paper-cone loudspeaker which is the father of most speakers in use today. In his later years with RCA, Dr. Kellogg was engaged principally in the development of equipment for sound motion pictures.

Given for the first time this year, the Emile Berliner Award for an outstanding development in audio engineering was presented to Henry C. Harrison. Oliver Berliner—grandson of inventor Emile Berliner for whom the Award is named—was present to transmit the first plaque to the Society. Berliner will be remembered as the man who perfected the first successful microphone using variable contact resistance, providing a low-cost unit which gave the Bell System a head start in the telephone business over Western Union. He is probably best known for having developed the lateral cut disc record which is the basis for all modern phonograph records.

Mr. Harrison, who received the award, was a member of the technical staff of Bell Laboratories throughout most of his working life, having retired in 1952. The development for which he was chosen to receive the award was the rubber-line recorder, which was one of the first electrical recording units used in the industry. This application of mechanical damping to an electrical device marked one of the first marriages of electrical and mechanical engineering—a basic fundamental research problem well solved. Mr. Harrison and the group under his supervision are also credited with the development of a vertical-cut or "hill and dale" recording which for many years established the basis for sound reproduction of high quality.

Dr. Edward C. Wente joined a distinguished group consisting of Dr. Harvey Fletcher, Prof. Frederick V. Hunt, and Prof. Vern O. Knudsen by being chosen the fourth honorary member of the Society. Dr.

(Continued on page 58)

New Emile Berliner Award was delivered to the Society by grandson Oliver Berliner, above. Award is in form of plaque.

Henry C. Harrison, recipient of Berliner Award, is responsible for development of the "rubber-line" recorder for disc recording.

it CAN be ATTRACTIVE

it all depends on you!

ONE OF THE CRITICISMS of the average hi-fi system is that it is likely to represent a maze of units, unsightly connecting wires, and plywood housings that wouldn't be included in the specifications for a decorator-planned home. And in many instances, that criticism is deserved. All of us have seen installations that have no more place in a home than a laboratory-type breadboard has in a Lord & Taylor window. Without attempting to delve into the psychological reasons for such unsightliness, let it be said that there is no valid excuse for a system remaining in that condition after the electrical performance has been perfected to the satisfaction of the owner. Not everyone can qualify as a furniture designer, and not everyone is adept enough to perform some of the modern miracles of cabinetry, but everyone does have access to a few of the home magazines —such as *House Beautiful, Better Homes and Gardens, House and Garden,* and so on. From those sources can be obtained many ideas which can be adapted to the specific needs of the individual. Fortunately the actual construction of modern furniture and cabinetwork is considerably more simple than that required for traditional decor, and modern is currently very much in vogue.

One of the virtues of the usual hi-fi system is that it is quite flexible. Few devotees will hold still for a loudspeaker and a phonograph turntable in the same cabinet, for example, which often requires that more housing units must be supplied than for a simple radio-phonograph combination. In this, however, lies much of the advantage of the separate-unit construction, for housing may be split up between cabinets and built-in units. In some houses, for example, there is a place where a divided-entry structure can be used for the tuner, record player, and amplifier, in a manner similar to that shown at the left. Those who own their own homes would want to make such an installation a permanent fixture, but those who are renting could easily arrange such a cabinet to be movable—being attached to the floor as close to the wall as possible. Such a dividing wall often adds to the convenience of living—separating an entryway from the room perhaps, or by making the room somewhat more livable by providing a feeling of intimacy.

In the installation shown—as conceived by Kierulff Sound Corp. of Los Angeles—the radio tuner is located in the top compartment, the phono equipment in the center, and the amplifier in the lower section. Ventilation is provided by the grille shown at the bottom and by vents into the adjacent wall. For a non-permanent installation, suitable grilles might be provided above the tuner panel or even on the top of the entire cabinet. Some form of ventilation is a necessity, and each installation may need to be designed specifically to include this much-needed feature in one fashion or another.

To go along with the divider installation, the owners wanted loudspeakers installed in the ceilings of their living and dining rooms, and in the breezeway to provide for summer evening dancing music. There is an axiom among custom installers that goes something like this—"Tell us exactly the facilities you require and we will build them for you." Occasionally, however, the owner will offer to provide an outlandishly small space for the loudspeaker—perhaps half a cubic foot—or he may want the equipment installed in built-in bookshelves that are simply too shallow for the required components. Here, again, one of the problems is that of ventilation, but it is usually possible to employ the walls to channel out some of the heat. One must remember that even the smallest amplifier-preamplifier combination will consume at least 60 watts, and it could range up to 200 watts in the largest models; the average tuner will consume around 75 watts, and a turntable from 15 to 50. Since little actual power is put out in the form of acoustic energy, most of that drawn from the power line is dissipated in the form of heat. Thus a typical installation will radiate about as much heat as a 250-watt lamp—easily enough to keep a pot of coffee hot even though it might not be sufficient to make the coffee in the first place.

At the right is shown an installation which is ideal for the small apartment where the addition of any more cabinets would seriously reduce the living space. Here the tuner and the record changer have been placed in a convenient bookcase, and the speaker has been installed in the three shelves above the tuner. This installation—by Electronic Workshop, New York—is somewhat deceptive to the eye, for it appears that these three shelves contain books. Such is not the case, however, for upon further inspection it will be seen that the books are false, and that the speaker is directly behind the space where the books aren't—at the center of the middle shelf of the three indicated by the arrows. In this instance, two of the shelves have been removed, a baffle board mounted at the front, with suitable grill-cloth covering, and then false shelves and book-backs have been appliqued. (Since seeing this photo, the writer has been curious as to what would happen if a guest decided to read one of the "books" in the speaker section.) The power amplifier for this installation is located in one of the built-in cabinets below the bookcase, and all necessary controls are on the tuner.

At the lower left is another arrangement which can be adapted in many types of homes. This installation, also by Kierulff, is in a den which adjoins an outdoor patio, reaffirming the importance that Californians place on outdoor living. The dwelling is a beautifully decorated home in San Marino, California, and all the components are clearly seen as regards their mounting and operation, with the exception of the main amplifier which is under the changer drawer. The tuner and changer are readily accessible, and the speaker is housed in another portion of the built-in section, at the left. The television set, just barely visible at the top, is not connected to the music system, but could be

All too often the home music system is anything but a delight to the eye. Whether built-in or housed in conventional cabinetry, there is no good reason why the home-assembled system should not be planned to provide both high-quality sound and eye-quality sight to please everyone in the home.

if it were deemed desirable. With the changer drawer closed, and with the doors over the tuner and the speaker closed, the existence of the system need not even be suspected—as though anyone might be ashamed of having a music system in his home.

Just how does one go about making such an installation? The easiest way is to outline the requirements to any of the specialists in custom building throughout the country. That way is likely to cost more than if the work is done by the owner himself, but there are many who shy away from cabinet work because of a lack of experience or the absence of adequate tools for the work. But nowadays there is so much information available in the "How to Do It" category that anyone with the desire and a slight amount of skill can turn out an acceptable job. Perhaps perfection

(*Continued on page 44*)

The White POWRTRON Amplifier

STANLEY WHITE*

A discussion of one possible cause of power distortion and a description of a circuit developed to eliminate it. The author also describes his method of dividing the frequency spectrum ahead of the power amplifier. This unit has been popular with listeners at recent demonstrations.

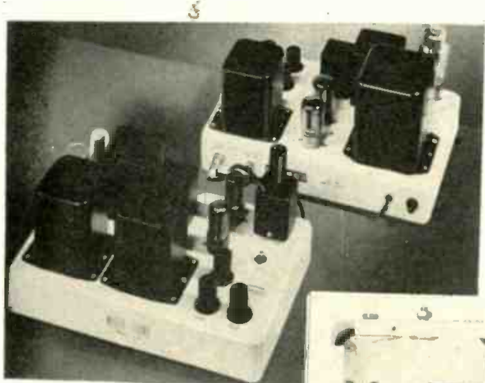


Fig. 1 (left). Top view of 10- and 20-watt White amplifiers with filter network plugged into the 10-watt unit. Fig. 3 provides for network to be plugged into the 20-watt low-frequency amplifier.

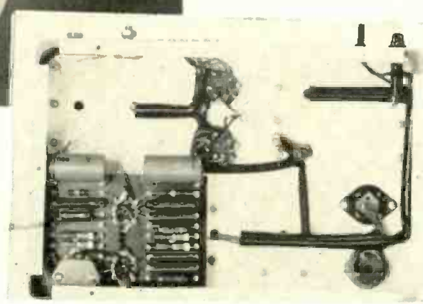


Fig. 2 (right). Underside view of the 20-watt amplifier. Large mica capacitor at lower left is C_1.

Most amplifiers are developed and tested using pure resistive load impedances across the secondary of the output transformer. Determination of intermodulation distortion, harmonic distortion, and power performance are based upon results obtained using these resistive loads although it is well recognized that speakers do not present a constant load impedance over the entire frequency spectrum. However, for want of a better method, resistive loads have been retained as a standard procedure in determining the performance and operating characteristics of amplifiers.

This paper proposes a basic change in amplifier circuitry that is inevitable if amplifiers are to perform their basic function—that of presenting an electrical power waveform to a speaker in such a manner that the acoustical wave radiated from the surface of the speaker is a

(Continued on page 52)

* *White Sound, Inc., 105 W. Madison Street, Chicago 2, Ill.*

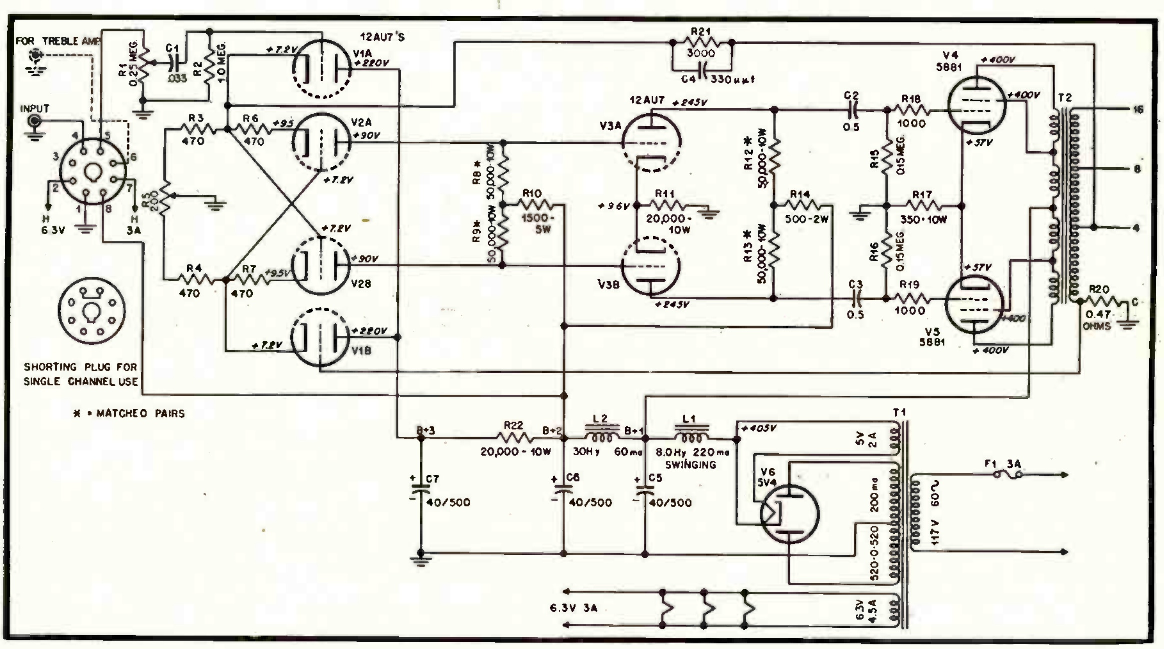
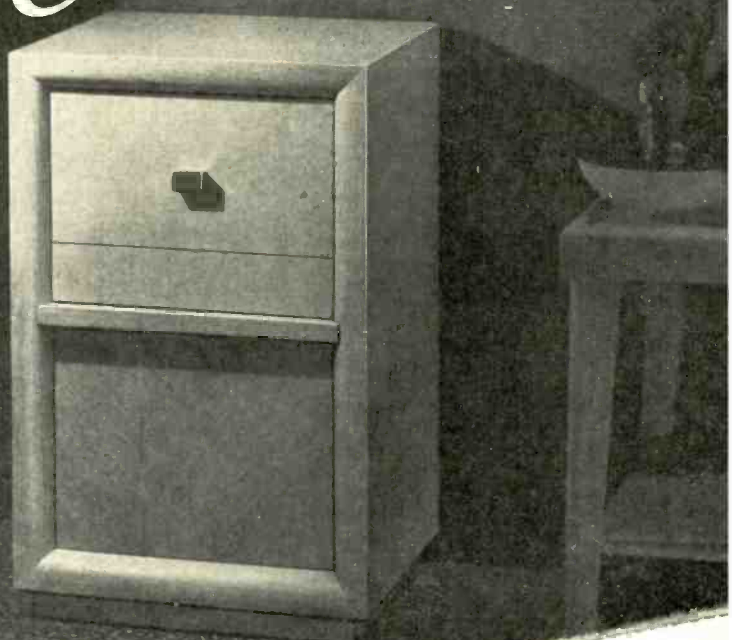


Fig. 3. Complete schematic of the 20-watt White amplifier arranged for plugging in the electronic filter network. 10-watt model is identical except for output tubes, which are 6V6's, and the output transformer.

the beautiful

Peerage

sound equipment console
for music lovers!



Pivoted, tilting top panel opens with brass pull and mounts all conventional tuners. In open position, controls are at easy-to-read 65 degree angle. Amplifier is mounted on back panel which is readily removed. Changer drawer is directly below tuner panel and is mounted on roller slides for smooth operation.

Note how the PEERAGE complements the famous E-V Aristocrat folded-horn enclosure (below). Its simple, graceful lines harmonize with other E-V enclosures as well and lend themselves to any contemporary setting.

Now, for the first time, a truly beautiful and practical console expressly designed to house virtually any combination of the popularly-known tuners, amplifiers and record changers! Made by furniture craftsmen, the PEERAGE is so cleverly planned that it is a simple task to install—*at home, with ordinary tools*—all the components needed for High Fidelity sound reproduction. The PEERAGE is made of sturdy, kiln-dried veneers and is available in lustrous Tropical Mahogany or sparkling Blond Korina.

Write for complete brochure No. 192 showing mounting arrangements, internal compartment sizes, and tuner-amplifier and changer combinations which fit the PEERAGE—or see your local E-V distributor.

DIMENSIONS:
29¾" high, 20½" wide, 18¾" deep.
WEIGHT: Net, 43 lbs. Shipping, 52 lbs.
PRICE (less tuner, amplifier and changer):
MAHOGANY, List, $160.00, Audio-phile Net, $96.00;
BLONDE, List, $170.00, Audio-phile Net, $102.00.

Electro-Voice Inc., Buchanan, Michigan

Export: 13 E. 40th St., New York 16, U. S. A. Cables: Arlab

Audio ETC

EDWARD TATNALL CANBY*

THERE'S NOTHING like a good trip away from home. In those few short weeks last summer when I was neatly isolated in Europe from audio and hi-fi and new records alike everything popped; plans secretly afoot for years burst forth in public announcements, audio prepared for its biggest "fall opening" yet—but the most important thing that happened was not in the audio field itself at all but outside, for it marked, by the most rigorous of American business judgments, at long last, Audio's Coming of Age. Suddenly, completely, audio was publicly recognized by the commercial radio-phono-TV industry! Recognized both in the heady persuasion of big-time publicity and in the fact of newly announced commercial phonographs, designated for the first time with the magic words, *high-fidelity*. So the fat's in the fire—and where, pray tell, do we stand now? A very interesting question.

I'd sort of expected, at this point, to quote a bit of chapter-and-verse indicating how much evidence we've been offering here, right along, that all this was bound to happen. My eyes gave out on me too soon—we've covered a lot of fine print in this department in six years—and so I'll do no more than remind you of that continuing cycle of development in the audio field, described intermittently in this space, which has led straight to the present point: the discovery, a long while back, that home record playing equipment made from separate units, sold "wholesale," offered unusual advantages; the gradual exploitation of this in a business way by the erstwhile wholesalers, now become audio men; the increasing concessions made to the needs of the buying amateur public—plug-together, pre-wired components, pre-chosen "package" systems, retail-style sales rooms with comparison facilities, increasingly wide advice service, and all the rest. This department has been all for it right along, and can claim a fairly remarkable coincidence between its suggestions and subsequent events, whether it be accidental or not. But let's look closer.

