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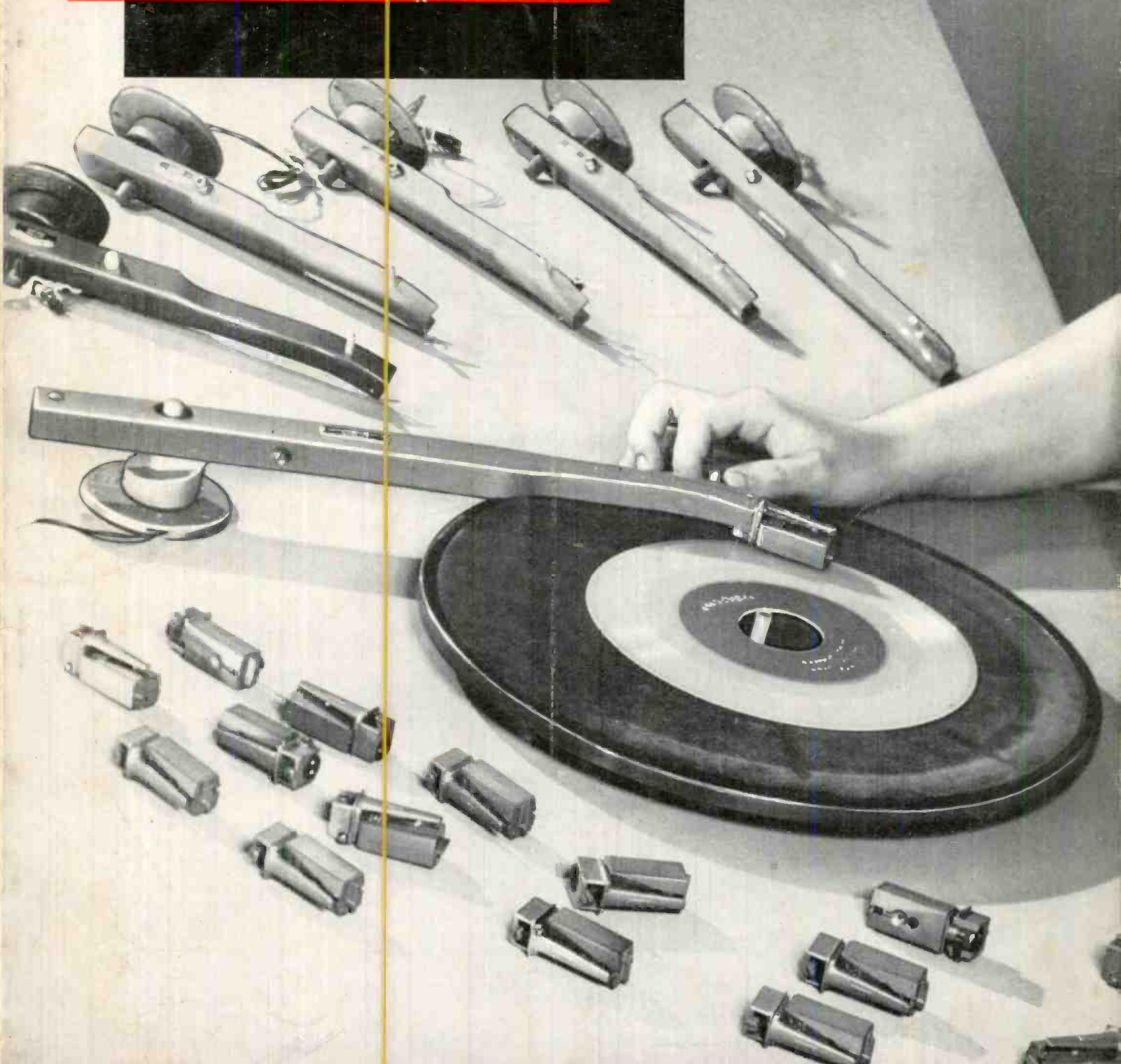

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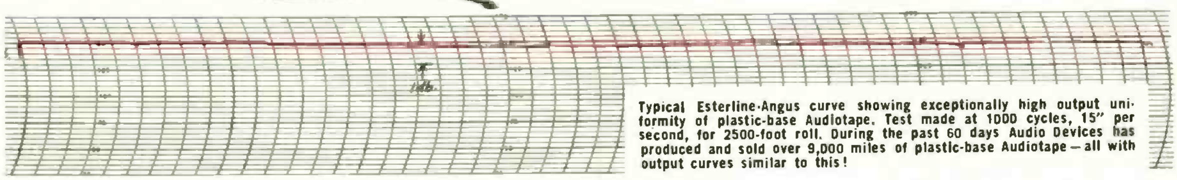

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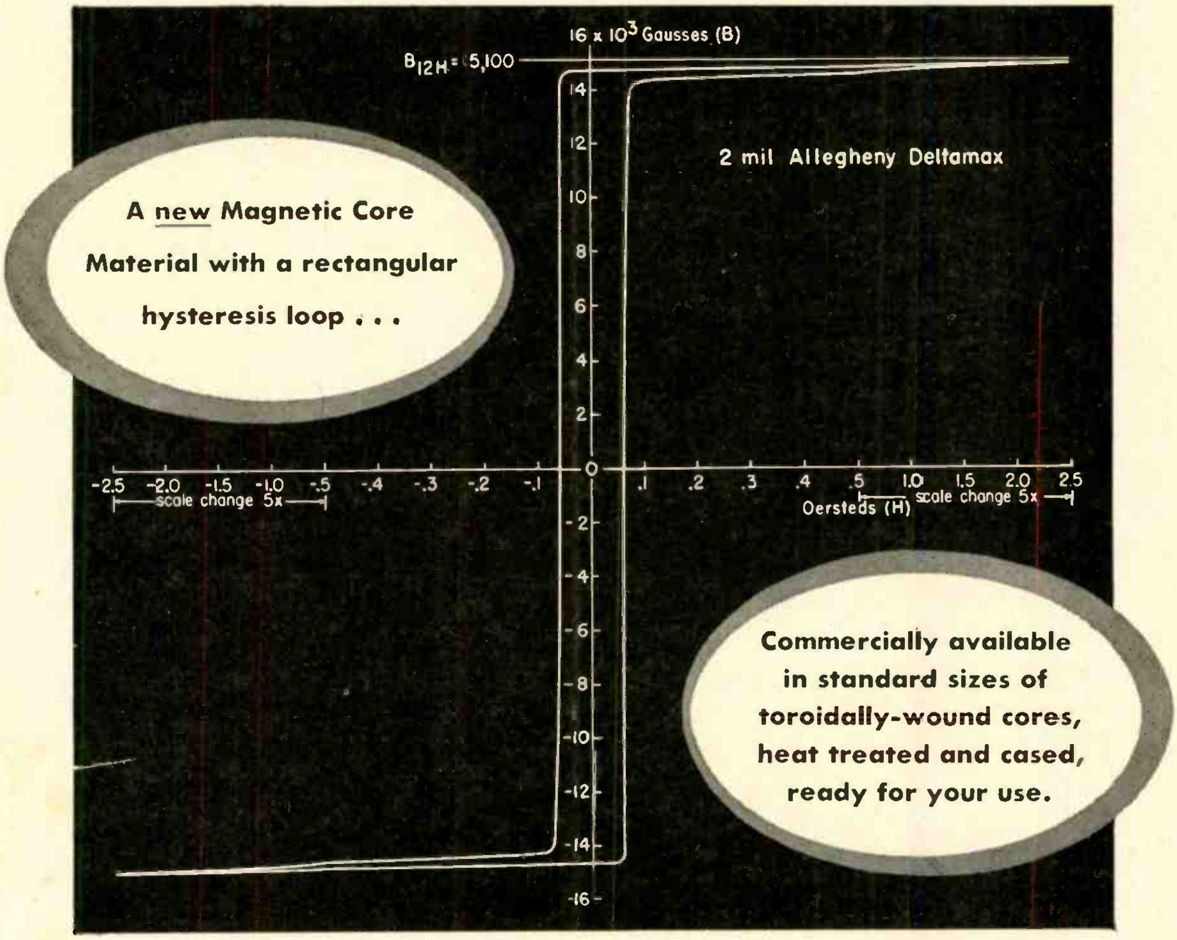

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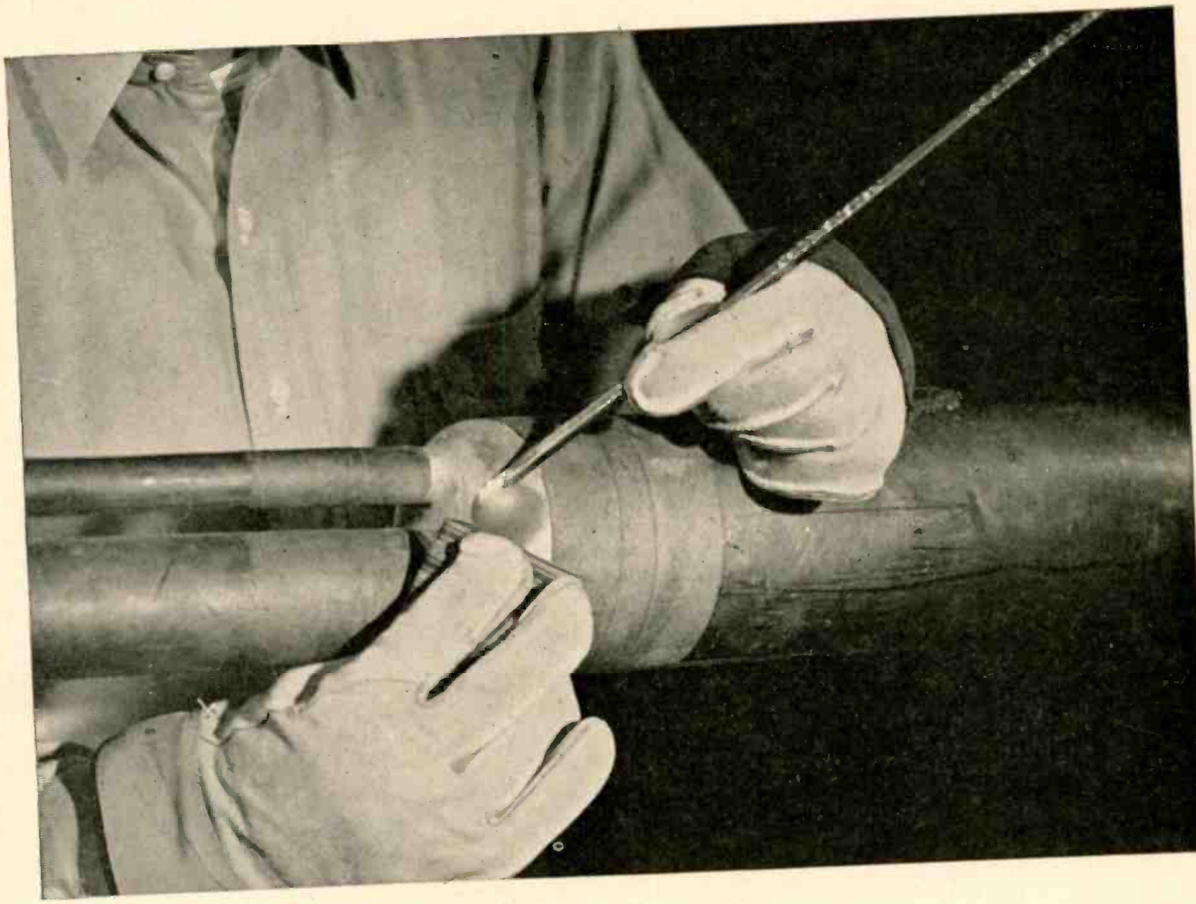

Transient Testing of Loudspeakers

MURLAN S. CORRINGTON*

A discussion of the relation between the sound-pressure curve of a loudspeaker and the transient response to a suddenly-applied unit sine wave, supported by photographs and oscillograms.

IT IS KNOWN from the theory of linear dynamic systems of minimum-net-phase-shift type that the amplitude response, the phase characteristic, and the transient response to various applied wave forms are merely equivalent ways of observing the same inherent performance of the circuit.[1,2] Any one of the three can be used to compute either of the other two. The labor of this computation is often great and is seldom attempted. If one had enough experience and were a keen observer, any one test would be adequate.

Many people use sound pressure curves to measure loudspeaker performance, and some laboratories now use transient tests also.[3-16] In the reproduction of speech and music, it is important that the sound start and build up as fast as the original, and when the signal ends the speaker should also stop. Thus when the hammer hits the string of a piano, the sound starts suddenly as the energy of the impact causes the string to vibrate. The loudspeaker must be able to start suddenly also, and when the damper comes down on the string at the end of the note, the loudspeaker must stop suddenly.