Ultimate Step

It was a year and some months ago that, under title of "Hi-Fi for Aunt Minnie" (Æ, August, 1952, p. 30) I described what seemed to be the last and ultimate step in this cycle that audio-for-the-amateur could take—the one-piece separate-unit "system," completely assembled in a cabinet and ready to play. This was the end-product, in a sense, of all that development that had begun with the strictly professional radio parts dealer and worked itself by degrees—still at wholesale or "net" prices—right up into a new major consumer's sales area. Having gone this far—what next? What more could audio do, with respect to merchandizing? The circle was almost complete. We had progressed back to the single phonograph again.

Would hi-fi next try to invade the mass market itself, in direct competition? Or, alternatively and perhaps simultaneously, would the big commercial concerns come the other way, and take over high fidelity for their own? If so, wouldn't there be a sort of final merging of the two, inevitably, so that the long-strict distinction between what we've come to call "hi-fi" equipment (leaving standards aside for the moment) and "commercial" equipment might begin to disappear? Worst of all (for us, in the hi-fi area), would Big Industry take over, and swallow up hi-fi with one vast gulp, when the time was ripe?

Until Columbia's "360" phonograph came out last year, the commercial industry had acted in just about every way as though hi-fi (and its wholesale system) didn't exist, or wasn't big enough to be noticed. With commendable discretion the industry avoided even the terms "hi-fi" and "high fidelity;" the nearest approach was an occasional modest (relatively) "fine" or "full" fidelity. The separate-parts audio field had hi-fi to itself, outwardly, without interest from the mighty on high. Children must play and (so one might have guessed) the "parents"—those radio-phono makers who, after all, had been supplying the nation's record playing equipment and radios for as long as most of us can remember—went about their business, occasionally denying with some asperity (through their retail dealer-representatives, when questioned) that this new upstart business really counted.

The asperity increased, quite naturally, as "net" price hi-fi mushroomed and it became increasingly difficult for retail radio-phono dealers to slough off hi-fi. Outwardly, there was no change, but we may now be sure that behind the scenes wheels began to turn, in secert, to meet the growing competition. It takes a mass industry a long time to get set for a major policy break; those wheels no doubt have been running faster and faster these last several years. How could it be otherwise, with the once baby hi-fi industry growing apace? Just a matter of time before things would bust wide open . . . right now.

What Favors Mass Production?

But before we carry this little narrative into a hypothetical future, look with me at the basic differences which have separated the two areas of home sound reproduction up to the present. What does "hi-fi" or "audio" (there isn't any official name for it) have to offer, that has boomed it so rapidly in the very face of commercial production?

In reverse order, more or less, we might say (a) higher sound quality for the dollar—the end-product; (b) separate units, out of numerous specialized makers—with attendant flexibility of choice and application; (c) the "net" price system of sales, which narrows the spread between manufactured cost and final cost—cuts out the middlemen, as the old saying goes; (d) (from the buyer's viewpoint) an entirely separate and distinct sales outlet mechanism, rigidly set apart from the retail dealerships.

The commercial phonograph (and radio-TV) is a mass produced unit, geared in its total existence to the typically complex American production system, from raw materials right through to sales. That system has enormous potentialities, as is obvious to anyone. But it has weaknesses, too. It is to big for quick change, and must depend largely on superficial modernizations, year by year, bolstered by all the arts of publicity.

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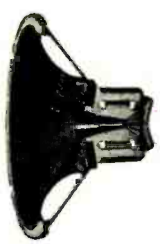

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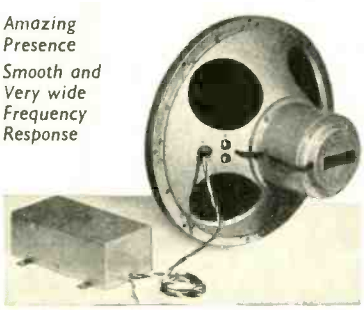

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The mass product system, moreover, depends on the complex, many-stepped distribution arrangement and the huge mark-up—and exists mainly because in so many cases it can make the basic product so incredibly cheaply, in quantity, that a large mark-up *is* possible.

More specifically we, in our own field, must understand that mass industry depends on two big factors for success—largescale heavy operations, like the stamping-out of auto bodies and fenders, and/or the high-speed automatic machine production of small parts, by the millions, and the high-speed assembly of same, often automatic. A large-scale production job is successful in these terms above all, and those products which are best adapted to this kind of production are the ones where big industry has expanded most successfully. Note, indeed, that products formerly hand-made, after a fashion, that can be newly adapted to mass production suddenly take on new business potentialities—I think at once of shipbuilding and pre-fab housing as recent examples. In the old days, the conversion of the auto industry was a celebrated case in point.

Now I ask you, is audio a "natural" for mass production in this sense? First, is there heavy work—large-scale casting, foundry stuff and the like—where big industry can get its grip for fair? No! Second, can small parts be turned out by the millions and assembled at high speed? No! Parts, yes—but not assembly. You can't whip amplifiers and pickups and speakers together. Lined up against thousands of other American products, the phonograph-radio and its component sections makes a relatively poor subject for mass production, and this in spite of the best that ingenuity has devised, to date.

The plain fact is that the sound reproduction mechanism *is favorable to mass production only in its simpler, cheaper, and cruder aspects*—small radios, portable phonos, and their equivalents hidden inside the fancier consoles.

As quality increases in audio equipment, susceptibility to mass production goes down. Not all the king's horses, nor the biggest producer in the industry, can change this. Quality audio is basically a craft industry.

Craft Industry

It's not hard to see, then, why in our particular area there has grown up a craft-based business to compete in the home with mass-made products and give a better value for the money in pure sound. We don't find that sort of development in areas where mass production is really at home. Who ever heard of a "craft" washing machine—a better bargain than a mass-made one? That's heavy industry. There are "craft" autos, to be sure, but only at a high price dictated directly by the unfavorable economics—in that area—of the craft system.

You can count on your fingers and toes those products which occur to you as basically of a craft nature, where mass production is at a natural disadvantage. You can count on your thumbs, I'll bet, those where a *big business* has been built on a craft basis offering values to compete directly with a parallel (more or less) mass industry. That's us. That's audio!

By "craft," I mean, of course, the modern equivalent of the old hand-made, one-at-a-time fabrication. In today's relative terms a craft industry is one where product runs are small, attention individual, flexibility in design change very great, where there is relative specialization as in our component construction. There is no exact dividing line, naturally, but the distinction holds in general and is, indeed, vitally important for us to understand.

Never the Twain Shall Meet?

And here we had better glance quickly at some interesting associations. In general, craft industry is associated in most minds with "small business." There are plenty of natural affinities. But audio is now straining its whole might towards being a collection of large businesses. Larger than small, anyhow. How big can a craft business be and still be craft? That is a vital point, in the present set-up.

Another association, in the audio field, is that of the craft-type industry as above described with the wholesale or "net" sales set-up—and this is an even more pertinent matter. For here are the two really basic divisions between the new audio industry, or "hi-fi," and the old "commercial" industry. Are the two *neccessarily* tied together? Must craft hi-fi necessarily be sold through the new "net" sales system and its newly grown outlets? And vice-versa?

At this moment, the tie-up is extraordinarily potent and, indeed, it would seem to me that the entire basic set of differences between commercial and craft audio has now been externalized into a straight fight between the two existing types of sales outlets—and never the twain shall meet. The situation is the more exciting right now because of numerous forays from one side to the other at present going on. Maybe the net price itself no longer has much meaning, literally, but until the day when a product—whatever product—can be sold at one and the same price in all of the present sales outlets, both the "retail" dealers and the new hi-fi stores, the basic difference continues.

Now the odd thing is that in all the present excitement over big-company entrance into the hi-fi field, the big-time confusion, even the delicately balanced in-between operations of the makers of true separate-unit one-piece hi-fi phonographs—I know of no case yet where the two sides have actually been bridged. Every product, from whatever source and however ingeniously compromised between craft and commercial, however deviously advertised, finds its sales place definitely on one side or the other of the Great Dividing Line—or if not, then it sells at *two* prices, list and net. (At the moment the only way to avoid this inexorable law of the times is to issue two models virtually identical but with a different title or name. Price them differently, channel them to different sales areas. So, I gather, has one of the big component makers recently solved his manufacturers' price vs. net price problem—the same thing on another level.)

The complexities of the great list-and-net problem are more than I dare explore further at this point, but we have enough here to take a good look again at the present explosive situation, as of this article's opening.

Commercial audio has at last announced its entrance in the "hi-fi" area, with publicity and with machines. Do these machines compete directly with present craft hi-fi equipment?

It would certainly seem that competition is wide-open—the ads say so and the public undoubtedly thinks so. Indeed, the public is not really aware that there are two sides of this question, two kinds of "hi-fi". Without the slightest doubt, then, the commercial machines that claim hi-fi will compete directly with craft audio *on paper and in the public mid.* This we must face, as soberly as we can, for the ad money is back of the commercial machines. The war of words is on.

But how do these commercial hi-fi machines stack up directly against their craft-type opposite systems, roughly cost for cost? Put aside the AB comparisons until we get two vital points absolutely straight.

First, however radical and ingenious and commendable the changes are towards adapting some of the principles of hi-fi to the commercial machine (and they are often to be admired), these new models are still mass-produced. They still must take along with them the whole of the baggage of the mass production system, the millstone of a basically unfavorable product in the mass-produced field. That basic situation cannot be quickly changed.

I say plainly, then, that no mass produced machine coming from the present manufacturing set-ups is going to compete in sound value, dollar for dollar with the craft type of sound system, nor can, except in the very low priced categories, where craft hi-fi has never claimed a place. The differences in convenience of operation and attractiveness, of ease of purchase (at the local retail outlet) and all the rest are another matter and continue legitimate, as before. We must remember that vast numbers of people still preferred even the old commercial machines to anything that craft hi-fi could offer. Present basic differences between commercial-type and craft-type equipment then will continue very much as they have been, in spite of the new models and the new advertising. *This we must not forget.*

Secondly, don't for one moment forget that the new commercial machines continue to sell strictly on a retail basis through retail outlets—and therefore on the sales floor they are in competition *only among themselves*, never directly with craft hi-fi products. The separation is extraordinarily complete, as far as I can see. (Except of course in the ads, on paper, and occasionally in the home.) There aren't any AB tests between the two types, because they never are found in the same place! I can't say what'll happen in the near future in the general fracas, but as of this writing I'll bet you can't locate any sales floor in the country where a true craft-type hi-fi system is in direct audible competition with any one of the new retail commercial machines. It won't happen if the makers can help it.

(*Continued on page 59*)

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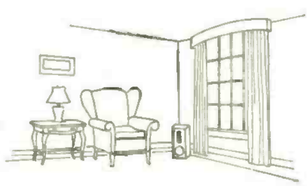

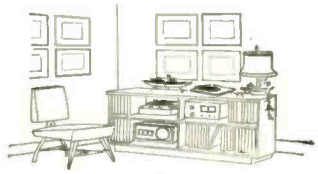

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PINES AND FOUNTAINS

Respighi: The Pines of Rome; The Fountains of Rome. NBC Symphony, Toscanini. Album booklet.
RCA Victor LM 1768

The most striking thing about this album, as everyone knows by this time, is the thirty-page bound-in collection of art photos in deep green of scenes of Rome—the fountains and the pines. (Having just come from there I marvel at the photographer's ingenuity in avoiding even so much as a trace of the teeming modern life of Rome—the autos, sightseeing busses, bicycles, trucks, trolley busses, trams, and, of course, city people, that normally throng about the scenes depicted! But that is perhaps the very art of it; the pictures are superb.) There is just the one record, and it's Toscanini through and through, though hitherto we have not found him often among "hi-fi" conductors.

Frankly, I never could like this music enough to enthuse over its undoubted hi-fi potentialities. But anyone with an ear can understand the Toscanini intensity, that taut, rapid, almost breathless super-control, those strangely whanging kettledrums (they sound the same, hi-fi or no), the steely potency of the climaxes that are so typically his. Nobody, but nobody, as Gimbels says, can beat the Old Man at this, nor at bringing out the most in Respighi. Not either of the other recent conductors who have taken a wham at the music for hi-fi, Dorati (Mercury) or Quadri (Westminster).

How is this as hi-fi? RCA's manual click-type groove pitch control ("margin control") gives the disc a very odd banded appearance and provides beautifully for the climaxes, at wide groove spacing, notably the final March. The New Orthophonic technique does all it should and the expanse of highs and lows is gratifying—but I suggest that one aspect beyond the control of any recording curve or cutting technique—the microphoning—is not quite ideal here. The sound is a bit narrow, not as full as it might be, and the lower end seems somewhat at a distance. Not, I am sure, a matter of curve or distortion at all but merely one of those subtleties of mike acoustics. Also, possibly a question of opinion rather than fact—better listen to the Westminster and Mercury versions (the latter definitely one-mike) for comparison. (See also Berlioz' Romeo and Juliet, below.)

THE SPOKEN WORD

John Brown's Body. Tyrone Power, Judith Anderson, Raymond Massey, adapted and directed by Charles Laughton; choral music and effects by Walter Schumann.
Columbia SL 181 (2)

Shakespeare: Macbeth. Old Vic Company.
RCA Victor LM 6010 (2)

Today, some five years after LP's debut, we are finally beginning to realize the full power of the new medium. Back in the late 40's, LP was still merely a new way to issue old-style records, though we all hailed the convenience of its length, sound quality, freedom from rhythmic background noise, unbelievably small bulk and gratifyingly low cost. LP was then a kind of adhesive tape with which short discs were stuck together into long discs, the breaks more or less concealed. And as long as the 78 kept alive as a parallel to LP, so long were we tied to the short slices, whether we heard them or not, and to the patch-it system.

Not now! Such ventures as the above, not to mention a gross of complete operas and no end of other large-scale endeavors, are inconceivable on the old discs. Of these two, "John Brown's Body" perhaps shows the most radical expansion of the recording technique, (speaking dramatically) but the rendering of Macbeth is surely as significant in its way.

"John Brown's Body" as a narrative poem was extraordinary in 1928; in the present adaptation by Laughton, equally valid on the stage (with modern dress and no scenery) or on records, the same sort of free-verse word-painting is as challenging as it ever was on white paper.

Three principal voices, speaking in rapid and easy alternation, share between them in the most impartial way both the continuing "role" of narrator or story teller and the actual voices of specific characters; the ancient and honorable tradition of the drama whereby each person in the play is represented by a specific body, a voice who speaks directly in his words, is thus blithely put aside and with the easiest charm you can imagine. Direct "quotes" change off with indirect narrative, as though the speaker were reading a novel out-loud; sentences are broken up between the contrasting voices even though the indirect narrative continues its familiar "he said" and "she said" pattern—and not a particle of sense is lost in the process.

In between, in the long-familiar technique of radio dramatics, serving as bridge and mood and background, as commentator and scene-shifter, is an a cappella chorus, without instruments. The music, as such, is conventional, out of a hundred similar dramatic works of a patriotic nature. But surely the choral medium has never been carried so far, the technique so expertly managed, as here. The chorus sings (with solos), hums, chants, shouts, makes sound effects—even the sound of a banjo—and bursts out periodically with that old piece of ham, "Glow-ry, glow-ry hallelooyah," sung in the best Broadway manner; a strange mixture of superb singing-acting technique and strictly big-time show stuff.

'Nuff said. A remarkable job and the words and story are absorbing and in plenty of spots superbly beautiful. The three voices are recorded with unbelievable clarity and without bottom-heavy tubbiness, even on large speakers. Hi-fi fans will exult. (Somebody did some good thinking on the problem of miking voices for close-to effect; as we all know it's not easy. Was there perhaps a low frequency cut-off?)

"Macbeth" is done straight, with few sound effects and those few of the cornier sort—thunderclaps and low-fi rain (probably from some elderly 10-inch 78), trumpet fanfares, studio-style crowds hailing the king—but what carries this recording to immense success is Shakespeare, and the excellent speakers who record his words. Note the Old Vic's modesty in billing no names, above, but Alec Guinness, Pamela Brown, Anthony Service and others of similar ability do the job. Acting is in the usual Shakespeare tradition of high-flying oratory, but these people know how to keep it within bounds (except for a few minor characters).