One test which is used to observe this performance is to apply a sine wave suddenly to the voice coil of the speaker and to observe the sound pressure with a microphone in front of the speaker on the axis. After a short time the applied sine wave is suddenly reduced to zero. The build-up and decay of the sound pressure is then observed on an oscilloscope. In many cases these results are confusing, because of lack of experience in interpreting the curves. Very little theory has been given in the literature to explain the effect of peaks and valleys in the sound pressure curve on the transient. This paper has three purposes. First there will be presented the theory of ringing of such a circuit when a signal is suddenly applied, and next it will be shown exactly how each peak contributes to the transient. Finally, a conventional 12-inch speaker will be used to show how the cone breaks up into symmetrical and asymmetrical resonant modes, and also the transient performance at each of the selected frequencies.

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Theory

We shall begin the theory by taking a sound pressure curve having two peaks near the high-frequency cutoff of the speaker, as shown by *Fig.* 1. The frequency has been normalized to unity at cutoff by dividing by the cutoff frequency ω_o. Thus, if $\omega_o = 10{,}000$ cps, for example, the first peak occurs near 5000 cps and the second at 10,000 cps. To simplify the interpretation, the low-frequency end is assumed flat. After this simplified case is thoroughly understood, it is easy to generalize to the more complicated curve of an actual speaker. It will be assumed that the loudspeaker is a minimum-net-phase-shift network. This may not be strictly true at high frequencies when cone breakup may cause cancellation at a point, but appears to be true for piston action.

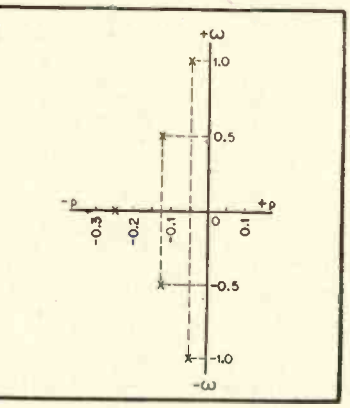


Fig. 2. Pole locations in complex frequency plane for a typical loudspeaker.

The locations of the poles in the complex frequency plane can be determined by noting that the maxima are near frequencies zero, 0.5, and 1.0. The Q's are different, and the pole at zero frequency is low Q, the one at 0.5 is higher, and the one at 1.0 is highest. This is easily decided by noting the width of the resonant peaks. The exact pole location can be found by using a probe in an electrolytic tank, by stretching a rubber sheet over some vertical posts, or by trial and error.[17-19] For the curve of *Fig.* 1, they are located at the points shown by *Fig.* 2. Although the curve is

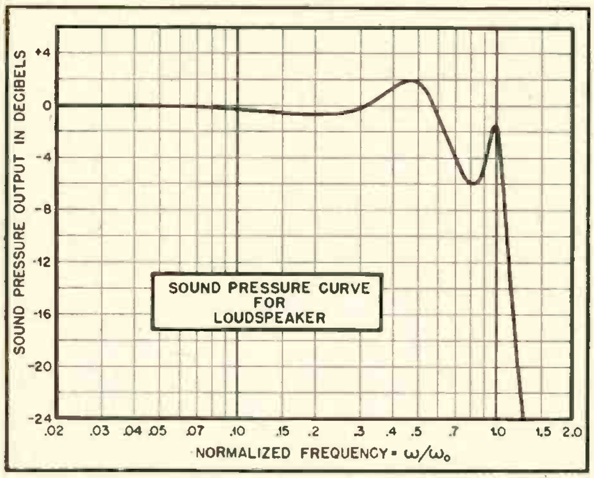


Fig. 1. Sound pressure curve for a loudspeaker.

for a loudspeaker, these results apply to any other linear system, such as pickups, electrical networks, microphones, etc.

All of the poles are in the left half of the p-plane. There is one on the axis at $p=-.25$, corresponding to the maximum in the sound-pressure curve at zero frequency. A conjugate pair occurs at $-.125 \pm 0.5\,i$ corresponding to the peak at frequency 0.5, and a second conjugate pair occurs at $-0.5 \pm i$, corresponding to the high-frequency peak at unity.

Since there are five poles and no zeros, the impedance function is easily found, as shown by equation (*1*).

$$Z = \frac{1}{[p+.25]\,[(p+.125)^2+.25]\,[(p+.05)^2+1]} \qquad (1)$$

The first bracket corresponds to the pole at $p=-.25$. The second bracket is obtained from the conjugate pair of poles at $p=-.125 \pm 0.5\,i$ as is readily seen, and the third bracket is obtained from the second conjugate pair of poles at $p=-0.5 \pm i$.

The transient response to a unit impulse, which is a spike of current of infinite height and zero duration, having unit area under the curve, corresponds to the transient generated by a noise pulse. This result can be obtained from the Heaviside expansion theorem,[20] by expanding in partial fractions and applying the inverse Laplace transform term by term,[21] or by evaluating the required contour integrals.[22] It is shown by equation (2).

Transient response to unit impulse

$$= (-.4984 \sin t + 1.1913 \cos t)\, e^{-.05t} + (1.7231 \sin \tfrac{1}{2} t - 4.8112 \cos \tfrac{1}{2} t) \times e^{-.125t} + 3.6199\, e^{-.25t} \qquad (2)$$

The equation shows, in the first line, that the pole at $p=-.05 \pm i$ causes ringing at the pole frequency, at $\omega/\omega_0 = 1$, and has a damping factor corresponding to the distance of the pole from the real frequency axis, $p=-.05$. The higher the Q, the nearer the pole is to the axis. For example, in an ordinary series-loaded parallel-resonant circuit this distance is $-\frac{\omega_0}{2Q}$, where ω_0 is the resonant frequency.

The second line shows the ringing caused by the pole at $p=-.125 \pm 0.5\,i$, and the third line is the ringing at zero frequency, which is an ordinary decay curve.

The coefficients are determined by the pole locations and moving any one pole affects all the coefficients.

The curve of the impulse response is shown by *Fig.* 3. It starts slowly from zero, builds up to the first maximum, and then decreases toward zero, oscillating about the zero axis. The two transients of frequency 0.5 and 1.0 are beating together. The components of the transient are shown. The one due to the pole at $-.125 \pm 0.5\,i$ is the dominant one, but the one at $-.05 \pm i$ dies out more slowly. The usual broadening of a pulse by the tuned circuits is evident.

Starting from the impulse response, the response to any other applied wave form can be obtained by applying the convolution or superposition theorem.[20, 21] Another way is to multiply the operational form of the impedance by the operational form of the desired applied wave form, and to find the inverse Laplace transform of the product.[21]

This latter method can be explained more easily in terms of spectra. By means of the Fourier transform or the Laplace transform it is known that the transform of a suddenly-applied unit sine wave $\sin \omega_0 t$ is $\frac{\omega_0}{\omega_0^2 - \omega^2}$. This result is equivalent to the amplitude and phase of the spectral density. For a wave of frequency one half the spectral distribution is as shown by *Fig.* 4. The curve rises smoothly from 2 at zero frequency, approaching infinity at frequency one half. At this point the phase shifts 180 deg., and the amplitude then rises smoothly from minus infinity toward zero. If the applied frequency is raised to unity, the shape is similar, as shown. To find the transient response at a given instant, this spectral density is modified in amplitude and phase in accord with the selectivity curve of *Fig.* 1.

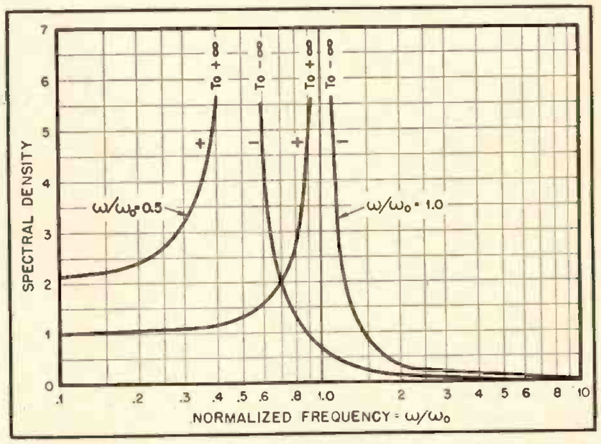


Fig. 4. Variation of spectral density with applied frequency.

It is easy to see that if the points of high spectral density are near to a peak in the response curve of *Fig.* 1, a great deal of energy will be impressed on the network at this frequency. The circuit will ring strongly at the frequency corresponding to the peak.

As an example of this theory, apply the unit sine wave to the two peaks of *Fig.* 1. When this is done, the response is as shown by the following two equations.

Transient response to suddenly applied unit sine wave at $\omega/\omega_0 = 0.5$

$$= -16.325 \sin \tfrac{1}{2} t - 9.383 \cos \tfrac{1}{2} t + (0.223 \sin t - 0.827 \cos t)\, e^{-.05t} + (19.797 \sin \tfrac{1}{2} t + 4.418 \cos \tfrac{1}{2} t) \times e^{-.125t} + 5.792\, e^{-.25t} \qquad (3)$$

Response at ω/ω_0 1.0

$$= 10.332 \sin t + 7.039 \cos t - (12.030 \sin t + 4.683 \cos t)\, e^{-.05t} + (3.191 \sin \tfrac{1}{2} t - 5.763 \cos \tfrac{1}{2} t) \times e^{-.125t} + 3.407^{-.25t} \qquad (4)$$

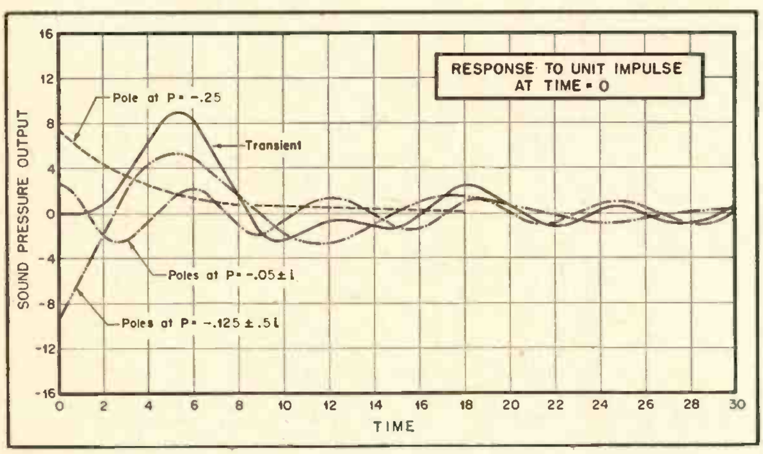


Fig. 3. Transient response to a unit impulse of a sine-wave signal.

Equation (*3*) corresponds to the first peak in the sound pressure curve, and equation (*4*) corresponds to the peak at frequency 1.0. The first line of each equation gives the steady-state term.

It should be noted that the peak nearer in frequency to that of the applied wave causes the stronger ringing, but both are present. As the frequency of the suddenly applied wave moves from the lower peak toward the other, the transient caused by the first pair of poles becomes weaker, and the other transient becomes stronger. The decay curve due to the pole at the origin becomes weaker as the frequency of the applied wave moves away from this pole. The amplitudes of these transient components, for varying applied frequency, are shown by *Fig*. 5. The closer the applied frequency is to a peak in the response curve, the stronger this peak will ring.

The response due to a suddenly applied unit sine wave at frequency 0.5, corresponding to equation (*3*), is shown by *Fig*. 6. The transient starts out slowly, due to the time required for the signal to pass through the network, reaches the first maximum, and then oscillates about the zero axis, rapidly approaching the amplitude and phase of the steady-state curve. The transient due to the pole at the same frequency as the applied sine wave is very strong, being nearly as high as the steady-state curve at the first maximum, but it dies out rapidly due to the heavy damping. The transient due to the higher frequency pole is weak, but dies out slowly.

When the frequency of the suddenly applied sine wave is moved up to the second peak of the response curve, the results corresponding to equation (*4*) are as shown by *Fig*. 7. The transient starts out slowly in the positive direction and soon reaches a maximum. Beyond this point the oscillation is about the zero-frequency axis, but of varying amplitude as the two oscillatory components come in and out of phase.