As an experiment—and not having read Macbeth for any number of dogs' ages—I listened to this "cold," without so much as a look at the labels, booklet, dramatis personnae or anything else, to see whether it might by itself make sense. It did, by golly, and remarkably well, though the voices and characters and the places were strictly unidentified for me. The truth is, as I had hoped, that Shakespeare's own texts take care of a surprisingly large part of the background information, and necessarily so since his plays were originally acted with virtually no scenery, in then "modern dress," with only the barest of hints here and there as to armies, balls, kings' courts. What could be better for the new recorded medium!

It's perhaps not so odd, in view of this, that there isn't a vestige of the "story" included in RCA's accompanying booklet, which treats mainly of the Old Vic company. Macbeth is left strictly to its own devices, and does royally by itself.

Berlioz: Romeo and Juliet. Complete Dramatic Symphony, op. 17. Boston Symphony, Münch; Harvard Glee Club, Radcliffe Choral Soc., solos.
RCA Victor LM 6011 (2)

It's not too strange to find this under the two above items, classed as "The Spoken Word." Of all musicians of his day, Berlioz came nearest to expressing the sense and the feeling of spoken intimacy via a large orchestral aggregation. Not Wagner, not Verdi, not even Brahms, came near to this strange vocal power; perhaps Schumann came closest in his orchestral works.

Last spring we had a semi-complete orchestral version of this music, filling out the familiar excerpts with new ones; this at last, is "the works" and for the first time we can see the whole plan. It's no symphony, nor an opera; the Berlioz methods of story-telling are as unorthodox as those of "John Brown" above. There is no Juliet, nor any Romeo though there are solos—a tenor and a contralto; the climaxes of the story are told through the orchestra alone, the actual voices silent. At times, Romeo and Juliet converse in the plainest and most moving tones—via cellos and violins. The chorus is more than Montagus and Capulets, its obvious background role—it echoes tirelessly the narration of the solo singers and of the orchestra itself.

You'll find this a superb piece of big-scale listening, except perhaps for the last side, where Shakespeare's wisely simple ending for a tragedy of two very young people is blown up by Berlioz into a French-opera climax of noise and exultation. The chorus, college-age, makes it wonderfully clear that Romeo and Juliet were indeed youthful, in spite of the middle-aged and well padded people who generally take their roles on the stage! The singing is lean, accurate, enthusiastic and the very spirit of youthfulness. Note especially the Funeral March for Juliet with its sharp reiteration of "Jetez des Fleurs" and the lovely wordless twining of the women's parts, soon after, as the men take up the narration. (Side 3, band 2.)

I had heard complaints that this recording was difficult to equalize satisfactorily; I don't seem to have any trouble. Again, I suspect that the seeming thinness of the highs in a few spots and a fairly unobtrusive bass end are merely acoustical

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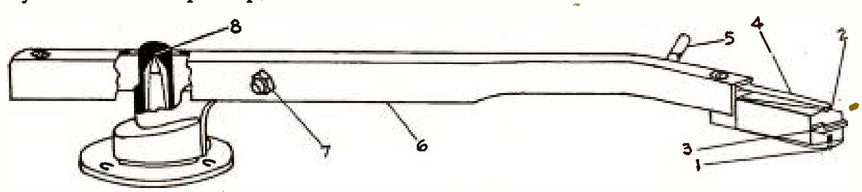

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tricks of the miking. It is conceivable, after all, that the bass end actually sounded that way—or the bass instruments were not as immediately close to the mikes as we are accustomed to. The recording was evidently multimiked and I feel that perhaps the sound ensemble is a bit "off-mike" ideally speaking, a shade less full and round than it could have been. And at one point what seem to be very close-by solo breathing sounds introduce a false "note" that indicates a possibly over-complex mike set-up. Speculation on my part; I wasn't there, and as always, opinion—any listener's—weighs heavily in such evaluations. Try a bit of Columbia's orchestral version (Mitropoulos, New York Philharmonic) for a valid comparison.

SPANISH

De Falla: Pièces Espagnoles, Ritual Fire Dance. Turina: Ninerias. Jesus Maria Sanroma, piano.

Polymusic PRLP 1011

Granados: 12 Spanish Dances. Jose Echaniz, piano.

Westminster WL 5181

Piano Music of Spain. Leonard Pennario, piano.

Capitol P-8190

Three dishes of Spanish tid-bits and entrées and I'd choose from them in the order listed. Sanroma, long-time official pianist of the Boston Symphony, has always been a strong-arm pianist —I remember calling him "the Powerful Sanroma" (after the Powerful Katrinka of comic fame) as far back as before the war. In the ready classics interpretations which most official pianists must turn out on order, I'd place Sanroma's in the hard-boiled category—note-perfect but often nerve wracking. However, he is of Catalan blood, born in Puerto Rico, and as one can instantly sense here in spite of some very loud sounds, the 19th century Spanish idiom is completely natural for him. I like particularly what may at first seem a too-great use of the pedal, in contrast to the drier technique of the other listed gentlemen. Here, it serves for color and atmospheric veiling and, in the last analysis, is not overdone in the sense of creating tonal confusion. Altogether a brilliant and essentially musical record, the seldom-heard Hurinas and De Fallas an excellent addition to the repertory. Good, middle-distance piano recording, some bad crackles on my copy.

José Echaniz, born in Cuba, seems to have different inclinations in regard to the Latin-Spanish idiom. His material, to be sure, is of less intrinsic interest, to my ear at least. The twelve dances, recorded complete and "for the record," are pleasant but not very strong music, semi-salon stuff, and the few famous ones do, for once, seem to be the best of the lot. The Echaniz technique, for a Latin, is strangely Bach-like; the inner accompaniment lines, which can add so much atmosphere, are here played loudly, clearly, dogmatically, the lilt of them is missing and the pianistic shadings of color and level and mood and phrasing seem weak. Ingratiating playing, even so, and there is a feeling of sincerity that is good.

Leonard Pennario has what is far from uncommon these days, a fabulous finger technique that can and will tackle virtually anything for his instrument. The present recording confirms my reluctant feeling that there is more fingership than musicianship in his performance. A hard, staccato technique, a cold (to my ear) approach, a lack of phrasing and shaping, go along, unfortunately, with a rather chilly and dry sort of piano recording, without liveness, that will sound fine if you can provide your own concert hall but may smack too much of wires and hammers in a small room.

Albeniz-Arbos: Iberia. Turina: Procession del Rocio. Granados: Intermezzo ("Goyescas"). De Falla, Interlude and Danza ("La Vida Breve"). London Symphony, Gaston Poulet.

M-G-M E3073

Side 1 of this disc makes an immediate hi-fi impression—the "Iberia" suite—but side 2, with the rest of the items, has a better musical sound for me at least. The Arbos orchestration of "Iberia" is fussy, complex, full of hi-fi noises but too involved in its own fancy trimmings to come through well musically—or at least not in a brilliant, close-to recording of this sort, which accentuates the orchestral colors and the solo

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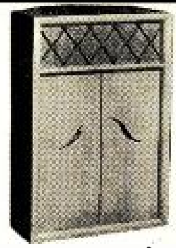

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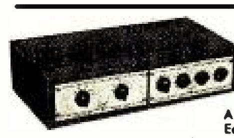

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voices at the expense of over-all ensemble. The second side features more conservative orchestration and what seems to be the better ensemble. Was there a different mike arrangment, or is the difference purely in the texture of the music itself? Some crackles in my copy.

FRENCH

Ravel: Valses Nobles et Sentimentales; Le Tombeau de Couperin. L'Orchestre de la Suisse Romande, Ansermet.
London LL-795

Here's one of the most satisfying Ravel discs for a long time, combining two works that have often eluded the right combination of recording technique and interpretation in performances hitherto released. The most shimmering of ffrr sound is beautifully applied here, the sharp, clean texture of close-up highs well balanced by the feeling of over-all liveness and atmosphere. The Ansermet interpretations are notably high-level, done with the exacting care that is required for every Ravel score, that each phrase, each shadow of tone color be in precise proportion, modelled, polished to a shine. To be sure, there are other and radically different approaches to the music of both pieces. Here, the Waltzes are relatively slow, much of the implied violence and frenzy is put aside in favor of their equally implied graciousness and color. Le Tombeau, which too often is tossed off with all its minuets and rigaudons as a piece of minor frippery, here finds its own best dignity as one of the very finest pieces in the Ravel literature. A wonderful record to complement the big hi-fi noise makers in your demonstration pile.

Ravel: Tzigane. Chausson: Poème. Honegger: Concertino. Milhaud: Piano Concerto #1. Eliz. Lockhart, London Symphony; Fabienne Jacquinot, Philharmonia, Fistoulari.
M-G-M E3041

Just skip the jargon printed above—this is surely one of the oddest collections of French music yet compounded on a single disc. Lockhart is a violinist and plays Chausson and Ravel; Jacquinot is a pianist and does the Honegger and Milhaud opuses; the whole, with two orchestras, is led by Fistoulari.

Gem of the collection is the late-Romantic Poeme for violin and orchestra of Chausson, who was a close follower of César Franck. Ordinarily the Franck satellites show up as pretty windy and overblown beside their master, who could blow a long tune himself, but in this performance, at least, Chausson comes through with sincerity and a very moving simplicity. A good deal must be credited to the performers; there is an unusual sense of quiet restraint here, a long-breathing, sustained line that is not too often heard on records.

The other items are of another world, the jazz epoch of the 20's. The Honegger Concertino followed right upon Gershwin and Milhaud (La Création du Monde) as an early try at "classical jazz"; today it is a feather-light bit of expert orchestral whimsy which is too heavy here for my taste—the whipped cream has gone flat. The Milhaud concerto, of the same snazzy period, has more to it, yet perhaps is actually less expertly molded as we now hear it.

Ravel's strange "Tzigane," an evocation of Gypsy improvisation, is almost entirely prelude—for the unaccompanied solo violin; the orchestra (in another version, the piano) doesn't appear until almost the end. The gypsy-like tunings-up, the dark and foreboding runs, double stops, harmonics, constitute a fiendishly difficult exercise for the player, though hardly a display piece in the usual sense. Lockhart's playing is the sort that takes extreme liberties with pitch, en route, so to speak. I can appreciate her desire to make this music guttural and stringy, in the gypsy manner, but even a gypsy would find ways towards more accurate playing than this! Maybe you have the very early 7-inch LP of the same by Szigeti (with piano); if so, you'll know the way it should sound.

Speaking of gypsies—

Gypsy Music, vol. III. Antal Kocze, King of the Gypsies, and His Band.
Westminster WL 3002 (10")

I'll have to admit that this gypsy, nominal prizewinner and hence "king" among gypsy players, swoops about the pitch much as does Lockhart, above, in these semi-improvised café pieces from Vienna. But on close listening, I think you'll find a basic steadiness beneath the

Kocze playing that belies its strangely drunken sound. Even so, steady or no, I'm afraid I'm no gypsy fan; the stuff on this record (and earlier ones in the series) puts me to sleep at once. Maybe the Duke of Windsor and Toscanini did like it. . . .

The miking has something to do with my feeling. The solo violin is very close, very loud, the handful of other strings virtually inaudible, only the accompanying cymbalom (like an old upright piano with the pedal stuck) comes through for harmony. That, too, may be quite proper and in the tradition, for all I can say . . . come to think of it, you'd better tear right out and get the record for yourself. You'll probably enjoy it, as a lot of people undoubtedly have.

NEW LITERATURE

• **CBS-Hytron,** Danvers, Mass., fills the need for a practical manual of basic information on transistors in a new eight-page booklet which is offered free of charge. Well-illustrated, the booklet is in three parts—Theory, Data, and Application. Problems which remain to be overcome before the transistor can find universal application are described, as are those which were solved to bring the device to its present stage of usability.

• **Automatic Electric Company,** 1033 W. Van Buren St., Chicago 7, Ill., has produced a helpful guide to engineers in a new catalog of "telephone-type" components for industrial use. Illustrated with scores of photographs and diagrams, it contains specifications and general data on key switches, impulsing devices, switchboard lamps, jacks, plugs, etc. Copy will be supplied on request.

• **Miniature Precision Bearings, Inc.,** Keene, N. H., has just completed an exceptionally fine catalog which tells just about all there is to know about the design and application of miniature ball bearings. Two-and-a-half years in preparation, the 20-page three-color booklet is a veritable encyclopedia of practical information, with all technical data liberally supported by drawings, graphs, tables, and photographs. If you use tiny ball bearings, you have a distinct need for this publication.

• **Radio Shack Corporation,** 167 Washington St., Boston 8, Mass., is now distributing free the largest catalog in the firm's 31-year history. Containing 224 pages in all, the catalog includes a 32-page rotogravure section devoted solely to high-fidelity audio equipment and custom-built home music systems. Highlighted in the general equipment section are extensive listings of transistors and germanium diodes, converters and test equipment for UHF-TV, printed circuit components, and radiation detection apparatus.

• **Hammarlund Manufacturing Company, Inc.,** 460 W. 34th St., New York 1, N. Y., describes equipment for the remote control of broadcast transmitters—a type of operation only recently made possible by an FCC directive—in a new brochure which will be mailed on request. The equipment makes use of audio tones for complete control and metering of the remote transmitter. It requires only a single circuit which may be wire or microwave. This publication will be of distinct interest to station managers.

• **American Standards Association,** 70 E. 45th St., New York 17, N. Y., emphasizes the economic importance of standardization in a new 24-page booklet titled "Standards Are Your Business." The booklet gives the philosophy and objectives of the voluntary standards movement in this country, and includes specific examples of recent savings effected through standardization by leading corporations. Copies are available without charge.

• **G & H Wood Products Company,** 75 N. 11th Street, Brooklyn, N. Y. has just issued a new catalog on its Cabinart line of custom-styled hi-fi cabinets and kits. Small enough to carry around while on a shopping tour for comparison purposes, this brochure describes the entire line, including the recently added Klipsch Rebel IV series. Complete specifications and choice of woods and finishes are given for each cabinet. Copy may be obtained from your local parts distributor or by writing the company direct.

it CAN be ATTRACTIVE

(*from page 31*)

may not be attained, but unless the job is inspected with a magnifying glass, most of the slight imperfections may not be noticed by the average person. The fact that the builder knows about a joint that is not exactly square or a crack between a door and the adjoining jamb is not uniform will not make any difference in the way it sounds, and such imperfections can usually be found in even the best-built homes. The most important considerations are those relating directly to the quality of the sound coming out and those are dependent on design rather more than upon the execution of the original plans of the owner.

Basic Requirements

A number of questions have to be asked—and answered—before a complete plan can be laid out for a home installation. For a built-in system, the space requirements must be considered. Listed in the next few paragraphs are the most important points that have to be covered before starting the actual work.

Loudspeaker. Whenever possible, the loudspeaker should be located in a corner. For built-in installations, this gets somewhat difficult, for very few storage-wall or conventional built-in cabinets provide a space suitable for a speaker enclosure across the corner of a room. But it should be considered if at all possible. This writer does not prefer that a speaker be mounted high up—such as a ceiling corner or above the television screen as on this month's cover, but in many instances no other solution is possible. In any case, adequate room must be provided—preferably six to eight cubic feet, although there are some very satisfactory enclosures that may simply be made a part of the built-in units, and which are of the order of two to three cubic feet. The interior walls of the enclosure must be well braced, and should be lined thoroughly with Ozite, Kimsul, or some other sound absorbing material. Needless to say, the back and side walls should be airtight.

If a two- or three-way system is planned, it is generally thought best to place the low-frequency unit at the lowest part of the enclosure, with the high-frequency unit(s) above.

Many installers use a piece of plywood for the speaker baffle—usually ¾-inch material—without any paint or staining prior to covering with the grille cloth. This usually results in dark circles where the speakers are mounted, for most speakers have dark gray cones, which reflect little light. One of the "tricks of the trade" is to paint or stain the front of the baffle board black or dark gray before mounting the speaker so that the entire front will appear the same color. Lumite grille cloth is recommended because of the firmness of its strands. Most cloth materials have progressively greater absorption of sound at the higher frequencies, with the result that the system is likely to sound dull unless suitable compensation is made in the tone control section.

Amplifier. A space 18 in. wide, 12 in. deep, and 10 in. high will provide for practically any of the power amplifiers on the market. Some of the McIntosh models—20W2 and 50W2—require more height, but if necessary they can be installed with the tubes horizontal. The control unit—or the entire amplifier in a single-unit system—should be located so as to be readily accessible to the user. Some installations require that the control unit be mounted vertically, and many of those on the market are arranged so as to have escutcheons that may be used either way. Ventilation is the big problem for the power amplifier, for it is the greatest radiator of heat. In cabinets of the type shown here, ventilation is best obtained by leaving the back off, or at least by providing large openings at both the top and bottom of the back, and preferably by providing several large holes in the bottom.

Typical cabinet housing the power amplifier in the lower portion, with a turntable and pickup and arm in the top along with the controls for the preamplifier which is custom-built and mounted directly on the motor board.
(Courtesy Kierulff Sound Corp.)

Phono Equipment. Whether the user employs a changer or a single-play turntable, it should be mounted in accordance with its instructions. Most changers are designed to mount with springs, furn-

ished with the unit, and this simplifies the installation. When necessary to use slides, it is suggested that heavy-duty types be employed so the changer may be pulled out or pushed back with a minimum of disturbance to the pickup on the record. A 6-c.p. bulb in a small fixture arranged to light up as the drawer is pulled out is a convenience.

If the system is to include a tuner mounted side by side with the changer, it is best to locate the changer on the right and the tuner on the left so that the pickup is as far as possible from the power transformer on the tuner. If crystal or ceramic cartridges are used, this caution may be overlooked, but with some magnetic pickups the field from a power transformer twelve inches away is sufficient to introduce so much hum into the system as to make it impossible to use the phonograph equipment with the tuner power turned on. And when the tone controls of the tuner are employed with the phonograph equipment, it is important that the power be turned on. This same problem must be considered in the installation of the power amplifier. One other hum-producer is the electric clock, which may be a convenience on the control panel. Make sure, however, that it is checked for hum before installing it permanently. A few inches one way or another may be sufficient to eliminate the hum problem entirely.

Tuners. The location of the tuner depends greatly upon the listening habits of the user and his household. Many families rely on the radio more than they do on records—there are others who are just the opposite. One will occasionally see an installation in which the tuner is almost inaccessibly mounted below the record player, making it necessary to get down on hands and knees to see the tuning indicator—if any. Of course, if records are the main source of entertainment, it may be more convenient to have the phonograph equipment above the tuner. The logical solution is to place them side by side, if at all possible.

Ventilation is important for the tuner, although it is not a great heat producer. With FM tuners in particular, there is likely to be considerable drift—even though most commercially built tuners have temperature compensating capacitors in the oscillator circuits so as to minimize drift, but too much heat will cause these circuits to exceed their limits and make retuning necessary at intervals. This caution applies even to those tuners which have a.f.c. circuits, for there are limits to how far these arrangements will work satisfactorily.

Preliminary Work

Once the various units of equipment are selected—their choice is not the province of this article—the first step is to plan for the installation of each unit. The space available must be considered in the selection of the units because one should not purchase a 15-in. dual loudspeaker to put in a 11-in. bookshelf, for example, and one should not choose an amplifier with a separate preamplifier-control unit unless he is choosing a tuner that is stripped of all controls except tuning and FM-AM selector. Other than making such decisions, it is desirable to obtain all of the components before starting any of the work of installation—or even of the actual planning. Place all of the units where they are to be located finally, hook up the system, and then try every possible listening combination. Try out the tuner—both AM and FM if you have them; try out the phonograph, then without a record on the turntable, turn the gain up to maximum and listen for hum. Move the pickup over the turntable and see if there is any hum at any point the pickup can traverse. If television is to be connected to the music system, try that out too. It may be that the illusion of sound coming from the picture will be destroyed if the loudspeaker is too far from the picture tube. A few hours spent in this work will result in greater satisfaction with the finished installation, and may save more hours of work in setting the system right after it is all finished. The front panels are not necessary just to determine how it will sound—except for the loudspeaker. After being thoroughly satisfied with the performance of the system in the location planned for it there is time for starting the actual construction.

All modern hi-fi components come with adequate templates for installation. One must make sure that the hole for the changer is laid out on the top of the motor board, for example. While it is often safer to work from the back or the

For the installation where a speaker can not be accommodated as a built-in enclosure, it is often desirable to utilize some form of ready-built cabinet, such as this one which houses two 15-in. woofers and a 2×4 multicellular horn. Properly designed, this type of cabinet can produce good sound.
(Courtesy Kierulff Sound Corp.)

underside of a panel, it will be found that templates are designed for marking on the front of the panel.

Panels for tuners and preamps may be made from ¼-in. hardwood veneer, and many units require that the panel be no thicker than ¼ in. When possible, it is preferred to use ⅜- or ½-in. panels to reduce the chance of warping, but if ¼-in. panelling must be used, be sure to provide means for attaching the panel firmly on all four sides. To cover the mounting screws, triangular moulding strips may be used—put together in the form of a picture frame, and fitting firmly in the opening provided. Felt washers around knob shafts will reduce light leakage from pilot lamps.

Slides for phonograph equipment are somewhat difficult to mount, but if one works slowly and carefully it should not be too difficult to end up with a smoothly operating job. It is important to keep the turntable level—whether for a changer or for a single-play turntable. Sufficient freedom must be allowed for the connecting cables from any equipment that is mounted on a slide drawer, and it is desirable to attach the cables to a hook at the top of the compartment at a point where they are just free when the drawer is pulled out as far as possible.

Electrical Connections

When separate units are installed in a system that envisages loudspeakers in several rooms, the problem of making the interconnections is sometimes frightening. In a single-story house, it is usually easy to gain access to the basement, or at least to the space under the floor. If so, holes in the floor may be employed to pass the wires. It is much neater to cut slightly larger openings and install some connecting receptacle—Cannon or Jones being recommened. For example, if speakers are to be located in three rooms in addition to the living room, an 8-terminal receptacle would be installed in the floor near the main amplifier, with leads running to the other locations where 2-terminal receptacles would be mounted, if for separate cabinets, or directly to the speakers, if built in. Some form of detachable connection is desirable in any case, so as to avoid the need for unsoldering in case any servicing becomes necessary.

In some instances there is no space under the house, and it may be necessary to do all the wiring in the attic. This is not a disadvantage, for built-in speakers are often located near a ceiling, which makes access from the attic quite simple. Leads from the amplifier can usually be snaked up through the wall (unless there is a fire stop) to the attic, but one method of getting from the basement to the second floor (or the attic) is quite ingenious. This method involves removing the door-stop strip from any convenient doorway and routing a groove on the underside of the strip. A hole from the bottom of the doorway—where it would be covered by the strip—leads to the under side of the floor, and a long electrician's drill will permit making an opening from the top of the doorway up to the second floor—through the wall and flooring. For such an operation it is well to choose the location carefully, but if the proper place is selected, the result is completely satisfactory.

For long runs, as may occasionally be encountered, there is no harm in running the wiring outside the house, if necessary to get the job done at all. Obviously it is much easier to make the installation of all interconnecting wires at the time the house is built, but the vast majority of installations will have to be made in houses that are already existent, and one must make the best of the facilities at hand.

With a little thought, a little care, and a little ingenuity, a built-in hi-fi installation can be just as attractive as the owner desires. There is no need for exposed chassis, unsightly wires, or unfinished cabinetry any more than there is any need for unsatisfactory performance. We would not buy an automobile that does not perform to our satisfaction, but we also make sure that it looks as good as we'd like. But with the home music system, the appearance depends entirely on the user.

—CGMcP

BOOK REVIEW

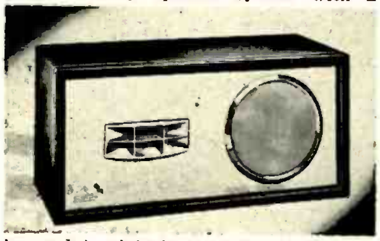
THERMIONIC VACUUM TUBES, by W. H. Aldous & Sir Edward Appleton. New York: John Wiley & Sons. vii + 160 pages. A "Methuen Monograph on Physical Subjects."

In this the sixth edition of this vest-pocket sized text, the authors present a completely revised and rewritten approach to the operation of the thermionic vacuum tube, from the simple diode through the latest reflex klystron and wave guide tubes. Naturally, in so small a book—and it is indeed a pocket edition—the coverage is brief, and extremely compressed. Relying upon the classical mathematical presentation, this is a book not for the student starting off in vacuum tube theory, but rather for one with the help of classroom presentations and tutorial guidance. Designed for the "student of general physics, who has not made a special study of radio-frequency phenomena" the book amply fills its destiny. But the serious student who wishes a more complete presentation, with descriptive explanation as well as mathematics will do well to look elsewhere in the technical literature.

Well annotated and with a good subject index, the format is annoying to the reader for there being nearly as many reference footnotes as pages, these have been collated at the end of the book, rather than placed at the specific page to which they pertain. For a quick refresher, or for reference purposes when seeking a specific formula, this book takes up little shelf space for the scope of its contents. —*L. B. Keim.*

NEW PRODUCTS

• **Small Hi-Fi Speaker System.** The new Jensen "Duette" meets the needs of the hi-fi enthusiast for whom space is a problem. Ideally constructed to be placed on a bookshelf, end table, or desk, it is a complete two-way speaker system with a

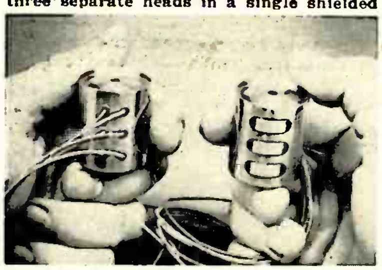


heavy-duty eight-inch woofer and a multicellular horn-type tweeter. The unit is attractively finished with a two-tone pigskin plastic covering accented with burnished copper trim. Although only 11"h x 23½"l x 10"d, the Duette affords excellent low-frequency response due to coordination in design of the woofer and the acoustic characteristics of the housing. Jensen Manufacturing Company, 6601 S. Laramie Ave., Chicago 38, Ill.

• **Record Changers.** Two new 3-speed record changers, differing only in the fact that one intermixes 10- and 12-in. records, while the other is of the non-intermix type, having recently been introduced by the Collaro Division of Rockbar Corporation, 211 E. 37th St., New York City. Both units are equipped with automatic shut-off. Turntables are precision-machined and

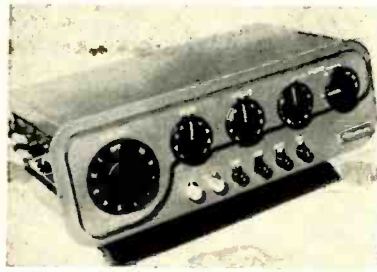
made of drawn steel, with top and sides covered with rubber. Designed for use with all standard magnetic or crystal pickups, the changers are supplied with plug-in shells. Among mechanical features are a jam-proof mechanism which permits handling of the tone arm even during a changing cycle without damage, a muting switch, and a 4-pole motor with self-aligning Oilite bearings.

• **Three-Channel Magnetic Playback Head.** Designed primarily for use on motion picture projectors which reproduce stereophonic sound, the new Tri-Di magnetic playback head is capable of exceptionally high quality sound reproduction. Advanced manufacturing techniques permit virtually perfect gap alignment. Comprising three separate heads in a single shielded

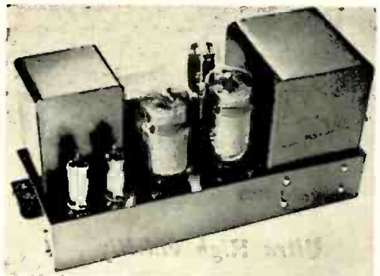


housing, the unit is machined to extremely high tolerances and is subject to rigid quality control. It has been tested to severe shock, vibration, and humidity conditions without apparent effect on audio characteristics, and conforms to requirements of the Academy of Motion Picture Arts and Sciences. Full technical details will be supplied to manufacturers of projection equipment by Tri-Di Sound Corporation, 4913 W. Jefferson Blvd., Los Angeles 16, Calif.

• **High Quality Audio Amplifier.** Push-button switching for three separate inputs and up to eight equalizing combinations for phonograph reproduction are included among the features of the new Q.C. II preamplifier-control unit intro-



duced recently in this country in conjunction with the new Acoustical Q.U.A.D. II 15-watt power amplifier. Although manufactured in England, both units are designed specifically for the U. S. market. In addition to volume and tone controls,



the preamp includes a continuously variable audio harmonic filter. Input sensitivity is three mv. Frequency response of the Q.U.A.D. is 20 to 20,000 cps within ± 0.2 db and 10 to 50,000 cps within ± 0.5 db. For complete information and literature, write Beam Instruments Corporation, 350 Fifth Ave., New York 1, N. Y.

• **Square-Wave Generator.** Extremely short rise time of approximately 30 millimicroseconds makes the new SKL Model 504 square-wave generator ideal for testing the response of audio, i.f., r.f., and video amplifiers. Producing a square-wave voltage without tilt or overshoot, the 504 offers continuously variable calibrated voltage from 0 to 11 volts. The

unit is equipped with a 9-position frequency switch, the first position of which permits operation at any frequency as determined by an external capacitor; the remaining positions afford frequencies from 0.5 cps to 500,000 cps in decade steps. The decade steps provide a convenient source of time bases from one second to one microsecond. The 504 and its self-contained regulated power supply are mounted in a compact, lightweight aluminum cabinet suitable for bench use. Further information can be obtained from Spencer-Kennedy Laboratories, Inc., 186 Massachusetts Ave., Cambridge 39, Mass.

• **Inverters.** Improved models of ATR inverters for operation from 6- or 12-volt storage batteries in automobiles, trucks, boats, and busses, have recently been introduced by the American Television and Radio Company, 300 E. 4th St., St. Paul,

Minn. Standard models provide 110-volt 60-cycle a.c. in various wattage capacities for the operation of dictating machines, tape recorders, radio receivers, and other equipment with similar power requirements. Special models are available for operation from other d.c. input voltages. Complete descriptive literature will be supplied on request.

• **Stylus-Check Disc.** Made of a specially-compounded soft material which is highly sensitive to erosion, the new Audak Stylus Disk provides a simple, yet effective means of home-testing jewelled styli for excessive wear. Grooves are recorded eccentrically in such a manner that the stylus under test is subjected to considerable thrust—first on one side, then on the other—with each revolution of the turntable. A worn or defective stylus will scrape the delicate surface of the grooves, leaving a visible indication of its condition. In normal use the disc should have a life span equal to that of about 20 styli. Audak Company, 500 Fifth Ave., New York 36, N. Y.

• **Transcription Console.** Every record-playing requirement of broadcast stations is filled by the new Rek-O-Kut Model B-16H three-speed turntable and matching console Model C-7B. Made of cast aluminum, the turntable exerts no pull on magnetic cartridges. It is rim-driven through idlers by a hysteresis motor, and reaches operating speed with one-half revolution at

33-1/3 and 45 r.p.m. A permanent built-in 45-r.p.m.-record bushing is flush-mounted around the spindle; a slight twist extends it above the table surface. When used with the C-7B console, the turntable is floated on felt; no bolts or screws are used. The cabinet stands on adjustable levelling casters and is attractively finished in metallic gray. An electrical outlet is built-in. Dimensions are 33"h x 22"w x 20½"d. Additional information will be supplied by Rek-O-Kut Company, 38-01 Queens Blvd., Long Island City 1, N. Y.

● **Test Level Indicator.** Operating on the principle that the loudspeaker of a home music system is driven by a potential that is measurable in volts, the new Dubbings Test Level Indicator may be used with any frequency test record to determine the frequency characteristics of the system, also to adjust the system for optimum performance. The device consists of

three low-current low-voltage bulbs so calibrated as to light up at 3-db intervals when connected across the output terminals of an amplifier. Although extremely low in cost, the indicator is an effective substitute for much more expensive equipment in checking frequency response. Manufactured by The Dubbings Company, 41-10 45th St., Long Island City 4, N. Y.

● **Stereophonic Amplifier.** Expanding its line of audio equipment for stereophonic reproduction, Livingston Electronic Corporation, Livingston, N. J., has recently announced a twin-channel amplifier designed specifically to take full advantage of the multidimensional sound sources currently available. Consisting of two

complete 10-watt hi-fi channels, the amplifier contains a stereophonic-monaural selector, a speaker reversal switch, with separate bass and treble controls for each channel. Control panel is edge-lighted Lucite. Amplifier and power supply are in separate matching cabinets, each measuring 9¾ x 8"d x 5¾"h. Interconnection is by means of a 3-ft. plug-in cable. Three twin inputs are provided for dual-channel discs, tape, and broadcast programs.