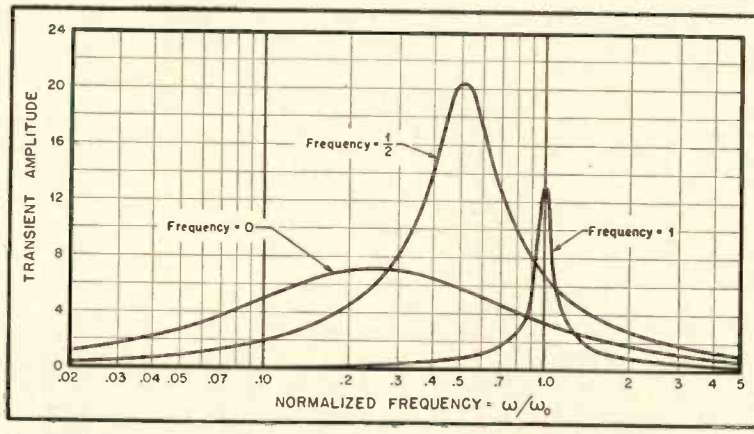


Fig. 5. Variation of transient components with frequency of applied unit-step sine wave.

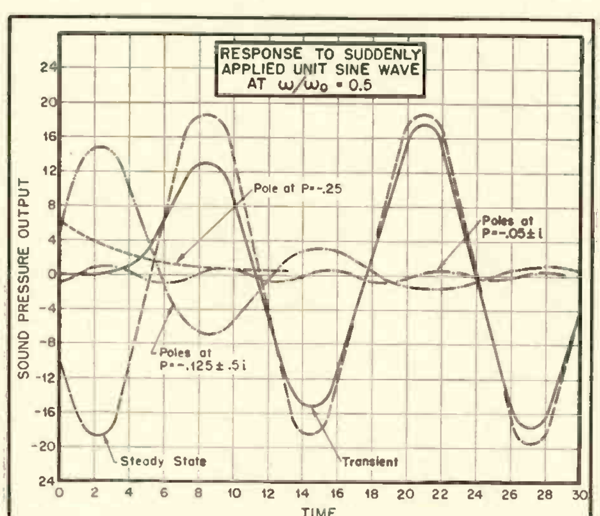
Because of the high Q of this pole, the resulting transient does not approach the final steady state nearly so rapidly as it does at the other pole (see *Fig*. 6).

Experimental Results

The sound pressure curve of a standard 12-inch speaker is shown by *Fig*. 8. The low-frequency resonance occurs at 75 cps, the usual rim resonance occurs in the region between 1200 and 1500 cps, and there is peaking of about 8 db in the upper register. The upper frequencies cut off rather rapidly beyond 6000 cps. The voice coil impedance shows the main resonance at 75 cps. The higher frequency symmetrical modes cause small variations in the impedance curve, but are largely swamped by the rising electrical impedance of the voice coil.

Several points have been marked with the letters *A, B, C, D*, etc. We will now examine the cone breakup and transient response to a suddenly applied sine wave at each of these frequencies. The inextensional radial modes occur at the low frequencies *A, B, C, D,* while the extensional circular modes occur at the high frequencies *F, G, H*.

Figure 9(A) corresponds to point *A* of *Fig*. 8 and was made by sprinkling lycopodium powder on the cone. The frequency was then set near the low-frequency resonance of the cone, which caused the powder to climb up the cone and distribute itself uniformly. The frequency was then raised to 400 cps and left there. The light yellow powder was shaken off of the moving parts of the



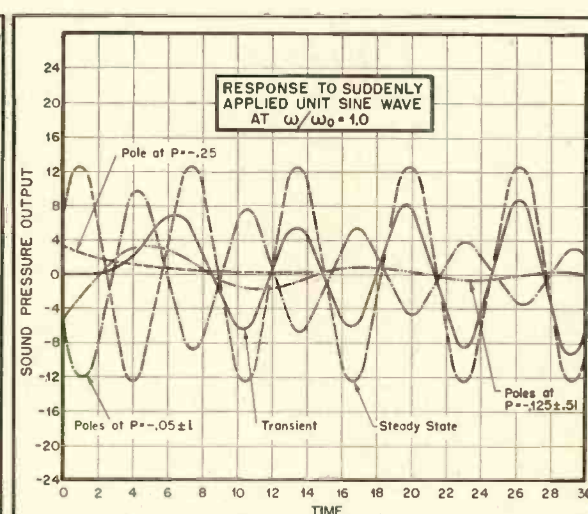


Fig. 6 (left). Response to suddenly applied unit sine wave at $\omega/\omega_0 = 0.5$. Fig. 7 (right). Response to suddenly applied unit sine wave at $\omega/\omega_0 = 1.0$.

cone, and allowed to remain at the nodes. There are thus four radial nodes, uniformly spaced, with the anti-nodes on opposite sides of a given node moving 180 deg. out of phase. This tends to pump air back and forth across a node, and does not result in a peak in the sound pressure output because of this "short circuit" of the air path.

Figure 9(B) shows the response to the suddenly applied sine wave. Since there are no pronounced peaks near 400 cps, the buildup is smooth and fast. The decay is rather uneven as the different resonant frequencies are excited at cutoff and die away at different rates. The frequency corresponding to the main resonance at 400 cps hangs on longer than any other because of the large amount of energy stored in the cone. There is a slow oscillation at 75 cps superimposed corresponding to the resonance peak due to the cone and suspension resonance.

When the frequency is raised to 450 cps, there are eight radial nodes, symmetrically spaced as shown by *Fig.* 10(A). This corresponds to point *B* of *Fig.* 8. There is little effect on the sound pressure curve because the antinodes merely pump air across the nodes.

Since there is no peak near this point, the transient buildup shown by *Fig.* 10(B) is smooth and rapid. When the signal is cut off, the ripple is at the small peak in the response at 480 cps. A slow oscillation at the 75-cps resonance is superimposed. Some high-frequency beating is evident right at cutoff as the higher frequency transients die out rapidly.

The peculiar standing wave pattern of *Fig.* 11(A), corresponding to point *C* of *Fig.* 8, is somewhat unsymmetrical and apparently is a mixture of two normal modes. The one wide node apparently is moving slightly in the center. The corresponding transient response is shown by *Fig.* 11(B). The 75-cps oscillation is superimposed as before, and there is considerable beating between transients just after cutoff.

When the frequency is 940 cps, corresponding to point *D*, the cone vibrates as shown by *Fig.* 12(A). There are two main nodes, but opposite sides are in phase and the rim is not moving strongly. The transient of *Fig.* 12(B) shows that the 75-cps oscillation is much weaker than in the previous cases, since the applied sine wave is much farther from this peak in frequency. The 940-cps note persists for a long time because of the high stored energy and low damping, since the voice coil need not move.

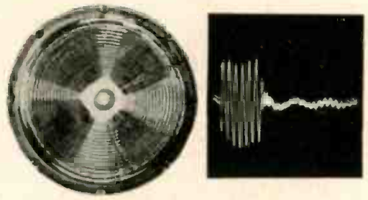


Fig. 9A (left). Cone breakup at 400 cps, with four radial nodes; point A. Fig. 9B (right). Transient response to same signal.

Figure 13(A) is one of the first symmetrical extensional modes and occurs at 1450 cps, at point *E* of *Fig.* 8. The frequency is high because the paper must stretch and this results in high stiffness. The rim is 180 deg. out of phase with the center of the cone. The powder cannot shake off the cap so it appears as a dense white cloud. This resonance is characteristic of all cone speakers where the rim is not properly terminated to eliminate standing waves, and normally shows up as a hole between 1000 and 2000 cps, although it may be somewhat lower in large cones.

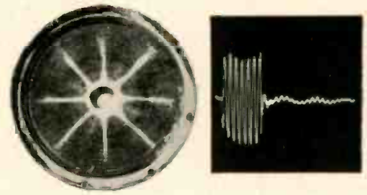


Fig. 10A (left). Cone breakup at 450 cps, with eight radial nodes; point B. Fig. 10B (right). Transient response to same signal.

As shown by *Fig.* 13(B), there is considerable ringing at buildup and decay, because of the dip in the sound pressure curve and because of the high energy storage. The high-frequency oscillation beyond cutoff corresponds to the adjacent peak near 1800 cps.

Figure 14(A) shows the next higher circular mode, corresponding to point *F*, with two nodes. The center cap is moving strongly, a node surrounds it, and there are two more antinodes. There is some evidence of superimposed radial nodes. The buildup and decay of *Fig.* 14(B) are fairly smooth, but there is considerable irregularity as the different transients come in and out of phase.

The next higher symmetrical mode, occurs at 2700 cps and is shown by *Fig.* 15(A). It corresponds to the peak at point *G* in the sound pressure curve. There are 3 circular nodes. The corresponding buildup and decay of *Fig.* 15B shows considerable evidence of the transients, corresponding to the various peaks, coming in and out of phase as they beat together.

The final photograph of *Fig.* 16(A) shows four circular nodes. These are not quite so clearly defined as the preceding ones because the corrugations affect the cone flexibility. The center of the cone is moving strongly. The buildup and decay of *Fig.* 16(B) show the expected interaction between transients at the beginning and end of the wave. Since this frequency is several octaves away from the 75-cps cone resonance, there is very little evidence of 75-cps components in the curve.

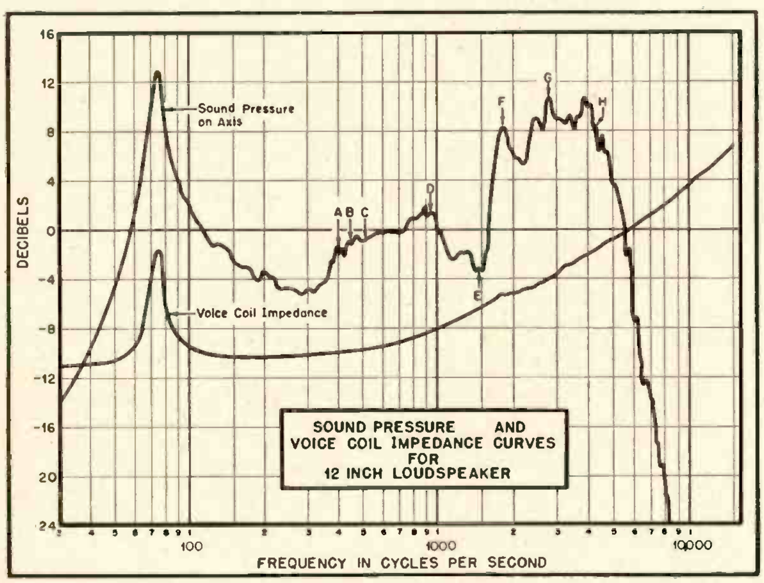


Fig. 8. Sound-pressure and voice-coil impedance curves for a 12-inch loudspeaker.

Conclusions

There are several ways to measure the transient performance of a loud-

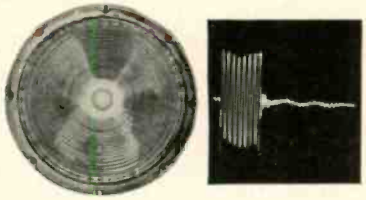


Fig. 11A (left). Cone breakup at 510 cps, with four radial nodes; point C. Fig. 11B (right). Transient response to same signal.

speaker. The unit impulse gives all of the information at one test, but is hard to interpret, because it causes all the peaks to ring strongly simultaneously, in proportion to the area under the curve. The suddenly applied unit sine wave is more selective, since it emphasizes the ringing of the peaks of nearly the same frequency as the applied sine wave.

The resonances in the cone fall into four general classes:

1. Low-frequency resonance—cone moving as piston.
2. Radial modes.
3. Symmetrical modes.
4. Combination modes.

They can be measured by means of

1. Dust patterns.
2. Acoustic probe.
3. Electrostatic or mechanical probe.
4. Stroboscope.

The dust-pattern method is very simple and direct, although the others may give more numerical data.

Whenever a transient wave form is applied to such a system, there will be ringing corresponding to each pole, or

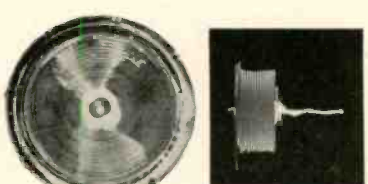


Fig. 12A (left). Cone breakup at 940 cps, with two radial nodes; point D. Fig. 12B (right). Transient response to same signal.

conjugate pair of poles, in the complex frequency plane. The amplitude of each component is determined by the spectrum of the applied wave, and also by the influence of neighboring poles on each other.

Since some of the frequencies generated are not harmonically related to the applied signal, they cause an annoying type of distortion somewhat similar to intermodulation. The ear is very sensitive to this type of inharmonic distortion, and it is thus evident that a high-quality speaker should be as smooth as possible in the sound pressure curve.