● **Portable Recorder-Playback System.** The new Masco Model RK6 is a portable three-speed disc recorder, record player, and five-watt public address system. Available with or without built-in AM tuner, the unit both records and plays back 45- and 33-1/3-r.p.m. microgroove discs, as well as standard-groove 78's. At 33-1/3 r.p.m. 15 minutes of recording can

be made on one side of a 10-in. record at 160 lines/in. Speed change switch affords automatic equalization for various recording speeds. Recordings may be made from microphone, tuner, tape or wire recorder, of from another phonograph. Output jack is provided for feeding an external speaker. Attractively styled, the RK6 is self-contained in a two-piece luggage-type carrying case. Additional specifications are available from Mark Simpson Mfg. Co., 32-28 48th St., Long Island City 3, N. Y.

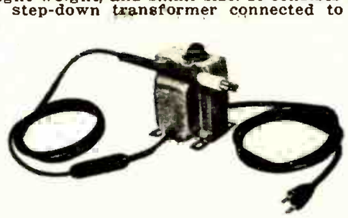
● **Low-Cost Mobile Amplifier.** Sturdily built but readily portable, the new Bell Model 3717-MB mobile amplifier is a 15-watt unit housed in a rugged steel cabinet with a sloping, indirectly lighted control panel. A built-in 78-r.p.m. rim-drive phono is easily accessible for mobile operation. Separate volume controls are provided for phono and microphone inputs. A stand-by switch affords power economy by removing plate voltage while keeping filaments hot. The unit may be operated on either

117 volts a.c. or 6 volts d.c., and is supplied with cables for both types of connection. Microphone and phono channels have 115 and 80 db gain, respectively. Output impedances are 2.5, 4, 8, 16, 250, and 500 ohms, and in addition there is a 70-volt constant-voltage tap. Where a complete range of turntable speeds is required, a deluxe model with 3-speed phono and turnover-type pickup is available. Bell Sound Systems, Inc., Columbus, Ohio.

● **Miniature Delay Relays.** Amperite Company, Inc., 561 Broadway, New York 12, N. Y., now has available its regular line of delay relays in 9-pin miniature bulbs. They can be supplied in all standard heater voltages such as 6.3, 26, and 115 volts, and with delays from 2 to 90 sec-

onds. Power consumed by the heater is approximately 2 watts, and contact rating is 115 v, 2 amp, non-inductive. Further information may be obtained from the manufacturer.

● **Thermo-Tip Soldering Pencil.** A soldering tool for miniature and subminiature work has been introduced by Ideal Industries, Inc., 4487 Park Ave., Sycamore, Ill. The new device features rapid heating, light weight, and small size. It consists of a step-down transformer connected to a



small soldering pencil and utilizes the principle of resistance heating with the soldered part becoming a part of the electrical circuit. Passage of a high current at harmless low voltage causes rapid heating, thus eliminating the possibility of poorly soldered joints. A variety of tips and attachments are available for specialized requirements.

The POWRTRON

(from page 32)

transformed replica of the voltage waveform at the input to the audio amplifier. It will be shown that present audio amplifiers create a power distortion of a magnitude of 6 to 8 db, and this type of distortion is not discernible by present day testing procedures.

Definition 1. Power distortion: A power waveform generated by an audio amplifier that deviates in any manner whatsoever from the form of the input voltage waveform is distorted with respect to power to the extent of the deviation.

From this definition, it can be seen that any distortion measurement of an audio power amplifier is, in fact, a measurement of power distortion. That is, power distortion is a generalized form covering intermodulation distortion, harmonic distortion, and so on. Any amplifier that changes its power output with changing load impedance suffers from power distortion to the extent that the power output is altered. It is recognized that the relationship between power, voltage, and impedance can be expressed by the formula

$$P = \frac{E^2}{Z} \qquad (1)$$

where P = power output,
E = voltage, and
Z = load impedance.

In test procedures using resistive loads, it can be seen that if E remains constant, the power output will remain constant. However, with variable load impedances the power output will bear an inverse relationship to the impedance.

From transducer theory, there are certain relationships between the electrical and acoustical characteristics of any speaker, and such factors as the resistance of the suspension system, the resistance of the air load, the reactance of the voice coil and cone, the reactance of the air load, and the reactance of the suspension system must be considered as affecting the total impedance of the speaker, in addition to the pure electrical impedance of the voice coil itself.

Effect of Feedback

The majority of hi-fi amplifiers employ some form of voltage feedback, but a study of equation (*1*) will show that if voltage remains constant there will be considerable power distortion, and it is agreed that voltage feedback tends to hold the voltage constant regardless of the load across the amplifier terminals. Thus any change in load impedance results simultaneously in an inverse power change. If electrical impedance characteristics and acoustical output characteristics of a given speaker were related in such a manner that electrical impedance peaks occurred simultaneously with acoustical peaks, the decrease in power response at the point of maximum acoustical output would be beneficial. However, in real speakers this condition seldom occurs.

The Powrtron circuit, *Fig.* 3, differs from conventional amplifiers in that it adds a small amount of negative current feedback to a usual amount of negative voltage feedback, with the result that over a reasonable range of load variations the power distortion is held to 1 db, whereas without the Powrtron feature the same amplifier shows a distortion of as much as 8 db.

Careful consideration of this will show that it is useless to attempt to control the behavior of a loudspeaker by means of a device that will sense impedance changes in the speaker, and this is exactly what is done with voltage feedback. Many other effects of voltage feedback are definitely beneficial, as is well known, but the effect on power distortion is to increase instead of decrease it.

Negative power feedback results in much less power change over a range of output loads than the other methods of operation. Positive current feedback reduces the internal impedance of power amplifiers to zero, but by so doing it increases power distortion.

The Complete Circuit

While the Powrtron circuit refers only to the addition of a single resistor in the output circuit and the connection back to a suitable point for the introduction of feedback, there are some advantages to the complete White amplifier and the method of introducing two separate kinds of feedback is simplified greatly. In *Fig.* 3 it will be noted that R_{21} and C_4 constitute a usual form of negative voltage feedback. The negative current feedback is obtained from R_{20} in the return leg of the secondary of the output transformer. The cross-coupled phase inverter, together with the direct-coupled driver stage make it possible to introduce the two different types of feedback with considerable ease. Furthermore, if a direct A-B test is desired, it is only necessary to short out R_{20}.

Since the circuit is somewhat unique, it may bear explanation. The input is fed into a level-adjusting potentiometer and thence to the grid of V_{1a} through C_1 and the grid resistor R_2. (The use of the octal socket will be described later.) C_1 and R_2 may appear unnecessary, but the slightest amount of d.c. on the grid of V_{1a} is sufficient to unbalance the operation of the entire system so C_1 is a mica capacitor—.033 µf or larger—which has been found to be completely free from leakage. The cathode of V_{1a} is directly coupled to the grid of V_{2b} and a tap on the cathode resistor string of V_{2a}. R_5 provides for a balance of d.c. voltages throughout the first three tubes—the method of adjustment being to set R_5 at a point where the voltage between the plates of V_{3a} and V_{3b} is zero. The negative current feedback is connected to the grid of V_{1b}—directly out of phase with the input section—and the output of V_{1b} is fed into the phase splitter in a manner similar to that from V_{1a}. The direct coup-

STATEMENT OF THE OWNERSHIP, MANAGEMENT, AND CIRCULATION REQUIRED BY THE ACT OF CONGRESS OF AUGUST 24, 1912, AS AMENDED BY THE ACTS OF MARCH 3, 1933, AND JULY 2, 1946

(Title 39, United States Code, Section 233)

of AUDIO ENGINEERING, published monthly at Lancaster, Pa., for October 1, 1953.

1. The names and address of the publisher, editor, managing editor, and business managers are: Publisher: Charles G. McProud, 204 Front St., Mineola, N. Y.; Editor: Charles G. McProud, 204 Front St., Mineola, N. Y.; Managing editor: none; Business manager: Henry A. Schober, 204 Front St., Mineola, N. Y.

2. The owner is: Radio Magazines, Inc., 204 Front St., Mineola, N. Y.; Henry A. Schober, 204 Front St., Mineola, N. Y.; Charles G. McProud, 204 Front St., Mineola, N. Y.

3. The known bondholders, mortgagees, and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages, or other securities are: none.

4. Paragraphs 2 and 3 include, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting; also the statements in the two paragraphs show the affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner.

(Signed) HENRY A. SCHOBER, Business Manager.

Sworn to and subscribed before me this 14th day of September, 1953.

(Seal) WILLIAM E. STOLT, Notary Public.

State of New York, No. 30-9205000. Qualified in Nassau County. My term expires Mar. 30, 1954.

ling between the phase splitter section and the driver is made possible by the use of a very large cathode resistor for V_2. It will be noted that these cathodes are about 96 volts above ground, resulting in a potential of approximately 90 volts on the plates of V_2—this same voltage being applied to the grids of V_3 which results in a bias of around 6 volts.

The output stage is the Ultra-Linear, which has been described heretofore.[1] In the 20-watt White amplifier, 5881's are used; in a very similar design for 10 watts output, 6V6's are used—this

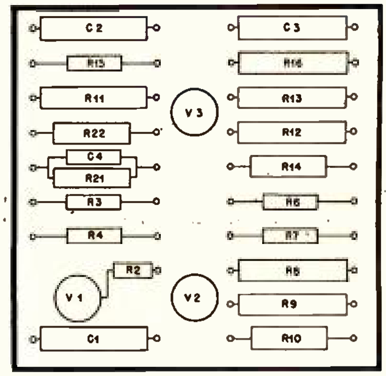


Fig. 4. Arrangement of parts on terminal board shown in Fig. 2.

latter amplifier being used with the 20-watt model to make the two-way amplifier system to be described.

The current feedback is developed across R_{20}, shown as 0.47 ohms. In construction, it is suggested that this value be obtained by the use of a 1-ohm 10-watt adjustable resistor. Slight variations in the power response characteristics may be had by changing the value of this resistor, with corresponding changes in the tonal quality of the output.

Figure 2 shows the underside of the White amplifier. Note that most of the components ahead of the output stage are located on the terminal board, which is laid out as in *Fig.* 4. The parts list indicates the wattages of the various resistors, as well as the types recommended.

In construction, it is suggested that the amplifier be assembled with semi-permanent connections between the driver stage and the output-tube grids, and with the negative-voltage feedback circuit—R_{21}-C_4—disconnected. Then pass a signal through the amplifier and note whether the signal increases or decreases when R_{20} is shorted. If the signal decreases, the leads to the two output grids should be reversed, since the feedback voltage developed across R_{20} should reduce the gain, and shorting the resistor eliminates the feedback. After the correct polarity is determined, the voltage-feedback circuit R_{21}-C_4 may be connected.

[1] David Hafler and Herbert I. Keroes, "The Ultra-Linear amplifier." AUDIO ENGINEERING, Nov. 1951.

The Octal Socket

The octal socket previously mentioned provides for the insertion of an electronic dividing network ahead of the power amplifiers. With the shorting plug in place, the amplifier functions normally, and may be used to feed a single speaker, or to feed a two- or three-way system with a conventional dividing network. However, one of the advantages of the White system is that the dividing network is used ahead of the amplifiers, providing the advantage of low source impedance for the speakers. The principal disadvantage is the need for two power amplifiers, it being quite usual to use the 20-watt model for low frequencies and the 10-watt model for high frequencies.

The shorting plug simply connects the incoming signal to the input of the amplifier. However, when it is desired to use two amplifiers, the shorting plug is removed and an electronic filter unit is inserted in the socket. *Figure* 5 is the schematic of the filter network, which consists of a dual triode connected as two cathode followers. Each follower feeds a filter circuit—one of low-pass configuration, and one of high-pass configuration. The low-pass output is fed to the associated amplifier, and the other output is fed to the treble amplifier. In the commercially available model, the treble output is fed through a pigtail cable, which is plugged into the second amplifier. As shown in *Fig*. 3 the treble output is channeled to another phono jack, which is connected by a jumper to the second amplifier. The terminals shown are not those used in the commercial version, but are indicated for study of the circuit.

Filter-Network Advantages

The most recent trend in amplifier design has been toward increased negative feedback, using output transformers of wider and wider range and placing more and more stages inside the feedback loop. For optimum operation, all of the push-pull stages should be balanced, and maximum phase shift must be kept to less than 180 deg. inside the feedback loop if oscillation is to be avoided.

The two regions in which phase shift will occur and oscillation becomes a problem are at the extreme ends of the audio spectrum. The ideal way to design an amplifier is to keep the phase shift through the electronic section of the amplifier limited to less than 5 deg. and allow the electrical characteristics of the output transformer determine the operating frequency of the amplifier. Unfortunately this ideal is seldom achieved.

It is well known that the reactive filter networks cause substantial distortion in the process of sound reproduction. However, the manner in which it is caused is not nearly as well known. The design of filter sections of constant-valued elements of resistance, capacitance, and inductance is standard engineering practice. However, the design

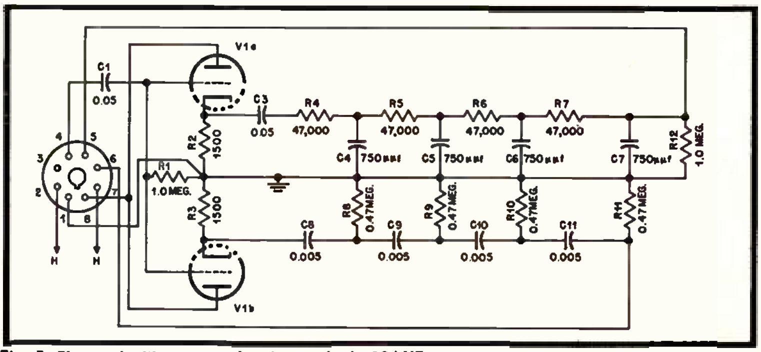


Fig. 5. Electronic filter network using a single 12AU7 as two cathode-follower sections to drive the R-C filters which comprise the dividing network ahead of the power amplifiers.

of filter sections capable of dealing with the variable impedance presented by a speaker is a problem of serious magnitude. The use of a dual-channel amplifier using electronic filter sections at the input of the system is deemed the best solution.

The crossover filter is constructed in a standard Vector CO-10-N turret can, making it readily interchangeable. Thus the experimenter can construct several different filter networks to determine the best operating crossover freguency for the speakers used, or by removing the network can restore the amplifier to normal operation with a minimum of effort. For the constants shown, the crossover frequency is approximately 560 cps.

In the hi-fi field the final judgement is always that of the listening test. In the case of amplifiers it is difficult to achieve a distinct inprovement, but it is felt that a listening test with the crossover amplifier will give the listener just such a distinct improvement.

Parts List (Fig. 3)

C_1	.033 µf, 1200 v. mica
C_2, C_3	0.5 µf, 600 v. paper
C_4	330 µµf, 500 v. mica
C_5, C_6, C_7	40 µf, 500 v. elect.
L_1	8 H, 220 ma, swinging choke
L_2	30 H, 60 ma, smoothing choke
R_1	0.25 meg potentiometer, audio taper
R_2	1.0 meg, ½-watt, deposited carbon
R_3, R_4, R_5, R_7	470 ohms, 1-watt, wirewound
R_6	200 ohms, 4-watt potentiometer, linear
R_8, R_9	50,000 ohms, 10-watt, wirewound, matched pair
R_{10}	1500 ohms, 5-watt, wirewound
R_{11}	20,000 ohms, 10-watt, wirewound
R_{12}, R_{13}	50,000 ohms, 10-watt, wirewound, matched pair
R_{14}	500 ohms, 2-watt, wirewound
R_{15}, R_{16}	0.15 meg, 1-watt, deposited carbon
R_{17}	350 ohms, 10-watt, wirewound
R_{18}, R_{19}	1000 ohms, ½-watt, deposited carbon
R_{20}	1.0 ohms, 10-watt, adjustable, wirewound
R_{21}	3000 ohms. 1-watt, wirewound
R_{22}	20,000 ohms, 10-watt, wirewound
T_1	Power transformer, White Sound or Chicago PCR-200. 520-0-520 v at 200 ma; 5.0 v at 2.0 a; 6.3 v at 4.5 a; potted.
T_2	Ultra-Linear output transformer, Acro TO-300, or White Sound
V_1, V_2, V_3	12AU7
V_4, V_5	5881 or KT66
V_6	5V4

Parts List (Fig. 5)

C_1, C_2	.05 µf, 600 v. paper
C_3, C_4, C_5, C_7	750 µµf, 500 v. mica
C_8, C_9, C_{10}, C_{11}	.005 µf, 500 v. mica
R_1, R_{12}	1.0 meg, ½-watt, deposited carbon
R_2, R_3	1500 ohms, 10-watt, wirewound
R_4, R_5, R_6, R_7	47,000 ohms, ½-watt, deposited carbon
R_8, R_9, R_{10}, R_{11}	0.47 meg, ½-watt, deposited carbon
V_1	12AU7

TECHNICANA

Diagnosis of Distortion

An article with the above title, written by E. R. Wigan, appears in the June, 1953, *Wireless World*. The article is not concerned with distortion measurement but with methods of diagnosis of audio distortion, and describes a technique for such diagnosis.

A pure sine-wave signal is applied to the apparatus being tested, and is also applied simultaneously to the horizontal plates of an oscilloscope. The output signal of the tested unit is passed through a network which deletes the fundamental wave, leaving only distortion, noise and hum modulation terms. This residual signal from the network is amplified, from 30 to 100 times, and then applied to the vertical oscilloscope plates.

When the relative phase of the vertical signal is properly adjusted, the trace resulting from horizontal and vertical inputs becomes a graphical representation of the transfer characteristic of the tested apparatus, with its defects enormously magnified. The author calls this trace the "difference diagram." Although the method is not proposed as a measuring technique it is stated that the magnitude of distortion can be read with useful accuracy, and that distortion components as small as 0.1 per cent can be recognized under good conditions.

The primary use of the difference diagram, however, is in enabling the operator to diagnose the source of distortion, from direct observation of the type of non-linearity of the transfer characteristic.

Loudspeaker Efficiency

The February, 1953, issue of *Wireless World* reports on a method of calculating loudspeaker efficiency, a method which is described as simpler and more closely related to conditions of actual use than the usual techniques. The normal figures for loudspeaker efficiency are derived from free-field measurements of output sound pressure, on axis and at selected angles off the axis. For each frequency, it is stated, eighteen separate measurements are usual. Even ignoring the physical difficulties involved in taking such measurements (which include the expense of anechoic chambers), once the figures have been recorded there remains the problem of how to integrate the results. The distribution of radiated power over different axes varies with frequency and is affected by diffraction.

The new technique places the speaker in a reverberation chamber instead of in an echo-free space, the speaker and microphone situated at opposite corners of the chamber. With a known power input to the speaker (produced by a warble-tone generator), the total sound output is calculated. The integration is thus performed automatically. Corrections are applied for room absorption and for the characteristics of the microphone.

LONDON LETTER

(from page 10)

interest in radio-phonograph combinations is likely to spread across the Atlantic. Most of the larger TV manufacturers were showing radio-phonograph console units. Probably 50 per cent of these units still have the controls on the top with the lid opening upwards. There were very few models incorporating TV.

The success of the Trix Portable Record Player has apparently encouraged many other manufacturers to bring out similar equipment, some of which now have a radio section as well as sound amplification. Probably the most novel in design was the H.M.V. portable three-speed radiogram which has three wavebands with the player section pivoted so that it is carried in a vertical position and of course played in a horizontal one. Alba showed a portable radiogram which could be operated from either batteries or Mains, a spring-driven motor being used.

Although a few tape recorders were on show, the interest in tape in Britain has not yet reached the proportions it has in the U.S.A.

For the first time at the exhibition, the E.M.I. Group devoted a large stand exclusively to records featuring the H.M.V., Columbia, Regal, Parlophone and M.G.M. brands. Thousands of photographs of recording stars were sold during the Show and record fans could hear many of their favorite artists by plugging earphones into sockets which were connected by line to 40 record changers housed in another part of the exhibition.

Although the exhibition had not the same technical interest as the British Radio Components Show which is held in April each year, it is indeed remarkable that more than a quarter of a million of the British public pay nearly 40 cents (which to them is equivalent to a dollar) to visit a public exhibition of TV, radio and records. There is nothing like this Radio Show in the U.S.A.

FAIR and CONVENTION

(*from page 29*)

Wente—for nearly 40 years with Bell Laboratories—has been in the forefront of development of sound equipment from the beginning, one of the first and most important contributions being the condenser microphone. His work with the ribbon-type light valve and many hundreds of other improvements in the sound recording field brought him the first progress medal of the Society of Motion Picture and Television Engineers.

The Society's Award, presented for meritorious service to the Society, was given to C. G. McProud, Æ Editor, and Fellowships were presented to C. J. LeBel, Howard A. Chinn, Chester A. Rackey, and H. E. Roys.

And with the conclusion of the 1953 Audio Fair and AES Convention, all eyes are now turned hopefully to October 13, 14, 15, and 16, 1954, for the Sixth Audio Fair—which will probably be bigger and better than the one just closed.

Colvin Joins Gates

John D. Colvin, former president of the AES, has been appointed director of engineering of Gates Radio Company, Quincy. Ill., manufacturers of broadcast equipment. Prior to joining Gates, Mr. Colvin was chief engineer of Commercial Radio Sound. Inc., New York, chief audio engineer for ABC, and systems engineer for RCA.

PATENTS

(*from page 6*)

2,486,208. Addition of transients—breath effects, etc.

1950

2,506,723. Mervin J. Larson, Stromberg-Carlson. Sine waves distorted for tone variations.

2,533,821. Langer, Central Commercial. Conversion of square to sawtooth waves.

Tremolo, Vibrato, etc.

1932

1,853,630. Maurice Martenot, France. Whole keyboard is slightly movable; vibration of hand on key produces vibrato.

1936

2,040,439. Langer. Neon-lamp vibrato circuit.

1949

2,466,306. Tremolo by varying speaker field current.

2,485,538. Paul H. Rowe, Mass-Rowe. Tremolo by oscillator varying grid bias of push-pull amplifier output stage.

2,489,653. Donald J. Leslie. Rotating vanes in front of speaker.

1950

2,503,352. Electronic variation of tube gain.
2,534,342. Same idea as 2,485,538.

1951

2,542,065. Baldwin. Separate tremolo for each manual.
2,565,033. Played back film track has vibrato added by cyclically moving scanning light or varying speed of film.
2,580,217. French inventor. Adding "movement" to tones to simulate random frequency variations of organ pipes.

1952

2,600,870. RCA. Synthetic reverberation with stretched string and magnetic transducers.

Complete Instruments

Photoelectric

1,980,292	2,169,842

Acoustic with Pickups

1,705,395	1,901,985
2,089,204	2,300,609
2,486,545	

Electromagnetic

380,035 (1897)	1,956,350

Electrostatic

Re. 21,554	Re. 22,321

Magnetic Recordings

2,549,145

Electron-tube Designs

1,190,332	1,661,058
1,911,309	Re. 20,831
2,211,540	2,233,258
2,245,337	2,254,284
2,276,390	2,294,178
2,295,524	2,301,871
2,310,429	2,478,867
2,489,497	2,497,661
2,540,727	2,544,466
2,545,665	2,562,908
2,563,477	2,568,644

Miscellaneous Patents

2,475,742. John Hays Hammond. Production of reentrant magnetic recordings.
2,491,189 and 2,491,190. Thomas H. Long, Conn. Harmonic wave analyzer.
2,538,184. Wurlitzer. Electronic pickup for piano tuning; eliminates need for rubber wedges.

AUDIO ETC.

(from page 36)

Big-Company Craft Hi-Fi

And the pay-off of this whole extraordinary situation—two water-tight lines of goods, absolutely separated in their physical existence, yet in hot competition on paper and via words—is that many of the large commercial companies have entered *both* sides of the Big Divide, offering lines of true craft-type equipment in the "net" or wholesale dealer area simultaneously with their commercial-type lines in the retail dealer field! This is an entirely reasonable procedure, as things now stand. There are true hi-fi component lines from GE, Stromberg Carlson, RCA and more. Some of these concerns, of course, have long been in the component business at net prices where conditions were favorable, notably GE with its reluctance pickup and the line of GE speakers. RCA's speakers have been on the net market too, though until now the fine Olsen LC1A has not been officially available through net dealers and was not seen in most hi-fi catalogues. Now, these lines have been rounded out into full-fledged craft-type hi-fi systems.

They are strictly isolated from the retail products of the same makers, from start to finish, manufacturing to final sale, nor could it be otherwise at present.

How, some who haven't heard may ask, can the companies produce craft hi-fi? The answer should delight every hi-fi maker's soul, of course, for it proves the validity of the whole craft hi-fi movement and at the same time is the best augury for its future. The big companies do set up certain sub-departments, operating on a smaller, craft-style arrangement, to make these more careful products in the craft manner. But not all. A major portion of at least one new famous-name component line is farmed out—to none other than those very concerns who have been building the craft-hi-fi business right along! No secret—you can guess the makers by the products' looks; nor is it any criticism of the big companies in question—rather, it is a tribute to their astuteness in recognizing the permanent values of craft-type small business. Again, that's us. That's audio.

It remains to tackle the question in all minds—how best can craft hi-fi meet the new barrage of commercial "hi-fi"? How can it exploit the virtues of its position?

The problem is not as simple as a plain AB. Do we need AB tests, for ourselves? They will only confirm what is inevitable—and remember that the public is not going to be able to make AB tests on present sales floors. Not without traipsing all over town, to encompass the two types of dealerships. We know, without prejudice to the commercial manufacturers, that their product is bound, under the circumstances, to be a commercial compromise with hi-fi quality. I was enthusiastic about the first such compromise, last year's pioneer Columbia 360 (Æ, March 1953, p. 46) because one could easily see in it imagination, enterprise and a high order of gadget-thinking, to meet the challenge of craft hi-fi in mass-product terms. The Columbia 360 started the avalanche. The others waited—and saw.

What To Do?

What is needed is not a narrow insistence on AB testing, but a clarification, for the public, of the true situation, and that by every bit of advertising and promotional persuasion that the collective audio business can summon to its aid. This is fair and honest competition—clarification vs. confusion! I'm not the one to write promotion, but these would seem to be the points that must be made, with honesty:

A. The public must understand that there are two types of equipment, representing two fundamentally unlike industrial systems. (Put it in your own words.) Without this understanding, craft hi-fi can't even begin to make its own position clear to the uninitiate. It will truly be swallowed—in confusion. What names, slogans, titles, are used to make this clear will depend on the status of the terms hi-fi and high fidelity. Up until now, that terminology has made the basic distinction—"hi-fi" equipment (craft) and "standard commercial."

B. There must be a vigorous attempt to keep the term hi-fi or high fidelity

within reasonable technical standards—though I fear it will be but partially successful; things have already gone too far. Nevertheless, the use of that term to cover sound quality that clearly is far below previously accepted standards is something we all must fight as well as we can, if only in the interests of intelligibility. Words can be killed as dead as any animal by gross mis-use.

I refer you to the statement last July from Leonard Carduner, of British Industries Corporation, headed "Let's keep the 'high' in 'high fidelity.'"* I agree entirely with his sentiments and admire the catch-phrase as a good one; but I am sure that in addition to publicising hi-fi standards (granted we can reach rough agreement, which we should), there must also be a frank explanation, as in A. above, of the existence of two kinds of equipment, or—

C. It might be better policy, asserting only the affirmative values, to stress the virtues of craft hi-fi and the industrial methods behind it, leaving the existence of a competing commercial-type of equipment to clear inference.

I propose, seconding our editor, that the word craft be associated as often as possible with the use of high fidelity in the previously accepted sense. The combination of the two is surely in the way of honesty and towards the actual virtues of the hi-fi movement as it has thus far developed.

* * * * * *

It occurs to me, on re-reading this, that it may seem a bit odd for this department to recommend steps for promotional procedure! It's not, really, for promotion when it is devoted to the propagation of the truth and to the clarification of same, is everybody's interest. The present situation is a touchy one, and any idiot—even a record reviewer—can see that its outcome depends about 90 per cent on the battle of words. I have as great an interest in good audio and, specifically, in craft-type audio, as any maker in the business, though I have no commercial conection with any of them; I'm a word-monger myself and you can't expect me to stand aside when it comes to a good fight—right in my own medium! And so—on to the battle.

* See Editor's Report, Audio Engineering, Sept. 1953.

SOUND HANDBOOK

(*from page 28*)

amplifier tubes unaffected, thereby involving a poorer signal-to-noise ratio.

Special Phonograph Circuits

Surface noise from the record, which is most annoying at the higher frequencies, may be suppressed by several methods in addition to application of the proper de-emphasis. These methods include:

1. The introduction of relatively steep cut-offs above selected frequencies. This makes it possible to reduce noise and distortion in a frequency band

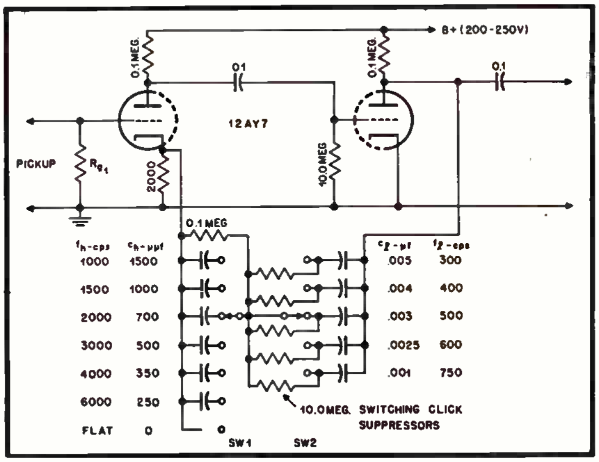


Fig. 14—11. Feedback preamplifier with variable characteristics. (*After Jones.*)

where there is little recorded signal. In any case the high-frequency noise reduction is achieved with minimum penalty to the signal. Steep attenuation slopes may be provided by L-R-C networks, by R-C parallel T networks,[10] or by the simpler circuit of *Fig.* 14—13,[11] in which advantage is taken of the inductance of magnetic pickups.

2. "Dynamic" noise suppression.[12, 13, 14] Here the high-frequency content of the recorded signal controls frequency discrimination, so that with little or no high-frequency signal the transmission channel is severely attenuated in the treble, while with normal high-frequency signal content the treble attenuation is instantaneously removed. In most circuits of this type the user is able to determine the amount of treble signal required to open the attenuator gate, that is, to control gate sensitivity.

3. Use of a recently developed squelch circuit,[15] which momentarily cuts off the signal channel when stimulated by the "pops" and "clicks" of modern plastic record surfaces. The noise pulses are distinguished from signal pulses by the fact that they have a higher energy content above about 20,000 cps. They are segregated from the signal by a high-pass 20,000-cps filter, and used to trigger the squelch circuit. It is stated that the ear is tolerant of momentary silences of less than 250 microseconds duration, and that the cumulative time taken up by the cut-off periods may be as great as one-tenth of the total program time.

Low-frequency noise from the turntable may also be a source of trouble, not only for its intrinsic annoyance, but because of the intermodulation products that may be formed with signal frequencies. A sharp cut-off high-pass filter[10] may be used to attenuate low-frequency response below the useful limit of 40 cps or so.

The dynamic range of recorded or broadcast music may be increased with a *volume expander*. Use of this circuit

[10] D. T. N. Williamson, "High-quality amplifier—new version," *Wireless World*, Oct., 1949, p. 365, and Nov., 1949, p. 423.

[11] C. G. McProud, "High-frequency equalization for magnetic pickups," AUDIO ENGINEERING, Sept., 1947, p. 13.

[12] H. H. Scott, "Dynamic suppression of phonograph record noise," *Electronics*, Dec., 1946, p. 92.

[13] H. F. Olson, "Audio noise-reduction circuits," *Electronics*, Dec., 1947, p. 119.

[14] C. G. McProud, "Simplified dynamic noise suppressor," AUDIO ENGINEERING, Aug., 1948, p. 17.

[15] "Suppressing gramophone surface noise," (Report on a lecture by D. T. N. Williamson) *Wireless World*, July, 1953, p. 298.

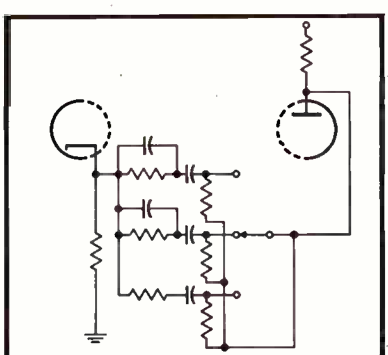


Fig. 14—12. Simplified feedback circuit for preamplifier of Fig. 14—11.