Acknowledgment

The equipment used for these tests was built by Roy Fine and Marshall Kidd of this laboratory, and they helped

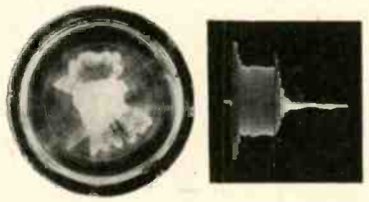


Fig. 13A (left). Cone breakup at 1450 cps, with one circular node; point E. Fig. 13B (right). Transient response to same signal.

obtain the photographs shown. The author wishes to thank them for this invaluable assistance.

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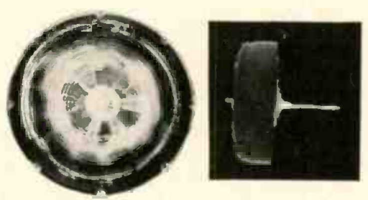

Fig. 14A (left). Cone breakup at 1800 cps, with two circular nodes; point F. Fig. 14B (right). Transient response to same signal.

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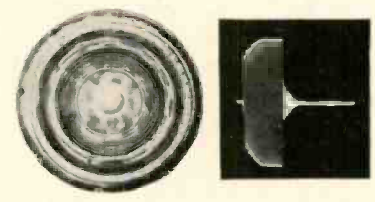

Fig. 15A (left). Cone breakup at 2700 cps, with three circular nodes; point G. Fig. 15B (right). Transient response to same signal.

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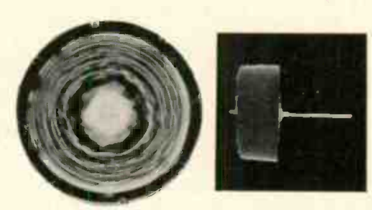

Fig. 16A (left). Cone breakup at 4200 cps, with four circular nodes; point H. Fig. 16B (right). Transient response to same signal.

Imagery for Describing Reproduced Sound*

VINCENT SALMON**

A description of the body of terms suggestive of the sensations experienced—classified, defined, and illustrated as much as possible to facilitate oral or written description.

MOST OF US LISTEN to sound for the pleasure and information we derive therefrom. There are, however, many individuals who are not satisfied with hearing merely the corpus of the sound: they must dissect it, name the parts, and describe the function of each, in order to discover the reasons for pleasant or unpleasant auditory effects. These audio anatomists have made their ears a substitute for a whole laboratory of such acoustical instruments as frequency meters, sound level meters, response curve recorders, wave analyzers, and integrators. The calibrations of the ear, however, are not expressed by the unique, constant, and universally understood readings as are associated with the physical instruments named. Rather, the judgment of the ear is expressed by a vague, inconstant and unorganized body of terms that both name the "instrument" and supply the "calibration." This study of vocalized terms constitutes the imagery by means of which the auditory sensations evoked in the auditor (person listening) are described.

When used by qualified auditors, this imagery permits defects located by the ear to be described to other persons and thus provides for communication between the auditor and the engineer who must correct the defects described. The imagery also allows a critic of recorded music to convey his evaluations to his readers; it may even be useful to the ordinary listener in deciding where to set his tuning, tone, or volume controls, or even the on-off switch. A standardized usage would be most helpful for all of these purposes.

In this paper an attempt will be made to organize the imagery; to elaborate on the meaning of some of the terms; to indicate the probable physical variables involved; and finally to arrange homologous terms in a scale of values for more or less quantitative use. The terms and definitions offered must be regarded as representing but one preliminary usage, and the definitions are stated in positive terms for convenience of language only. It is hoped that after a period of field use and experience more sharply drawn definitions may be warranted. The opinions expressed are of course purely personal and do not necessarily represent those of the author's employers.

* Presented in part at the Thirty-third Meeting of the Acoustical Society of America, May 8–10, 1947. Many of the data herein reported were obtained while the author was employed by the Jensen Manufacturing Company, Chicago, Illinois, and are published with their permission.

** *Stanford Research Institute, Stanford, California.*

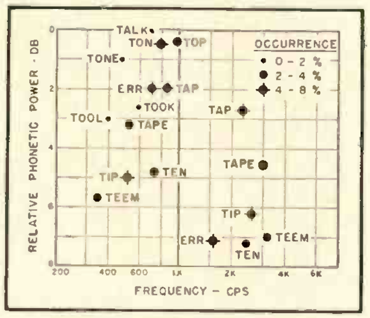

Fig. 1. Distribution of vowel phonetic power by formant frequency and rate of occurrence. The type of symbol indicates the fraction of the time the energy level shown is exceeded.

The terms may be divided conveniently into four groups:

1. Colorful synonyms for sensations due to objective characteristics of a sound system, such as noise and distortion.
2. Terms used for indicating sensations characteristic of a given frequency region.
3. Terms comparing the sensations produced by two important frequency regions.
4. Terms referring to rather tenuous sensations due to the over-all effect of the sound as a whole.

The treatment of the terms will be preceded by a discussion of the pertinent physical characteristics of sound sources, particularly for speech and music, and a subjective frequency-range notation will be offered. For convenience the terms will be set off in italics.

Sound Sources

Generally speaking, the most striking audible characteristics of a sound system arise from the response-frequency characteristic and the interferences, the latter including both noise and distortion. As ordinarily semi-subjectively used, response refers to the transmission characteristics (of a linear system) which determines the spectral composition of the output when the input is a signal of complex frequency composition. In musical terms, a non-flat response is recognized by a change in timbre, the amount of change depending on the source spectrum and the response of the sound system. Hence a knowledge of the spectral characteristics of sound sources will indicate the regions in the frequency scale to which particular attention must be paid in assessing the effect of response changes in the sound system.

We will first examine the characteristics of male speech.[1] Since vowels account for the major portion of the loudness of speech sounds only these speech sounds will be considered. *Figure* 1 shows the relative phonetic (short-time) power of typical vowels as a function of the frequency at which maxima occur in the spectra. Since not only the loudness but also the relative rate of occurrence is important, this rate is shown by the type of symbol on the diagram. A brief examination reveals that there are two fairly well-defined frequency regions in which male vowel sounds have high energy, roughly 500 to 900 cps and 1500 to 3000 cps. In terms of loudness, the upper region is the more important because of the increased sensitivity of the ear in this octave. In fact, one may suspect that evolution is responsible for this coincidence.

In *Fig.* 2 are shown similar data for musical instruments,[2] revealing a somewhat less marked division of important regions. From this diagram and from the original data the important regions turn out to be roughly 300 to 700 cps and 2000 to 3500 cps.

While the preceding data are rough and subject to considerable explanation of what is plotted, they agree in pointing out that the regions of 300 to 800 cps and 1500 to 3500 cps are the most important for both speech and music. We may go further and venture the statement that these frequency regions are critical as regards the response of a sound system, and that particular attention should be given them in designing, installing, and operating electroacoustical equipment.

Frequency Range Notation

Just as colors have common names in addition to standard tristimulus values, the audible spectrum has a more or less accepted pitch subdivision into low, middle, and high ranges supplementing a statement of the frequencies of signal components lying in each range. This subdivision was first proposed by Knowles[3] as a result of

[1] H. Fletcher, "Speech and Hearing," New York: D. Van Nostrand Co. Inc., 1929; pp. 64–84.

[2] L. J. Sivian, H. K. Dunn and S. D. White, *J. Acous. Soc. Am.*, 2, pp. 330–371 (1931).

[3] H. S. Knowles, in Pender and McIlwain, "Electric Communication and Electronics Handbook." New York: John Wiley & Sons, Inc., 1936; pp. 6–16.

synthesizing listener reactions, and is shown modified in *Fig.* 3 to emphasize both recent usage and the two important frequency regions of speech and music. Although the boundaries of these regions are not as sharply defined as implied by the diagram, it is seen that the *lower middle* and *lower high* frequency regions cover the important ranges discussed earlier. When a sound system is audited, these ranges may be located by listening for vocal and instrumental sounds having large components in the region of interest. In male speech and singing the long vowels ā and ē are very useful sign-posts, especially in the *lower highs*. In orchestral instruments, the bass viol, trumpet, trombone, and cymbal furnish guide-points over the whole spectrum, whenever they are sufficiently audible above other instruments.

If both music and speech are averaged, the mean spectrum depicted in *Fig.* 4 results, in which the relative pressure level per unit frequency interval is shown as a function of frequency. The total power integrated over the whole spectrum may be expected to be about 28 db above the value at the spectrum maximum. It is seen that the two important frequency regions fall along the upper slope of the spectrum, the slope being about −6 db per octave. The *lower middles* start with the spectrum maximum, and the *lower highs* include a hump at 2500 cps. It should be emphasized that this spectrum is obtained from the average of a good many consecutive measurements, and hence does not necessarily correspond to what is heard at any one instant. We actually hear a succession of transients, rather than the steady state implied by these curves.

For convenience, the frequency range notation depicted in *Fig.* 3 is shown in Table I.

Synonyms for Objective Characteristics

The disrepute in which the critical listener holds those reproduced frequency components that are not present in the original signal is evinced by the number and vehemence of the terms used to describe noise and distortion. Distortion, usually due to non-linearity of the steady-state transfer characteristic, is noticed by its absence in a *clean* system. If noticeably present, the sound is *dirty:* in a badly overloaded amplifier, e.g., we can hear the *hash-up* or *mush-up*. If this is accompanied by sudden rectification (as in single-ended output stages or in moving-coil loudspeakers with an asymmetrical magnetic field and suspension system), one can hear the *thump* when the signal *hits-bottom*. In a badly overloaded system, energy is transferred to the harmonics, and often the sound becomes *strident* if the harmonic energy peaks in the *lower highs*.

In ordinary recorded music, the inability of the stylus to track at high groove curvatures leads to objectionable high-frequency distortion variously described as *fuzz,* or *lace*. If it occurs principally on high-amplitude peaks, the resulting *crackle* is a form of overload distortion. A rather small amount of distortion together with excess loudness in this high-frequency region will cause violins to sound *wiry,* male voices to have *kazoo,* and brass instruments to show *jamming* in the upper octaves.

Many loudspeakers are two-way: that is,

TABLE I

Frequency Range Notation

Designation	Frequency Limits
Extreme Lows	Below 100 cps
Lows	100–300
Lower Middles	300–800
Upper Middles	800–1500
Lower Highs	1500–4000
Highs	4000–8000
Extreme Highs	Above 8000

the frequency range is divided, and each portion is handled by separate radiating systems. This sometimes leads to *cross-over distortion* in the region in which the energy shifts from one speaker to the other. While the causes are obscure, it is quite likely that rapid phase shifts at *cross-over* may lead to interference peaks in the signal wave form, causing the *marbles* or *garble* sometimes observed. If the dividing network permits both speakers to radiate in an appreciable common frequency interval, the interference may lead to a very *rough* over-all sound, corresponding to the erratic behavior with frequency of the received sound pressure in the *cross-over* region. It is hence best not to place the *cross-over* frequency in the center of the critical bands of either the *lower middles* or *lower highs.*

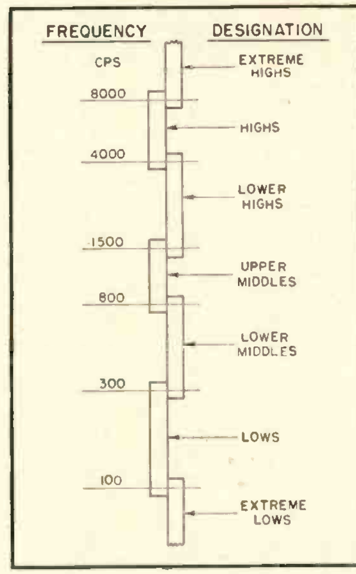

Fig. 3. Frequency-range notation.

Some loudspeakers (principally cone-type direct-radiators) produce subharmonics when a steady sinusoidal signal of the proper frequency is applied above a minimum power level and for a long enough time. Although these three conditions are rarely met in reproducing the succession of transients that constitute music and speech, the distortion, known as *breakup,* is evinced by *birdies* and *tweets,* and is startling and unwelcome.

Another type of distortion, due to intermodulation, shows up as a *harsh* and sometimes disagreeably *rough* tone. As source material for seeking this distortion, a *clean* program employing two sopranos or soprano and flute, following melodic lines of parallel thirds or sixths, is very suitable.

Transient distortion, while not as yet completely understood in terms of its effects on the ear, does cause trouble at the resonant frequencies of smaller direct-radiator loudspeakers, diaphragm-type crystal microphones, and crystal pickups. The devices are shock excited by the signal, and are usually insufficiently damped, so that the excited resonant oscillation *decays* slowly, and *hangs-on*. This also results in altering the *attack* of a suddenly applied signal, which may become *slurred.*

Another type of interference is noise, here understood to be an irregular perturbation ordinarily present even in the absence of the signal (note, however, modulation noise in magnetic and other recording processes). When the cause of the noise is mechanical, as in defective or ill-designed speakers, pickups and microphones, we may hear *rattles, needle-talk, buzz, rub,* or *wheeze*. The last refers to the passage of

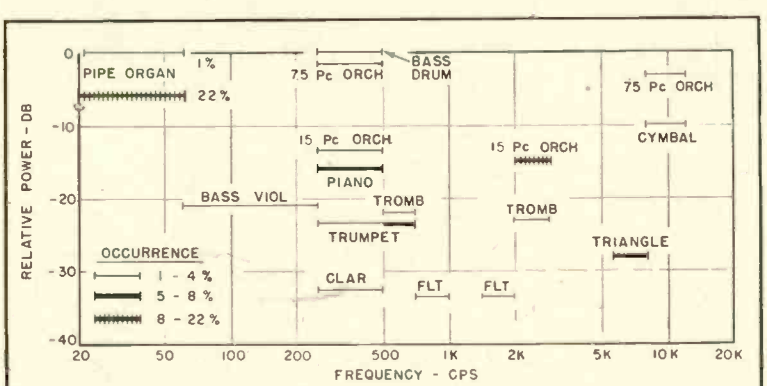

Fig. 2. Distribution of energy in orchestral instruments by dominant frequency ranges and rates of occurrence. The type of symbol indicates the fraction of the time the energy level shown is exceeded.

[*Continued on page 28*]

The Art of Tape Recording—IV

JOEL TALL*

The mechanics of tape editing—covering the actual methods of cutting and splicing magnetic tape recordings into a finished program.

DISREGARDING every other quality which makes tape recording valuable to professional workers in audio, tape would still continue to be valued because of its facility of editing. How well the tape can be edited depends upon the judgment of the production personnel, the expertness of the tape editor, the recording itself, and last and possibly least, the facilities that are available. In any case, the edited version of the recording can be no better than the original as far as tonal quality is concerned, although some improvement in tonal balance can be achieved through the various processes of re-recording.

There are certain logical steps which must be taken in the production of a completely edited tape before the tape is ready for playback. Consider one simple form of tape editing, the process by which a talk or speech is condensed without disturbing its meaning or impact. Assume that a half-hour recording of a political speech must be cut to nine minutes and thirty seconds air time. The permission of the speaker must be obtained to condense the speech, and its sense must not be disturbed. Obtain a typed draft of the speech, if it is available, or have a competent stenographer make a typewritten transcript from the tape itself. After this transcript of the speech has been studied, a capable director can condense the speech into the required time *on paper*. (A word of warning may be in order at this point. Occasionally a speaker will wander from his script and "extemporize." In such cases the tape editor will be at a loss unless he makes a practice of not discarding any part of the recording until the editing job is finished.) After the speech has been edited on paper, the production personnel and the tape editor should monitor the tape two or three times: first, to make certain that the excerpts preserve the ideas the original tape contained; and second, that the parts that are to be joined together are "joinable."

That strange word "joinable" means this: A speaker will try to convince his audience by the use of oratorical devices. He will change mood, level, pace, and inflection. He may be sad, joyful, sarcastic, cynical or earnest. It is impossible to edit tape without taking into consideration all of these factors. To attempt to separate mood from pace or level from inflection is useless. They must be considered together, in the many combinations of sounds that make the human voice a most expressive musical instrument. The art in tape editing lies in the editor's ability to interpret correctly the many factors contained in speech and to utilize them in producing a coherent and authoritative product. Because of this, there can be no hard and fast "rules of editing." There are some fairly adequate generalizations that will result in better productions. For example, it would create a weird effect if a phrase spoken in a high-pitched, excited voice were joined to another phrase in a calm, low-modulated voice. Or suppose that the speaker were popular and frequently had to over-ride applause during his speech. A phrase from the "applause in background" portion could not be joined to a phrase from the "no applause" portion without dubbing-in applause where it is needed.

Where to Cut and Why

As the advertisements tell us, tape is edited by cutting with scissors and splicing the two ends together with an adhesive. The actual methods now in use will be described later. Right now the question is "Where shall I cut the tape?" There are many places where you *can* cut it but there is only *one* spot that is exactly right. In order for you to understand why there is only one right place to cut the tape, we shall diverge from editing to a short discussion on the subject of "hearing."

* *Columbia Broadcasting System, New York.*

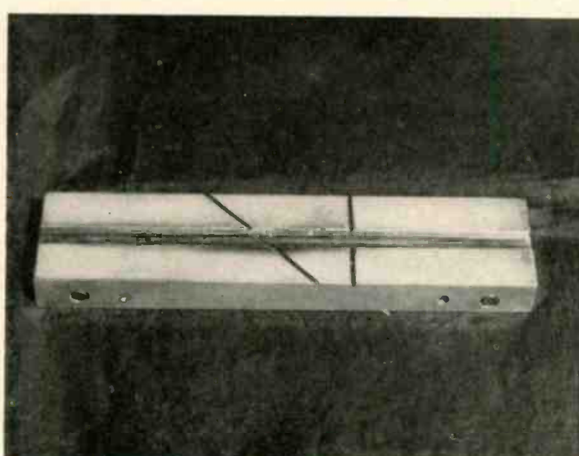

Fig. 1, left. Adjustable splicing block. The original was designed by the author in 1947 and made by Victor Piliero, CBS engineer. Fig. 2, right. Method of marking a cut with a grease pencil inserted through the marking aperture which is at the center of the playback head.

The human ear, when it is behaving normally, can understand, or perceive, an unrelated sound following another sound after a period of time approximately 0.14 seconds long. At the standard tape speed of 15 inches per second, that length of time represents about 2.27 inches of tape. (The ordinary key-click at the above speed would occupy from ¼ to ½ inch of space on the tape.) This 2.27-inch space, in normal speech, represents about twice the distance between words. Therefore, to edit accurately, you must find *the right place* to cut within a space of one to two inches. Within that space you must try to match, as closely as possible, the background sound recorded at the beginning of the next phrase to be joined. After you have noted that the backgrounds match, you must still observe the speaker's natural "pace." The speaker's "pace" or "gait" will vary according to what he is saying and his natural pace must be observed and followed in the edited version so that it is the same as in the original recording. In this connection do not forget that the man who speaks must breathe. Allow time for this function even though it is not audible. The expert tape editor will observe natural breathing habits and edit accordingly. Occasionally this will force him to clip out "breaths" of various lengths and intensities, and sighs and hesitant speech sounds, and insert them in their proper places in the edited tape.

Mood, pace, level, and inflection should be considered together. When a speaker becomes angry or excited, he generally speaks more rapidly, at an increased level and in a higher pitched voice. The tape editor should be able to judge, before cutting the tape, whether two wanted sequences of a tape recording can be joined with reasonable naturalness and credibility. If it is evident that they cannot be matched together as originally recorded, they may be matched by re-recording, utilizing some of the methods previously noted. If re-recording is inconvenient, and the sequence is absolutely necessary to the show, a pause of matching background sound may be put between the two segments to give the sequence some flavor of actuality.

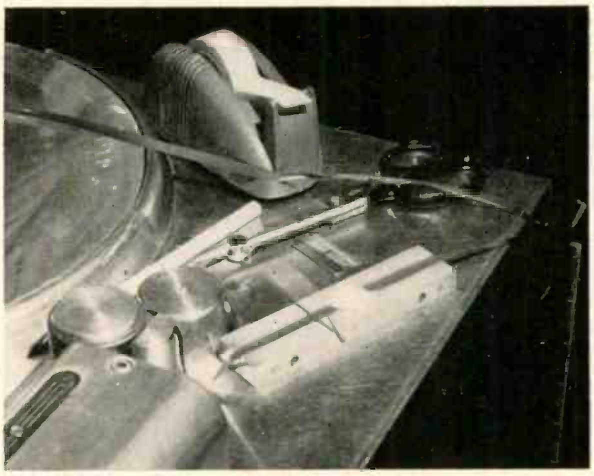

Fig. 5. Tape ends are joined together in the splicing block. The #41 Scotch tape is applied at an angle to the magnetic tape so there will be the least possible disturbance to smooth motion of the tape through the head assembly.

It is not desirable to end a sentence with an "up" inflection unless the speaker is meant thus to interrupt himself or to be interrupted by another voice or sound *immediately*. There must be no pause whatsoever on an interruption of this nature. It should be completely evident to the listener that it *was* an interruption and no background sound should intervene.

At other times the editor will find places in his show where a pause is required for an effect, dramatic or otherwise. In such cases it is important that the background sounds in the pause match the background of the end of the preceding tape segment and that of the beginning of the following one. If there is an unavoidable change in the character of background sound from one tape sequence to another, there is only one short-cut to making the whole thing believable. That is to leave in the background of one *or* the other sequence and clip the other sequence close to the first word. Another way to achieve homogeneity is to dub both sequences accompanied by another masking sound at fairly low frequencies, but intelligibility will then be diminished.

Where a transition effect on tape is needed it may be obtained either by re-recording and cross-fading or by using a recorded fade-out of one background and a fade-in of the other background. Effects of this nature on tape are limited only by the ingenuity of the engineer and his experience in the medium.

Editing Quiz Shows

Radio showmen who are alive to the possibilities of tape consider it is best used for editing audience-participation shows. It is only by using tape that some

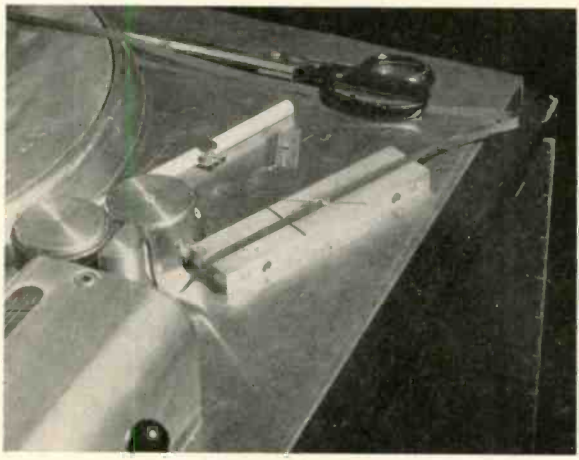

Fig. 3, left. Marked tape ready to be cut at the first mark. Use a slicing action when cutting to avoid fracturing the tape ends. Fig. 4, right. Running off tape to be discarded. This section of the tape is between points previously marked.

artists turn in consistently excellent performances. The artist (or master of ceremonies, if you prefer) is then relieved of the fear of a "dead" or "wise" participant, for he can be clipped out easily.

There is no great obstacle for the engineer who edits a first-class quiz-show. If he understands his medium and knows the routine of the show, he can turn in a very creditable job. The same conditions prevail as in the editing of a speech, except that the pace is generally faster, there are more interruptions and the backgrounds change rapidly. Perhaps it will be of use to outline the procedure in editing a typical quiz show.

Fig. 8. Tape editor A. J. Sisco splicing tape at NBC cutting room. (NBC photo)

The show was recorded in duplicate and lasted approximately forty-five minutes. The personnel of the show knew it was being recorded for editing. If an error in a music cue or commercial was made, the show was stopped and the error corrected. (In most cases, however, because of background change, it proved to be better to use the original than the amended version.)

When the original show was performed it was also recorded on disks for the use of the producer. He and his staff would then time the sequences needed, figure out the necessary editing and approximate the position of each part in the finished show. Thus when the time came for editing the tape, the editor knew approximately whether or not the parts would fit together. Rarely, however, would the show be put together in anything like the sequence in which it was recorded. To get listeners' interest, the first contestant in the original show might become the fifth in the edited version and vice versa. In order to fit these parts of a tape-puzzle together it was necessary to match wherever possible. Some pieces joined on applause, others on a laugh. Once, when it was necessary to cut the show by one chorus of a song the same note in two different choruses was cut in half and the two half notes joined together. Luckily the musicians stayed in pitch. However, it is possible to edit musical numbers in this way only when the music is played rapidly and there is little reverberation. It is not workmanlike to edit music unless it is possible to hit the same note exactly, played by the same instruments in the identical manner. All factors must match, otherwise a re-recording session and cross-fading is called for. After the show was edited to the proper time (29 minutes and 45 seconds), the edited tape was played back and a copy made on fresh tape. While recording the copy, which was for air use, the levels were corrected so that the overall effect was as smooth as possible.