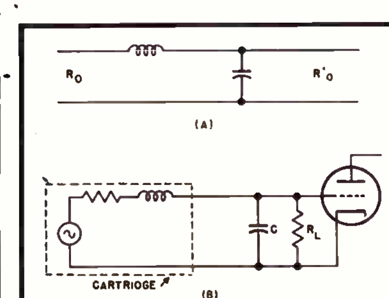


Fig. 14—13. An R-L-C filter for the price of a capacitor. Method of introducing relatively sharp high-frequency cut-offs for magnetic pickups. Design data can be found in footnote reference 11. (*After McProud.*)

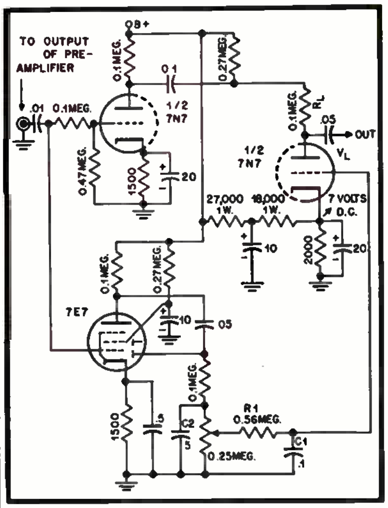


Fig. 14—14. Variable-plate-resistance volume expander. The attack time, in seconds, is the time constant (R × C) of R_1 and C_1, and the release time is the time constant of the potentiometer and C_2 plus R_1C_1. The potentiometer controls the amount of expansion, to a maximum of about 7 db. (*After McProud.*)

has declined greatly with the advent of modern LP records and FM broadcasting.

Volume expanders make use of a d.c. control voltage whose instantaneous value is a function of the average signal amplitude over a small period of time. This voltage is obtained by tapping off a part of the signal energy, amplifying and rectifying it, and then passing it through smoothing or delay networks. The delay networks are necessary so that the control voltage does not vary with individual cycles or does not respond to pulses of very short duration.

The control voltage may be used as bias for a variable μ stage, thereby causing the amplification of the tubes to increase with increased signal amplitudes, and to decrease with decreased signal amplitudes. Such a circuit has the disadvantage of introducing distortion unless the input signal is limited to very small values, of the order of 0.1 volt.

The circuit of *Fig.* 14—14[16] illustrates a volume expander which has limited expansion but low distortion. The d.c. control voltage varies the plate resistance of V_L, a tube which acts as the lower arm of a voltage divider across which the signal is applied. Thus the signal does not actually pass through V_L, but only appears across it, with an amplitude dependent upon the instantaneous value of R_P in relation to R_L.

The delay networks for attack and decay can be made variable, although the compromise values shown are generally satisfactory. Expansion may produce very unpleasant effects when it is applied to unsuitable program material. In voice, for example, an artistic vibrato may be converted to a coarse tremolo.

[16] C. G. McProud, "Experimental volume expander and scratch suppressor," AUDIO ENGINEERING, Aug., 1947, p. 13.

THE PIANO (from page 24)

What, then, determines the difference between an artist's and a tyro's interpretation of a piece? Besides a vast difference in technique, particularly as regards rapid passages, there are those subtle variations in timing that break up an otherwise machine-like procession of tones; there is the variation in loudness between successive tones and between those forming a chord, between the loudness of the right hand and the left hand.

In short, there are many ways in which an artist can vary a rendition of a piece, even though variation in tone color independent of loudness is denied to him. Nevertheless, many pianists still believe that they can vary the tone color and not the loudness by varying the touch, although others, notably the late Paderewski, did not think so.

It is not to be inferred from the foregoing that the stance of the player, the way he holds his hands and arms and fingers, is not important. It is important in that it determines the facility with which his muscles can act; the speed with which he can play, and the length of time he can play, particularly rapidly, without tiring. But so far as touch is concerned, it appears that once a certain final velocity has been imparted to the hammer, both the loudness and tone quality are determined; how you impart that final velocity (how you strike the key) is immaterial.

The Pedals

There is one method of affecting the tone quality that appears valid, and that is by means of the pedals. Pianos have at least two, and usually three in the case of a grand piano. These pedals have the following functions:

(1) The left pedal—the so-called soft pedal—shifts the entire action mechanism so that the hammers strike only two strings of a trichord, in the case of a grand piano. In the case of an upright piano, including the spinet, the hammers are moved closer to the strings, so that they do not acquire as high a velocity by the time they strike the strings, and thus produce a softer tone. Some grands do this too; a short cut that is considered bad practice.

A question that arises in connection with this, and that has not been investigated, is the effect of the coupling of an unstruck string or strings upon the struck string or strings. Ordinarily, when the three strings of a trichord are struck, they act like three electrical generators in parallel. Hence, they are three tuned systems coupled together through the bridge and they act as a single generator and tuned system.

When, however, only two of the three strings are struck, the effect of these two strings coupled to the third, unstruck, string may be noticeably different. In this case we have two resonant systems coupled together, and there should be a transfer of energy from one system to the other, just as in the case of that favorite physics experiment of the two pendulums both suspended from a horizontal string that serves to couple them together. If one pendulum is swung, its motion soon dies out, but at the same time the other pendulum begins to swing and attain full amplitude, while the other apparently comes to rest. Then the latter begins to swing, and the other comes to rest, and so on until all the energy is dissipated.

In the case of the strings, we might expect some similar effect, and perhaps a change in pitch. If so, the effect is very small, but may nevertheless have some effect on the tone quality.

However, another effect can be expected, and that is a diminution in sound intensity owing to the transfer of energy from the struck strings to the unstruck string, accompanied by the inevitable losses that attend such transfer. This may account in part for the lower volume when the left pedal is used, although the major reason must be the fact that only two instead of three strings were struck by the hammer. Some experiments by F. A. Saunders[15] on the violin seem

[15] F. A. Saunders, "Recent work on violins," *J. Acous. Soc. Am.*, Vol. 25, No. 3, 1953.

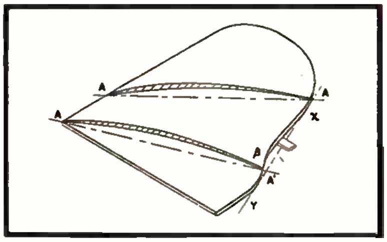


Fig. 16. Showing curvature of soundboard and taper toward edges. (*Courtesy J. Acous. Soc. Am.*)

to bear this out.

(2) The right pedal—sometimes erroneously called the loud pedal—is the sustaining pedal. It lifts up *all* the dampers, thus allowing lower strings to vibrate at some higher mode in sympathy with the struck string.

The effect is some change in tone quality, although not in a sense of the nature just discussed, because the coupling of remote strings via the bridge is probably negligibly small. However, the primary function of this pedal is to tie the notes of a phrase together by slurring one into the other, somewhat like playing all the notes in one bow in the case of a violin. An objection is that earlier notes still continue to be heard, so that much pedal may blur the passage. Certain pieces, like those of Bach, are often played without the use of this pedal.

(3) The middle pedal is seldom used, and often omitted in the case of an upright. Yet it can produce certain desirable effects, if the artist will only avail himself of it. If *first* a key (or keys) are struck, and then this pedal is depressed before the key is released, it will take over the function of holding that particular damper away from the string as long as it is depressed.

This is the true sostenuto pedal. In many pianos the third pedal is often the damper pedal for the bass, only. This is useful, say, in dance music, where the left hand can first play a chord in the bass, which is then sustained, while the same hand shifts to play what may be considered the second-violin part, while the right hand plays the first-violin part.

But keys struck *after* this pedal has been depressed will act in the normal manner. Hence, a tone or chord can be sustained while a phrase of notes following it is played. The latter stand apart from one another, while the first tone or chord remains sounding in the background.

Thus, besides dynamic and agogic (timing) emphasis, the performer has the pedals as an aid in interpreting the selection.

Although the music literature demands the sostenuto pedal, many of today's artists never use it, so that the importance of this pedal is decreasing. This may represent a trend that began years ago. In the Victorian era, pianos had cymbal and mandolin attachments, as well as cannon booms for playing the "Battle of Prague," as described by Mark Twain.

The Soundboard

Since the soundboard radiates the acoustic energy and helps to determine the tone quality, it can be expected that it would be the subject of much investigation. Although soundboards are normally made of spruce, they have been constructed of steel, aluminum, plywood and other woods, such as mahogany, and these materials should not be dismissed from future consideration. Much nonsense has been written in the past about the noble qualities of wood, its mellow effect upon the tone, and so on. Nevertheless, spruce does seem to be as desirable a material as any for this purpose.

An improvement in soundboard construction that has been made in the last ten years or so, is the diaphragmatic soundboard of Steinway.[16] The experiments and changes were made by Paul H. Bilhuber of Steinway in collaboration with C. A. Johnson of the E. E. Free Laboratories.

Briefly, the three main changes were as follows:

(1) The soundboard was made thinner at the edges in accordance with a parabolic curve, as shown in *Fig.* 16 at AA. This increased the compliance at the edges about 20 per cent, and caused the soundboard to vibrate more nearly like a diaphragm, hence the term *diaphragmatic soundboard.*

(2) Owing to the crown in the soundboard after it is glued to the ribs, the portion between X and Y is in a plane higher than the rest of the edge. In the past the entire edge was glued to the top of the inner rim of the casing, which all lay in one plane. Hence, the soundboard was subjected to considerable buckling strain. The remedy was to raise the top gluing edge of the inner rim to meet the contour of the soundboard.

(3) The crown in the soundboard causes the bridge to raise the strings up at that point above a straight-line path between the agraffe and the hitch pins. This in turn causes the string to press down on the bridge and hence transmit its vibration to the bridge and associated soundboard, just like the violin and other string instruments.

However, investigation showed that the downward pressure varied from one set of strings to the next, and thus unequal buckling stresses were set up in the soundboard owing to strain. The downward pressures were accordingly readjusted in terms of a pre-determined optimum. However, this is a matter of soundboard bearing, and is no part of the diaphragmatic claims. All piano makers plane the bridges to the proper height to adjust the tone.

Tests were made with a vibration pickup set at the center of each of small squares into which the soundboard was marked off. For all notes the intensity of vibration was found to be greater, and in general a greater area of the

[16] P. H. Bilhuber and C. A. Johnson, "Influence of the soundboard on piano tone quality," *J. Acous. Soc. Am.*, Vol. 11, No. 3, p. 311, 1940.

soundboard was set into vibration. The high notes were also benefited by this treatment, although it admittedly did not affect the radiation characteristic of the cast-iron plate.

An interesting feature was that although the tones were on the average 1.6 db louder, showing that the acoustic radiation resistance was higher, nevertheless the tones did not die out as rapidly. This indicated that the over-all damping, probably frictional within the soundboard, had been lowered to an extent that more than compensated for the increase in the (desirable) radiation resistance.

Today the soundboard is constructed by placing the spruce assembly, of initially uniform thickness, on a table that is dished out by the proper amount. The center of the board is pressed down into the hollow of the table, so that it is now lower than the edges. The top of the board is now planed flat; this obviously produces a cross-section which tapers from the center to the edges.

The soundboard is now turned over and the process repeated. The result is that now both surfaces taper equally toward the edges. For the larger concert grands only, the area near the edges is thinned down, since this larger soundboard has inherently less stiffness and therefore tends to vibrate more freely. The soundboard, in any case, is then glued to the ribs in another specially dished out table to give it the crowned shape desired.[17]

It is felt that the bridge should be more closely coupled to the ribs than through the compliance of the intervening spruce soundboard. Hence, where the bridges cross each rib, a hole is drilled through the bridge, soundboard, and rib, and a maple dowel, covered with glue, inserted in this hole. Also, Baldwin uses a maple disc or grommet, which is glued into the soundboard at this point, and the dowel actually glues into it. The dowel thus acts as a pin that ties the three components together even more closely. This maple-dowel extension of the bridge, it is felt, transmits more effectively the vibrations via the ribs to all parts of the soundboard, and thus tends to make it vibrate more uniformly.

Miscellaneous Considerations

We come now to the questions, "What are the characteristics of the piano tone?" "What is the range of audio frequencies encompassed?" and "What is the volume range?" Some work has been done on this, as might be expected.

First, some tests were made on the decay rates of piano tones by Dr. D. W. Martin[18] while at RCA. The tests were made in relation to some experiments on an electronic piano, and indicated that when the soundboard was removed, there was still acoustic radiation, but it was 14 db lower. This indicates a surprising efficiency for the soundboard as a radiator. The rate of decay is approximately halved by removal of the soundboard; the effect is somewhat greater on the low tones.

A piano tone normally decays at two rates; an initially rapid rate of from 4½ to as high as 80 db per sec., increasing with the pitch, and a slower decay rate after the first few seconds of tone that is normally of significance only in sustained passages and particularly where the sustaining pedal is used. The method of measurement is to employ the average rate of decay to determine the time required for the sound to decay 60 db.

Thus, for the initial slope, the time may be anywhere from 12 to 3.5 sec. for a baby grand piano, and 11 to 3.5 sec. for an upright piano, depending upon the pitch of the note. For the final decay time, the values may be from 30 sec. to 5 sec. for the baby grand piano, and 25 to 7 sec. for the upright. Above about F_{57} (the 57th key from the bass end), the two rates merge, i.e., the initial and final rates of decay become identical.

In listening to a tone, one can note the initial and final rates of decay, and there is also noticeable an accompanying change in tone quality. This is due to different rates of decay of the partials

[17] Other makers make the soundboard thinner at the edge by planing *on one side*, but Steinway uses straight rather than crowned ribs, which do not perhaps strain the soundboard's undersurface unduly in gluing in spite of it also being planed.

[18] D. W. Martin, "Decay rates of piano tones," *J. Acous. Soc. Am.*, Vol. 19, No. 4, p. 535, 1947.

or overtones in the notes; they are greater for the higher partials. In general, the partials of the higher notes decay much more rapidly than those of the lower notes, thus giving rise to the less pleasing tones of the higher notes.

Similar results were noted by Schuck and Young.[5] There are also fluctuations in the amplitudes of the partials with time which may be due to rotation of the plane of vibration of the string, as well as possible transfer of energy from one mode to another. It was also noted that the initial build-up of the tone exceeded the speed of recording of the high-speed level recorder, which is nominally 50 db/sec., and is of course due to the sudden impact of the hammer.

A series of tests were made by Sivian, Dunn and White,[19] of the Bell Telephone Laboratories, to determine the peak amplitudes of various musical instruments, and also their combination in an orchestra, both over the entire range, and in different parts of the spectrum.

We are particularly interested in the results obtained for the piano. An average of three different methods of calculation would indicate a peak power output of 267 milliwatts, taken from measurements made at ⅛-second intervals. This corresponds roughly to a short musical note, the "musical syllable." These tests were made using a reproducing mechanism and a music roll. Further tests using an actual artist showed a maximum peak output of about 2 watts.

Most of the peaks are concentrated in the 250 to 500-cps band, of practically the same amplitude as those of the whole spectrum. Furthermore, peak power—as measured over the entire spectrum—occurs for about 16 per cent of the measuring intervals. Peak power—as measured over the 250 to 500-cps band—occurred in one measurement for 7 per cent of the time; in another measurement, for 14 per cent of the time.

There are, of course, components in the higher and lower ranges of the spectrum. For example, in the 4000 to 5600 cps band, some energy is present, but it is about 55 db down as compared to the average value. Similarly, in the 5600 to 8000-cps band, the energy is about 55 db or so down compared to the average value, and occasionally, in the 8000 to infinity band, energy but 40 db down maybe encountered. Nevertheless. in recording, quite satisfactory results can be obtained using a band width of but 6000 cps or so; the piano does not seem to require the extreme frequency range that, say, the cymbals or even a violin might require.

What about the character of the piano tone itself? An interesting discussion by Fletcher[20] has bearing on this ques-

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[19] L. J. Sivian, H. K. Dunn, and S. D. White, "Absolute amplitudes and spectra of certain musical instruments and orchestras." *J. Acous. Soc. Am.*, Vol. 2, No. 3, 1931.

[20] Harvey Fletcher, "The pitch, loudness, and quality of musical tones," *Amer. J. Phys.*, Vol. 14, pp. 215–225, July–August 1946.