It can be readily understood that the tape editor must be more than a mechanical splicer of loose ends of tape. Whether the show be musical, dramatic or quiz, the "feeling" of the show determines how it should be edited.

Many special instances could be cited, but the following is an example of what can be accomplished through the exercise of judgment and common sense.

Several years ago a recording of a native woman made on one of the South Pacific Islands required editing. She had recorded, in English, her distrust and distaste for the invaders of her island. As she said the word "Soldiers!" explosively, she followed it with a nervous laugh. In the sequence in which her words had to be used, the little nervous laugh after "those soldiers" would have been completely misunderstood. Thus, in order to retain what dramatic value there was, the laugh was changed into a sob by inverting its inflections, which left the sequence entirely in character.

No doubt it is understood that recognition of sound depends upon the speed at

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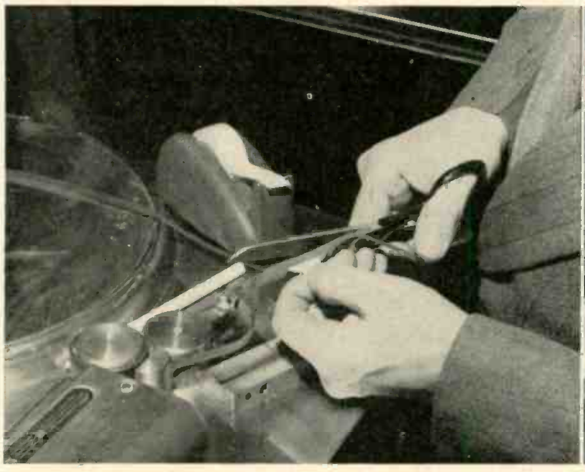

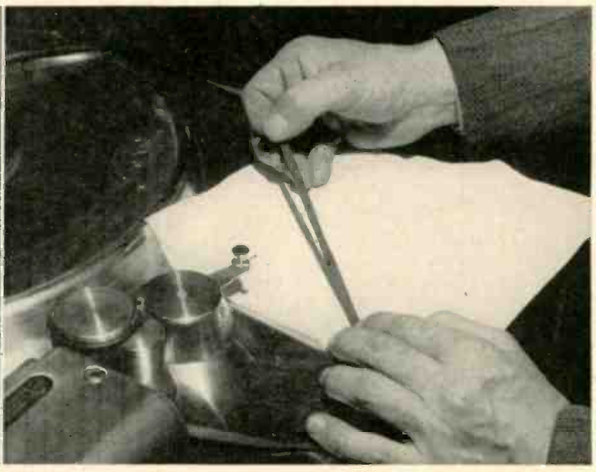

Fig. 6, left. Undercutting at the splice. The cut should taper out at both ends. Fig. 7, right. A completed splice. Note that the cut can be seen. A perfect splice cannot be noticed easily when running through the playback machine.

AUDIO engineering society

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AES Convention and The Audio Fair

THE SECOND ANNUAL CONVENTION of the Audio Engineering Society, to be held at Hotel New Yorker on October 26, 27, and 28, promises to be even more interesting and instructive than the first, held last October.

John D. Colvin, chairman of the Convention Papers Committee, has secured over twenty papers from engineers throughout the country, and they will be presented at four technical sessions—Thursday afternoon, Friday morning and afternoon, and Saturday morning. The Thursday session will be preceded by the annual business meeting of the Society, at which time the new officers will be installed.

The Annual Banquet will occupy the evening of Thursday, Oct. 26, and will be held in the Main Ballroom of the hotel, with accommodations for over four hundred people.

The Audio Fair

Running concurrently with the convention of the Society, The Audio Fair 1950 will open at 9:00 a.m. on Oct. 26 and continue to 6:00 p.m. on Oct. 28. The exhibits will be open until 9:00 p.m. on Friday, Oct. 27, thus permitting those who cannot attend during the daytime hours to see and hear the wide variety of equipment on display.

Because of the great increase in the interest shown in all phases of audio over the past few years, and the consequent desire of manufacturers to display their products as completely as possible, The Audio Fair 1950 will occupy two floors of the hotel—the fifth and the sixth. This additional space will give more room for the visitors, as well as more display space for the exhibitors.

The 1949 Audio Fair attracted 3022 visitors, with practically every state represented, as well as 28 foreign countries. The 1949 Audio Fair, it must be remembered, was the first exhibition ever held that was devoted entirely to audio, and the success of the convention and exhibits presents a convincing argument of the wide interest in audio.

The Audio Fair idea—that of being able to *hear* as well as see the equipment being exhibited—was a distinct innovation in the exhibit world, but its value was demonstrated beyond question at the first Fair. Visitors were most enthusiastic over the method of presenting the exhibits, and the advantage of seeing and hearing was shown to be a requirement in displays of audio equipment.

As before, all exhibits are free of charge. All visitors will be required to register and will be given identifying badges so that it will not be necessary to register each time they come to the hotel. Technical sessions of the Society are free to members, with a nominal charge being made to non-members for attendance.

Formal announcements of the Convention and The Audio Fair will be sent to Society members during August, together with advance registration cards and requests for hotel reservations at the Hotel New Yorker.

LECTURE COURSE NOTES AVAILABLE

For those who did not attend the Society's Fall Lecture Series which commenced last November and continued weekly until the end of February, the announcement of the availability of the Lecture Course Notes will be of considerable interest.

The course covered the Elements and Practice of Sound Recording, with thirty-two lectures ranging from the subjective aspects of recording to day-to-day maintenance problems. The subjects covered include: a general survey of recording methods; discussions of disc, tape, and film recording principles and equipment; microphone placement and studio acoustics; speech input systems; monitoring philosophies and methods; over-all system layout for recording and re-recording plants; and equipment scheduling and maintenance.

The notes are those furnished to registrants for the course, and in addition to containing much information in themselves, they cite collateral reading in the form of an extended bibliography. To cover the thirty-two lectures, the notes consist of 117 pages and over 250 illustrations. Page size is 8½ × 11 in. and the sheets are carried in a binder.

Society members may obtain copies of these notes at a cost of $2.00—actually less than the cost of preparation of the notes themselves. The rate for non-members is $3.00. Checks or money orders should be made payable to the Audio Engineering Society, and mailed to F. Sumner Hall, 153 W. 33rd St., New York 1, N. Y.

Employment Register

POSITIONS OPEN and AVAILABLE PERSONNEL may be listed here at no charge to industry or to members of the Society. For insertion in this column, brief announcements should be in the hands of the Secretary, Audio Engineering Society, Box F, Oceanside, N. Y., before the fifth of the month preceding the date of issue.

- **Audio Technician.** Employed in audio field at present; experienced in development and construction. Enthusiastic, good troubleshooter and maintenance man; wide knowledge of serious music. Desire position in studio, lab, or custom installation firm. Box 801.
- **Radio Engineer Wanted:** by prominent Chicago electronic mfgr. to design and supervise mfg. of full line of com'l ampls. Must have engineering degree or equivalent, and minimum of 2 yrs. design exp. in commercial P.A. systems. Give details including age, education, experience, reference, availability and salary expected. Box 601.
- **Electrical Design Engineer Wanted:** By large, modern, Eastern manufacturing firm for experimental development work in industrial electronics. Applicant must have degree in electrical engineering with communications or electronic option or equivalent in 10–15 years practical experience. Give details, including age, education, experience, references, availability, and salary expected. Box 401.
- **Audio, TV Field Engineer.** 10 yrs practical experience in maintenance of professional audio, TV, and radar equipment; design and maintenance custom home music systems. Member AES; Assoc AIEE. Good tech. educ. bkgnd; exc. references; exp. customer relations; extremely conscientious. Presently mgr. TV service lab and field service technician, electronic organs: Desire field work hi-fi audio or TV. Prefer Washington, D. C. area; consider other. Box 701.
- **Audio Engineer.** BS in radio from NYU, 26, married. Well versed all phases comm'l disc and tape recd'g. Presently employed large NYC studio, but not happy. A "future position" more desirable than a "present job." 9 yrs audio exp; available immediately, NYC metropolitan area. Box 501.
- **Audio and Electrical Engineer:** MS in physics; MS in EE. 10 yrs research, development, and design experience with magnetic and disc sound recording, acoustic measurements, and transducers. Also experienced in magnetic recording systems for computer applications. In present position for 10 years, but desire change to smaller company. Box 402.

AUDIANA

LEWIS S. GOODFRIEND

Equivalent Circuits

In many audio circuits, both electronic and acoustic, it is often desired to study the circuit behavior over a wide range of frequency and parameter values. To do so without actually constructing the unit involved requires that a circuit be drawn which is not the schematic of the parts as planned, but is the actual circuit at all frequencies. Then this *exact* circuit may yield several circuits that are its equivalent at some specific frequency or over a particular range of frequencies. From this equivalent circuit it is possible to derive relatively simple mathematical expressions for the operating characteristics. Also from the equivalent circuit the designer may determine the effect on operation of varying values of circuit constants.

To obtain the equivalent circuit we must first have the exact circuit. This is not, in general, the same as the schematic diagram which shows the electronic symbol for the part that is to go at a certain point in a piece of equipment. Where a wire wound resistor may be shown on the schematic, a resistor and inductance in series must be shown for audio work (it should be noted that even the exact audio circuit is only an equivalent circuit for low frequencies if the entire radio spectrum is considered, and distributed capacitance between turns of a wire-wound resistance shall be neglected along with a few other items of interest only to UHF engineers). Also a vacuum tube must be considered as a generator having an internal impedance and series and shunt capacitances. An example of the use of the equivalent circuit and its derivation is afforded in determining the gain of a triode at all frequencies.

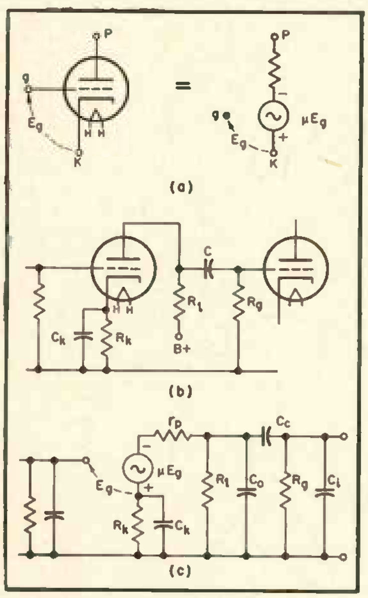


Figure 1

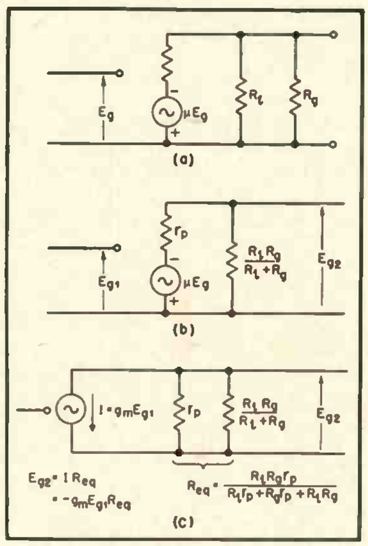


Figure 2

In *Fig.* 1 the original schematic has been redrawn as the exact circuit (for audio). It may be seen that the grid resistor of the tube under study and its input capacitance are considered with the preceding stage, while the input capacitance C_i of the following stage is included in the analysis along with its associated grid resistor. In designing triode amplifier stages, the coupling capacitor is chosen so that its reactance is small even at low frequencies, and that the load resistor R_l is small compared with the reactance of the capacitances in the output. Finally, the cathode bypass capacitor is selected so that its reactance will be very small at the lowest desired frequency. These original design requirements indicate possible simplifications of the circuit to enable the development of mathematical expressions for operation in the middle frequency region. This equivalent circuit for the mid-frequency band is shown in *Fig.* 2. The equations may be obtained by applying Kirchoff's law and Ohm's law to the loop. However, we have now reduced the circuit to the generator impedance in series with a pair of resistors in parallel. This permits an even simpler solution if we transpose the source to a current source. This is done at (C) in *Fig.* 2. The result is now obtained in one step.

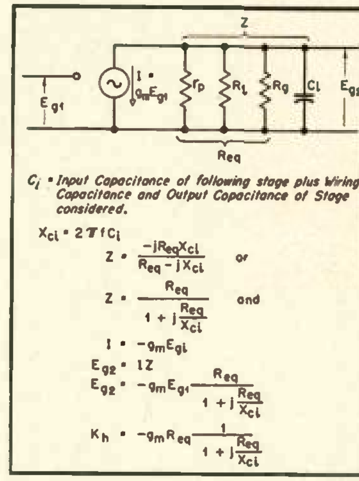


Figure 3

$$K = \frac{E_{g2}}{E_{g1}} = -g_m R_{eq}$$

The substitution of a current source with equal parallel resistance for a voltage source with a series resistance will not be proved, but the reader may refer to

Electric Circuits by the E. E. Staff, M. I. T., published by John Wiley and Sons, New York. This substitution is frequently useful, in this case having saved four steps.

High-Frequency Equivalent Circuit

Another circuit that is easily analyzed by this substitution is the high-frequency equivalent circuit which is shown in *Fig.* 3, along with the equations. It is obvious that this expression for the gain at high frequencies is the same as that at mid-frequencies multiplied by the factor

$$\frac{1}{1+j\dfrac{R_{eq}}{2\pi fC_i}}$$

The low-frequency equivalent circuit may be solved without considering the reactance of the cathode bypass capacitor, which is the usual case. However, for a complete solution, Terman has shown that a third multiplier may be included. This gives the general expression for the gain of a triode amplifier at any frequency as

$$K=-g_mR_{eq}\frac{1}{1-j\dfrac{2\pi fC}{R_o}}\times\frac{1}{1+\dfrac{R_{eq}}{2\pi fC_i}}\times\frac{1}{1+\dfrac{g_mR_k}{1+j2\pi fC_kR_k}}$$

From this expression, many authors have derived a set of general frequency-response curves plotted against $\frac{f_2}{f}$ and $\frac{f_1}{f}$, in which case the following relations hold

$$f_1=\frac{1}{2\pi R_oC},\ f_2=\frac{1}{2\pi R_{eq}C_i},\ \text{and}\ f_3=\frac{1}{2\pi C_kR_k}$$

and the gain becomes

$$K=-g_mR_{eq}\frac{1}{1-j\dfrac{f_1}{f}}\times\frac{1}{1+j\dfrac{f}{f_2}}-\frac{1}{1+\dfrac{g_mR_k}{1+f/f_3}}$$

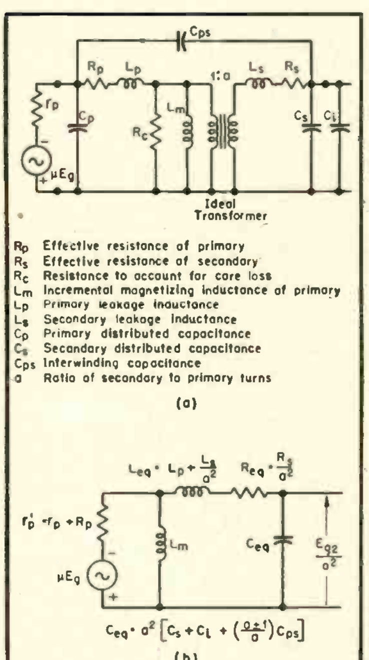


Figure 4

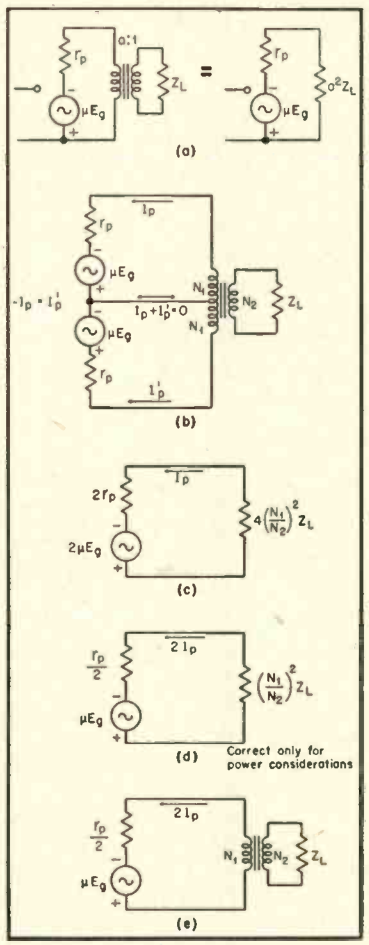


Figure 5

In all of the above equations it is possible to have a complex gain, and the phase angle may be determined readily from the expression after numerical substitutions have been made.

Transformers

The audio engineer draws the symbol for a transformer on a sheet of paper, writes some numbers down, and there the transformer engineer takes over. However, what happens inside the case does not always give the desired result. When it does, it is probably being done by an expensive transformer. The reasons for this are manifold. Besides using plenty of core material the designer has to cope with some conflicting requirements. Among them are: the core size needed for linear operation coupled with the increased losses in the larger core; increased copper losses; and increased winding capacitance. These last two items are caused by the longer winding length per turn needed to wind coils for the larger core. The whole picture is shown in *Fig.* 4, where the various items are listed along with the exact and equivalent circuits. In this case even the exact circuit is not absolutely correct since it is impossible to indicate the distributed parameters, such as the capacitance between turns and the copper loss. They are therefore indicated as lumped constants, and do provide accurate results. In the equivalent circuit all values have been referred to the primary.

The simplifications provided by the use of the equivalent circuit is shown in the case of the push-pull output stage, *Fig.* 5. Any of the circuits shown are equivalent to the push-pull arrangement, but permit simpler methods of study.

[*Continued on page 37*]

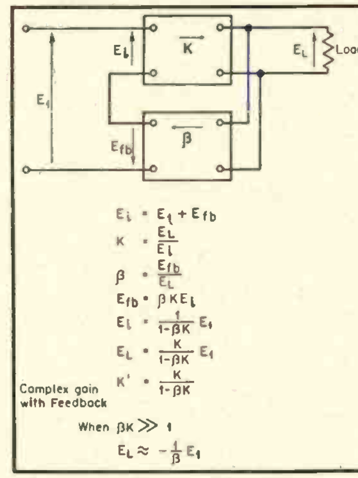


Figure 6

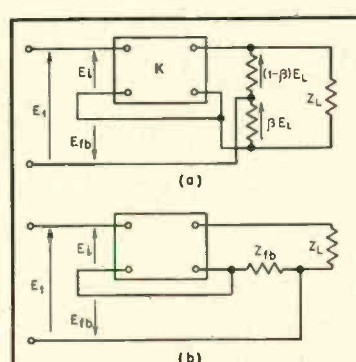


Figure 7

Simple Stroboscopes

Dr. L. B. HEDGE*

A discussion of a device so familiar that its users rarely consider the fundamental principles under which it operates.

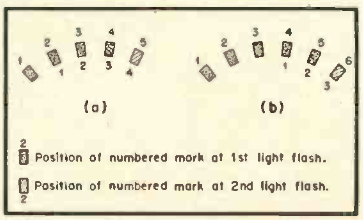


Fig. 1. Stroboscope pattern formation: (A) basic or first-order pattern; (B) higher-order pattern—in this example, the third.

THE STROBOSCOPE has been and is widely used in simple as well as complex applications for measuring, checking, and controlling speeds of rotation and other periodic motions. In more complicated arrangements it is used for the observation and study of repeated phases of intricate motion cycles. For the experimenter and technician it furnishes an accurate and easily contrived method for measuring motor, turntable, capstan, and drive speeds in recording and reproducing equipment, and for maintaining checks on them.

A simple stoboscope for speed check use on rotating equipment consists of an accurately timed, flashing light source and a circular array of equally spaced marks so arranged that successive marks occupy the same physical position during successive light flashes—the pattern of these marks thus appearing stationary, as at (A) in *Fig.* 1. The speed of rotation of the array which will make the pattern formed appear stationary is related to the angular spacing of the marks and their total number by the simple formulas:

$$S = \frac{\theta f}{6} = \frac{60 f}{n} \quad \ldots\ldots\ldots (1)$$

$$\theta = \frac{6 S}{f} = \frac{360}{n} \quad \ldots\ldots\ldots (2)$$

$$n = \frac{60 f}{S} = \frac{360}{\theta} \quad \ldots\ldots\ldots (3)$$

where

S = rotational speed (revolutions per minute)

f = light flash repetition rate (flashes per second)

θ = angular spacing between successive marks (degrees)

n = total number of marks in the array.

It should be noted that the flash repetition rate is twice the supply frequency for a glow lamp operating on alternating current. Also to be remarked is the fact that any integral multiple of n marks will give a stationary pattern also, and that a similar effect will be observed if the n-mark array is rotated at a speed which is an integral multiple of the speed S, as at (B) in *Fig.* 1. For example, an array of lines spaced 4 deg. apart will appear stationary under illumination from a flash lamp supplied by a 60-cps source at a rotational speed of

$$S = \frac{4 \times 120}{6} = 80 \text{ rpm.}$$

(basic or 1st order stationary pattern)

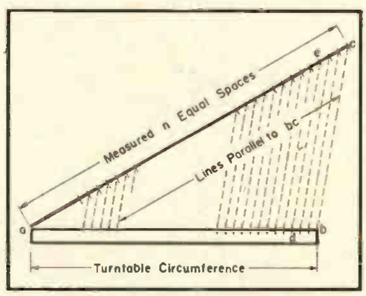


Fig. 2. Simple method commonly used for laying out a rim array for a phonograph turntable.

and it will also appear stationary at speeds of 160 and 240 r.p.m. (2nd and 3rd order stationary patterns). Stationary patterns of higher orders than three are usually too blurred to be useful except with special short-pulse lamps.

If an array designed to give a stationary pattern with given lamp frequency and rotation speed is rotated under that light at a different speed, the pattern will move. This motion of the pattern, if it is not too fast, may be timed and used to give an accurate speed indication over a range of speeds above and below the design stationary pattern speed. Thus an array of lines spaced 4 deg. apart and illuminated by a 60-cps (120 flash per second) flash lamp will appear, when rotated at the standard phonograph turntable speed of 78.26 r.p.m.,[1] as a pattern turning backwards (in the direction opposite to the rotation of the array) at 1.74 r.p.m.—if the array is rotated at 90 r.p.m., the pattern will appear to rotate forward at 10 r.p.m. The time required for an element of the pattern to make one revolution can be easily checked to within one second with a watch or clock which has a sweep-second hand. In the example above this will give an accuracy of speed measurement of not less than 3 per cent between 70 and 90 r.p.m. Between 75 and

[*Continued on page 31*]

[1] More exactly 78 6/23; see the fourth line of Table 1.

TABLE I

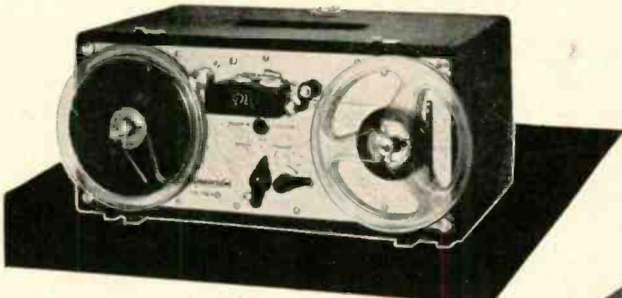
Design Constants for Simple Stroboscopes

ARRAY NO.	LAMP FREQUENCY		50			100			120		
	PATTERN ORDER		1	2	3	1	2	3	1	2	3
	No. of Marks	Angular Spacing									
1	72	5°	$41\frac{2}{3}$	$83\frac{1}{3}$	125	$83\frac{1}{3}$	$166\frac{2}{3}$	250	100	200	300
2	80	4° 30'	$37\frac{1}{2}$	75	$112\frac{1}{2}$	75	150	225	90	180	270
3	90	4°	$33\frac{1}{3}$	$66\frac{2}{3}$	100	$66\frac{2}{3}$	$133\frac{1}{3}$	200	80	160	240
4	92	3° 54' 47"	$32\frac{14}{23}$	$65\frac{5}{23}$	$97\frac{19}{23}$	$65\frac{5}{23}$	$130\frac{10}{23}$	$195\frac{15}{23}$	$78\frac{6}{23}$	$156\frac{12}{23}$	$234\frac{18}{23}$
5	120	3°	25	50	75	50	100	150	60	120	180
6	132	2° 43' 38"	$22\frac{8}{11}$	$45\frac{5}{11}$	$68\frac{2}{11}$	$45\frac{5}{11}$	$90\frac{10}{11}$	$136\frac{4}{11}$	$54\frac{6}{11}$	$109\frac{1}{11}$	$163\frac{7}{11}$
7	144	2° 30'	$20\frac{5}{6}$	$41\frac{2}{3}$	$62\frac{1}{2}$	$41\frac{2}{3}$	$83\frac{1}{3}$	125	50	100	150
8	160	2° 15'	$18\frac{3}{4}$	$37\frac{1}{2}$	$56\frac{1}{4}$	$37\frac{1}{2}$	75	$112\frac{1}{2}$	45	90	135
9	180	2°	$16\frac{2}{3}$	$33\frac{1}{3}$	50	$33\frac{1}{3}$	$66\frac{2}{3}$	100	40	80	120
10	216	1° 40'	$13\frac{8}{9}$	$27\frac{7}{9}$	$41\frac{2}{3}$	$27\frac{7}{9}$	$55\frac{5}{9}$	$83\frac{1}{3}$	$33\frac{1}{3}$	$66\frac{2}{3}$	100

Rotation speeds for stationary patterns under common power-line frequency flashing lamp illumination.
Lamp frequency is equal to twice the power frequency for an a.c. flashing lamp.