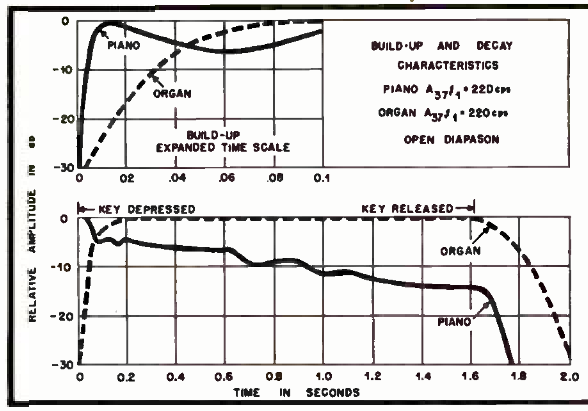

Fig. 17. Build-up and decay characteristics of organ and piano tones.

tion. The six physical aspects of a musical tone are its intensity, its fundamental frequency, its overtone structure, its duration, its growth and decay time pattern, and its vibrato. The latter is of no concern in the case of the piano.

In *Fig.* 17 is shown the manner in which a piano and an organ tone build up and decay. The upper graph shows that the piano tone builds up to its maximum in about 0.01 sec., whereas the organ tone takes about 10 to 100 times as long to build up. The decay time for the piano, or rather the time required to extinguish the tone after the key is released, is about 0.1 sec. or about the same as the organ build-up time. Hence, it is not surprising to find that a recording of a piano tone, when played in reverse, sounds like an organ tone. The abrupt build-up now becomes the decay time, and merely makes the tone sound like an organ played staccato.

The loudness of a musical tone, such as that of the piano, depends upon the duration, if it is less than ¼ sec. For tones of longer duration than this, the loudness is unaffected. Since most musical tones have durations in excess of ¼ sec., we can expect the loudness to be independent of the duration for most tones that are used in music.[21]

It will be of interest to conclude this discussion with the overtone structure for the piano tone C_{28} for which the frequency is 131 cps. Fletcher gives it the notation shown

$$S \rightarrow \frac{1}{0}, \frac{2}{3}, \frac{3}{10}, \frac{4}{9}, \frac{5}{17}, \frac{6}{5}, \frac{7}{17}, \frac{8}{10}, \frac{9}{19}, \frac{10}{19}, \frac{11}{15}$$

The top number in each case represents the overtone: 1 is the fundamental; 2 is the second harmonic and so on. The corresponding lower number represents the number of db this overtone is below the fundamental. Thus, the second harmonic is 3 db below the fundamental (which is of course 0 db below itself); the third harmonic is 10 db below the fundamental, and so on. Actually, however, the structure changes to an appreciable degree with the intensity.

[21] However, some of Chopin's Etudes, such as Op. 10 and Op. 75, have a sequence of from 400 to 600 notes per minute, so that each note lasts but 1/10 second.

Acknowledgements

In concluding this article, it is a pleasure to acknowledge the help and cooperation of several people. Mr. Theodore D. Steinway, Chief Engineer, not only took the writer through the Steinway factory and showed him the various processes, but discussed very frankly some of their manufacturing techniques and thoughts about piano design and construction. He also suggested some of the books mentioned in the bibliography, and kindly agreed to read this article for accuracy of technical content, particularly where it concerned the Steinway piano.

The rather complete bibliography of articles from the *Journal of the Acoustical Society of America* was very generously furnished by Dr. D. W. Martin, Supervisor of Acoustical Engineering for the Baldwin Company. He and Mr. J. F. Jordan, Chief Engineer of the Baldwin Company, also discussed many of the technical problems involved, and furnished the writer with many interesting and pertinent technical concepts concerning the piano, as well as agreed to review this article for technical soundness of presentation. In addition, Mr. J. M. E. Mixter and Mr. T. M. Wulsin were very cooperative in furnishing the literature and illustrations so necessary for this exposition. Finally, acknowledgment must be made of the many helpful discussions the writer had with Mr. Walter A. Anderson, who must be an excellent piano tuner, since he knows so much about the piano.

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MAKE YOUR OWN WOOFER

(from page 19)

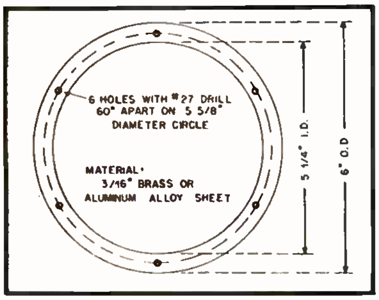

Fig. 4. Details of spider clamping ring.

eter will be approximately 6⅞ in.

7. With the ring still in the lathe, enlarge the center hole to 2⅝ in. inside diameter.

8. Transfer the terminal strip for the voice-coil leads to the new basket.

9. Press the iron ring into the circular groove in the new basket, making sure that the four 9/32-in. holes near the periphery of the ring line up with the corresponding holes in the basket.

10. Apply a coating of good speaker cement to the back rim of the new cone and the recessed rim of the new basket.

11. Set the cone into the basket, in approximately its normal position. Quickly assemble the spider and its clamping ring, with the six 6/32 screws. Insert the screws so that the heads are in the recesses in the rear surface of the basket. Use a split lock-lockwasher and nut on the threaded end washer under each screw head. Put a of the screw after it is in place.

12. Insert the fishpaper shims, provided with the new cone assembly, into the gap between the iron ring and the outside of the voice coil. With the voice coil thus roughly centered, tighten the screws that hold the clamping ring and spider.

13. Press the edge of the cone into place around the edge of the basket. Allow the cement to dry for about ten minutes; then smear on another layer of cement and add the felt quadrants which are also provided with the new cone assembly.

14. Lay the new cone and basket assembly face down on a flat surface, put a few books on top of it, and allow the cement to dry for at least four hours. Remove the fishpaper shims.

15. Slide the cone and basket assembly into the magnetic structure, being careful to retain the brass spacer in place around the center polepiece. Insert and tighten the four ¼-in. bolts, which were removed in step 1.

16. Solder the voice coil leads to the terminals on the terminal strip, using care to keep the soldering iron away from the cone.

17. Loosen the six screws holding the spider clamping ring, insert three of the shims 120 deg. apart in the gap between the voice coil and the center polepiece, and tighten the screws holding the clamping ring.

18. Set the speaker on the wood block; mark, drill, and countersink (from the bottom) the four holes required, and attach the unit to the wood base. The speaker is now ready to be mounted in its enclosure.

The field coil requires 35 watts of well-filtered d.c. The Capehart units were usually wound to 400 ohms resistance, and a selenium or germanium diode full-wave bridge rectifier, operating without a transformer directly across the 115-volt line, together with a choke coil and two 80-μf electrolytics, will make a good field exciter for a 400-ohm field.

The efficiency of this speaker is high. It is about 2 db lower than the current model Jensen units using these cones, but it is several db higher than other 15- and 18-inch woofers now available.

This unit should be used only as the low-frequency radiator in a 2-, 3-, or 4-way system. The frequency response curve, *Fig.* 1, indicates an optimum crossover frequency of 400 cps, for the cone is working as a piston only up to this point. A crossover frequency as high as 800 cps may be used, but in general this is not desirable, for frequencies above 400 cps begin to give "presence" and localize the source.

PARTS LIST

1 Capehart (Jensen) 14-inch speaker
1 Jensen 18-inch cast aluminum basket
1 Jensen 18-inch woofer cone, #2248-2
1 spider clamping ring, made as per *Fig.* 4
1 hardwood block, approx. 14 × 6½ × 2½ in. thick
6 RHNP brass machine screws, 6/32 by ½ in. long, with 1 nut and 2 split lock-washers each
4 steel hex head bolts, ¼-28, 2½ in. long, with nuts and split lockwashers
1 tube speaker cement

A MONTHLY SUMMARY of product developments and price changes of radio electronic-television parts and equipment, supplied by United Catalog Publishers, Inc., 110 Lafayette Street, New York City, publishers of Radio's Master.
These REPORTS will keep you up-to-date in this ever-changing industry. They will also help you to buy and specify to best advantage. A complete description of most products will be found in the Official Buying Guide, Radio's Master—available through local radio parts wholesalers.

Recording Equipment, Speakers, Amplifiers, Needles, Tape

ALTEC LANSING—Decreased price on Model "800" speaker system to $340.00 net.

ELECTRO-VOICE—Increased price on model 848 Compound Diffraction Projector Loudspeaker System to $39.00 net.

HALLICRAFTERS CO.—Increased price on Model SX-71 Double Conversion Receiver to $249.95 amateur net.

KARLSON ASSOCIATES—Added Model 15PU rough plywood loudspeaker enclosure at $75.00 net. Discontinued Model 15P rough plywood loudspeaker enclosure.

PACIFIC TRANSDUCER—Model 271 sapphire needle decreased to $0.75 net.

PAR METAL PRODUCTS—Discontinued transmitter chassis Models 20183, 20184, 26222, 26223, 26224.

PENTRON—Increased price on Model 9-T3C portable multispeed tape recorder to $139.50 net.

PERMOFLUX CORP.—Added new series of Super-Royal speakers.

RECORDING WIRE & TAPE—Added Jiffy Tape Rase at $21.60 net. Increased prices on 7-in. Magna-Reel Chest to $4.02 net; 5-in. Magna-Reel Chest to $3.36 net.

V-M CORP.—Discontinued Model 150 manual 3-speed phonograph.

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SELL: Altec 604C speaker, network, original crate, new $130. Wm. Tannenbaum, 160 Bennett Ave., New York 33, N. Y. TOmpkins 7-1698.

FOR SALE: Meissner 9-1091 AM-FM tuner in excellent condition. Cost $205: best offer. S. Kalman, 95 W. Palisade Ave., Englewood, N. J.

FOR SALE: Concertone 1401 tape recorder including footage counter, console tray with built-in 6 x 9 oval speaker and cooling fan, and reel adaptors. Pete Helffrich, Wescoesville R. # 1, Pa. $245, or best offer.

FOR CANADIANS
FISHER model 60-R tuner, 60-A amplifier, 60-AP power supply; recently overhauled, adjusted and new tubes by Fisher factory service, $275. JENSEN model G-610 15-in. triaxial speaker installed in Jensen back-loading folder horn cabinet; as good as new, $300. ALTEC-LANSING model 604 15-in. coaxial speaker in their bass-reflex cabinet, $150. All securely crated, FOB my express office. Donald Ells, Port Williams, Nova Scotia.

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Industry People...

AUDIO FAIR REMINISCENCE: Art Odgers, president, Northern Radio Company, Inc., entertaining friends and associates in the New Yorker's lavish 38th-floor penthouse suite . . . **Gene Smith,** high-fidelity expert of The New York Herald Tribune, mixing business with pleasure as he ogles exhibits with one eye while keeping the other on his watch—deadlines . . . Ditto **John Briggs, Murray Schumach** and **Harold Schoenberg** of The New York Times, **Al Hughes** of The Christian Science Monitor, **Arthur Bronson** of Variety, **Iz Horowitz** of The Billboard, **Charles Sinclair** of Sponsor, **Guy Shipler** of Business Week, **Norman Weiser, Nat Hentoff** and **Bob Parent** of Downbeat, **Stanley Krigfeld** of The Wall Street Journal, **Bill Herrman** of Retailing Daily, **Neil Harrison** and **Ralph Freas** of Record Retailing, **K. Inoue** of Asahi—Japan's largest newspaper, **Martin Mayer** of Esquire, **William Lansdale** of House and Garden, **J. T. Urban** of Musical America, **Rocco Famighetti** of Broadcasting-Telecasting, and many, many others.

Lewis Goodfriend, prominent audio consultant, receiving congratulations on birth of a new baby girl... **Arthur H. Miller,** public relations consultant, displaying supreme grace in the face of unfortunate cancellation of TV broadcast he had planned . . . Nat and Chuck Mendelsohn getting acquainted with major manufacturers as the final step in opening their new high-fidelity studios and sales room located eight miles from George Washington Bridge in Paramus, N. J.—company name will be Music Age, Inc.

NEWS FROM HERE AND THERE: Edwin C. Roworth, secretary of Stromberg-Carlson Company, retired recently after 48 years of continuous service . . . **Phillip B. Williams** has been named chief engineer of Jensen Manufacturing Company, according to word from **Thomas A. White,** president . . . Appointment of **Charles B. Denton** as market manager has been announced by Weston Electrical Instrument Corporation . . . **Melvin C. Sprinkle** has been named audio sales manager of the Ampex Corporation's Washington, D. C. district office—formerly chief engineer for Shrader Manufacturing Company and for many years in sales engineering department of Altec Lansing Corporation . . . **Raymond S. Perry** is the new president of Federal Telephone and Radio Company—succeeds **Henry C. Roemer** who returns to IT&T as administrative vice-president . . . **Donald LeRoy** is new advertising manager of Raytheon Manufacturing Company's Television and Radio division.

John S. Margolin, Sales Manager, and Will Brooks, Chief Engineer, respectively, of tapeMaster, Inc., have both resigned to become full partners in the Chicago Rep. firm of J.K.M. Inc., according to R. M. Karet, president of the Rep. firm. . . . William W. Garstang moves from position as Works Manager for Television and Radio Division of the Raytheon Manufacturing Company to Assistant Vice-President in charge of manufacturing.

Industry Notes...

Bell Sound Systems, Columbus, Ohio, has been purchased by **Thompson Products, Inc.,** Cleveland, and will be operated as a subsidiary of the **Thompson** electronics division—Floyd W. Bell, founder, will remain with the organization . . . **Pyramid Electric Co.,** North Bergen, N. J., is planning January 1 occupancy of a new 160,000 sq. ft. plant in Gastonia, N. C.—will eventually employ nearly 1000 persons . . . **American Institute of Management** has awarded associate membership to Miryam Simpson of the **Mark Simpson Mfg. Co.,** manufacturers of **Masco** sound equipment.

The National Tax Association has elected as president for 1954 John L. Connolly, secretary and general counsel of **Minnesota Mining & Manufacturing Co.** . . . **International Standard Trading Corporation,** New York, announces the appointment of **Kingdom Products, Ltd.,** also New York, as exclusive distributors in this country for **Lorenz** high-fidelity speakers . . . **Capitol Commodities Company, Inc.,** and **Radio Surplus Corporation,** both Chicago, have merged under the name **Capitol Commodities, Inc.**—street address is 1229 W. Washington Blvd.

ADVERTISING INDEX

Allied Radio Corp. 47
Akustische und Kino-Geräte 66
Ampex Corp. 15
Amplifier Corp. of America 63
Arnold Engineering Co. 5
Asco Sound Corp. 65
Atlas Sound Corp. 71
Audak Co. 39
Audio Devices, Inc. .... Cover 2

Beam Instruments Corp. 46
Bell Sound Systems, Inc. 62
Bell Telephone Laboratories 18
Brush Electronics Co. 4

Camera Equipment Co. 55
Cannon Electric Co. 6
Capitol Records, Inc. 71
Chicago Transformer Division 40
Classified Ads 70
Commissioned Electronics Co. 72
Compco Corp. 72
Conrac, Inc. 52
Crestwood Div., Daystrom Elec. Corp. .. 8

D & R, Ltd. 58

Electronic Instrument Co., Inc. 71
Electro-Voice 33

Fairchild Recording Equipment Co. 56

General Electric Co. 44, 56

Hartley, H. A., Co., Inc. 72
Harvey Radio Co., Inc. 41
Heath Co. 45, 59
Hollywood Electronics 71
Hughes Aircraft Co. 1
Hycor Sales Co. 54

Isotone Acoustic Spiralways, Inc. 66

Jensen Mfg. Co. 37

Kellogg Switchboard & Supply Co. 60
Kierulff Sound Corp. 71
Kingdom Products, Ltd. 61

Lafayette Radio 67
Lambda Electronics Corp. 58
Lansing, James B., Sound, Inc. 70
Leonard Radio, Inc. 51

Magnecord, Inc. 42
Measurements Corp. 13
Minnesota Mining & Mfg. Co. 3

Orradio Industries, Inc. .... Cover 3

Partridge Transformers, Ltd. 67
Peerless Electrical Products 12
Pickering and Co., Inc. 17
Precision Film Laboratories, Inc. 10
Presto Recording Corp. 7
Professional Directory 71

Rauland-Borg Corp. 61
Reeves Soundcraft Corp. 9
Rek-O-Kut Co. 11
Rider, John F., Publisher, Inc. 69
Rinehart Books, Inc. 53
Rockbar Corp. 59

Shure Brothers, Inc. 14
Simpson, Mark, Mfg. Co., Inc. 60

Tannoy, Ltd. 35
Terminal Radio Corp. 63
Texas TV 70
Thermador Electrical Mfg. Co. 2
Turner Co. 43

U. S. Recording Co. 71
United Transformer Co. .... Cover 4
University Loudspeakers, Inc. 48

V-M Corp. 57

White Sound, Inc. 49

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