* *7211 Massachusetts Ave., N.W., Washington 16, D. C.*

NOW YOU CAN *Monitor* DIRECT FROM THE TAPE!



THE NEW

PT63-JA

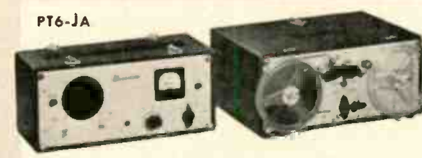
Magnecorder

HAS EVERYTHING!

3 HEADS! Separate erase, record and playback heads let you monitor direct from the tape while recording. Prevents recording errors. Heads can be individually aligned or replaced. Response flat from 50-15kc, ±2db at 15". New PT63-J amplifier has separate record and playback amplifiers plus 10 watts of audio. Switch for bias, record or playback VU meter readings.

3 SPEEDS — Double recording time! PT63 or PT6 units also available with 2-speed hysteresis synchronous motor. Will provide 3¾", 7½" or 15" tape speeds. Slower 3¾" tape speed gives response flat from 50-4000cps, ±2db. One hour on 7" reel! Excellent for interviews, conferences — all voice work!

PT6-JA



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EDWARD TATNALL CANBY*

Hi-fi at Seven-and-a-Half

MORE OR LESS BURIED in the midst of this this magazine's small type in the April issue (p. 47) was an announcement of a lot more significance than may have seemed off-hand. A new tape playback machine was described, the Ampex model 450, a non-recording machine using the double track system with automatic reverse, playing at 7½ in. per second. Its intended use, as one could glean from the brief description, was mainly in the fields of "wired music" and other background long-play systems. The joker, which was probably missed by most of our sharp-eyed readers (so used are we to seeing sensational announcements in sensational-sized type!), was in the specs. Especially since those specs, I have reason to know, are decidedly on the conservative side and quite cautiously worded.

"The tape speed is 7½ in./sec. and frequency response is within ± 2 db from 50 to 10,000 cps, ± 3 db 30 to 12,000 cps, with less than one per cent harmonic distortion at an output level of + 17 dbm." Better read that twice.

Advance Demonstration

Back in the early spring I was first let in on the new set of tape developments on which this later announcement presaged the beginning of commercial operations. Two machines were brought to New York (and later to Chicago) by Ampex; both, it seemed, were more or less experimental models, partly made of present-stock mechanical parts. One played at 7½-in., twin-track, the other at 3¾ in., also twin-track. One of them incorporated a new thyraton reversing system, a clear improvement over the earlier type of reverse in the other. Various other mechanical details of improvements were also pointed out—which would normally be of great interest in any good quality new machine. But these things were not what had me excited.

Performance, electrically, was the astonishing, almost unbelievable feature. To put it in slightly slangy terms, here was a machine which, at 7½ in. per second, double track, was able to play music *essentially flat to 15,000 cps!* I heard it. (True, I "saw" no actual tests, but the quality was obviously different from anything I had before heard at 7½ in. Printed confidential specifications, plus an explanation—to follow here in a moment—did the rest.)

Here was a second machine, running at the crawling speed of 3¾ in., which reproduced its music *essentially flat to 9000 cps*. The performance here was even more startling.

The music had presumably been recorded, in both cases, on equipment of similar design, though the recording unit was not demonstrated.

Why and Wherefore

If you will think a moment, you will note that performance of this sort, from tape, in effect does what had begun to seem extremely unlikely to most of us—it *doubles the efficiency* of the tape medium, as compared to presently existing machines, both amateur and professional, and even including the famous Ampex model 300, which claims no more than 50 to 7500 cps. at the 7½ in. speed. As one advertiser of phono equipment puts it, this calls for a WOW of appreciation! — Followed immediately, double-take-style, by a somewhat startled "HOW"?

Claims vary from one tape machine manufacturer to another, partly as a matter of degree of caution. But it will be evident immediately that the average claim *in re* frequency range for existing machines runs between 7000 and 9000 cps as the top at 7½ in., 12 to 15 kc. at 15 in. Sonar claims 9,500 as the top at 7½ in its new machine. My own Magnecorder at the moment measures "flat" (again speaking slangily) to 9000 at that speed, to 18,000 at 15. But no one, so far, has made the slightest pretense of claiming what Ampex claims—in the wildest of optimistic publicity! Ampex is hardly in a position, on the other hand, to make unsubstantiated claims of any sort, especially in this respect.

The answer, if I understand it, is in a genuinely new advance in manufacturing technology. The gap width, thanks to what is fundamentally not an electrical but a mechanical problem, has been reduced from

[*Continued on page 35*]

* *279 West 4th Street, New York 14, N. Y.*

Pops

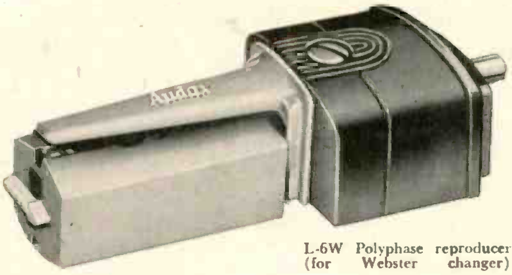
RUDO S. GLOBUS*

YOU WILL EXCUSE me if, for once, I indulge in a rather generalized discourse (probably more with myself than with a reading audience) about many things related to the subject matter of this column. My piece of last month is certainly at the root of all this, as well as a great deal of recent soul-searching on the situation of the technician . . . sic Audio Engineer. There will be much that is unfunny . . . and much that is rather (to use a technical term) metaphysical. If you object to the ponderous pretentiousness involved in an attempt to explain the vast confusion entailed in the problem confronting our ilk, pass on to the appended reviews or skip me this time. If you don't object . . . consider seriously what is to be said. The tone is not intentionally dogmatic. Following your own soul searching, I believe either a rebuttal or an advanced statement of what is to come very much in order.

Let's not fool around. If we are to be radically open and aboveboard about the situation as it stands, we are faced with a most appalling conglomeration of trash, nonsense, muddle-headed thinking . . . and a purely mechanical submission to the power of techniques, disemboweled formulations, and a vulgar, low-level status. Beginning with the purely technical problem, I will cite another example relevant to a situation mentioned some months ago. Those of us who are at all interested in listening to recorded music of any and all types still require an "apparatus" to take the physical phenomenon of an impressed disc out of its moribund "materialism" and project it in some form vaguely approaching the musical. In order to do this, we must either be adequately trained engineers . . . therefore capable of building our own "transforming" machines, or of coming to some conclusion as to components available on the market. If we are not adequately trained, we must pass this responsibility over to someone who

[*Continued on page 33*]

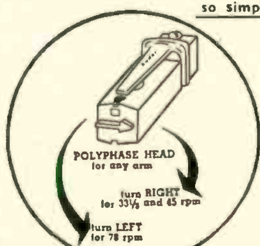
* *960 Park Ave., New York 28, N. Y.*



L-6W Polyphase reproducer (for Webster changer)

The Standard by Which Others Are Judged and Valued

so simple



From a letter: ". . . Have been hearing some very fine reports on your new POLYPHASE reproducer. However, in your advertising, you do not give any figures on compliance and distortion. . . ."

Here is our answer

COMPLIANCE: "No one is interested in meaningless figures—although they would embellish the advertisement. However, we are sure that everyone is much interested in a compliance that is greater than that of any pickup ever created. . . . that is POLYPHASE."

DISTORTION: "No one is interested in any form of distortion, as such. However, we are sure that everyone is much interested in the practical absence of distortion. . . . that is POLYPHASE."

VIBRATORY MOMENTUM: The vibrating mass in POLYPHASE is tinier, by far, than in any pick-up hitherto created. VIBRATORY MOMENTUM at last approaches the vanishing point. The result is a facsimile of the original performance.

Never before such EAR-QUALITY, such FAITHFUL REPRODUCTION . . . that is POLYPHASE.

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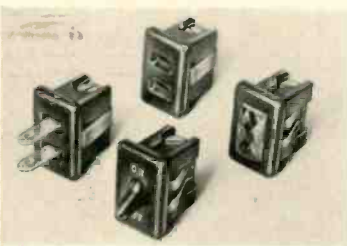
NEW PRODUCTS

● **Three-Speed Record Player.** Expanding its line of audio equipment, Newcomb Audio Products Company, 1605 Cahuenga Blvd., Hollywood 28, Calif. announces the Model B-12 portable record player, de-

signed particularly for school music appreciation classes and for use as a counter record demonstrator. Among its features are a 6 × 9 in. Alnico speaker protected by a kickproof metal grill, a 5-watt Newcomb amplifier, and a washable maroon fabricoid case 13¾ × 14⅛ × 7¾ inches. Handles records of all types up to 12-inch diameter.

● **Improved Connectors and Switches.** Wider face areas together with wider flanges to overlap greater area around installation holes are featured improve-



ments in the newly designed line of Diamond H Snap-In line of electrical connectors, pilot lights and switches. All items of the new line are available in black, brown, white, or special color to harmonize with the equipment in which they are employed. Manufactured by The Hart Manufacturing Company, 110 Bartholomew Ave., Hartford, Conn.

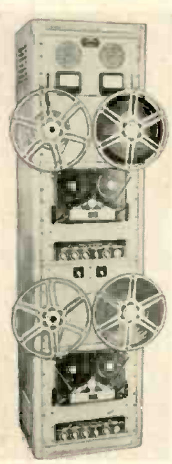
● **Record Cleaner.** Goodell "Record Life" is a liquid solution designed to remove dust particles and to thoroughly eliminate electrostatic charges from all types of record surfaces. It is non-toxic, contains no wax, alcohol, or other solvents, and

does not depend for its action on hygroscopic agents that might leave sticky or hard residue in the recording grooves. Manufacturer is Minnesota Electronics Corporation, 97 East Fifth St., St. Paul, Minn.

● **P. A. Driver Unit.** Operating flexibility is the keynote in the new Racon model PM-708TR all-purpose driver. In addition to being completely waterproof and tropicalized, designed with 75 to 100 per cent overload capacity, and built to withstand abnormal diaphragm excursion, it features a built-in 25-watt vacuum-impregnated line-matching transformer offering

available impedances of 15, 500, 1000, 1500, and 2000 ohms. The voice-coil suspension is made of bakelized linen cemented to the phenolic diaphragm with a thermosetting plastic. Induction heating is used to bake the diaphragm, voice-coil suspension and voice coil into an unbreakable bond. Full details of the PM-708TR will be supplied by Racon Electric Co., Inc., 52 East 19th St., New York 3, N. Y.

● **24-Hour Reference Recorder.** Unattended round-the-clock recording is a reality with the Magnemaster tape recorder now being manufactured by Amplifier Corp. of America, 398-4 Broadway, New York 13, N. Y. Designed for commercial applications where unattended, continuous recording is essential, the Magnemaster may easily be modified to suit specific requirements, including installation of a voice-activated circuit which provides start of tape feed within 0.1 second. The instrument consists of two complete rack-mounted recording-playback systems, each of which operates continuously for 12 hours at a tape speed of 3 inches per second. At the completion of 12 hours of twin-track recording



on one reel, a relay instantly sets the other reel into operation. Frequency range of the overall system is 50 to 4500 cps. Full technical information will be supplied free by the manufacturer.

● **440-Volt Rectifier Cartridge.** Answering the need for high-voltage rectifier cartridges in the radar, sonar, photoflash

and kindred fields, International Rectifier Corporation, 6809 S. Victoria Ave., Los Angeles 43, Calif. has developed a new line of selenium units available in phenolic, glass or hermetically sealed assemblies. Typical of the new line is the rectifier rated at 440 volts d.c. at 10 ma. with a peak current rating of 120 ma. and a peak inverse rating of 1500 volts. It is of the half-wave type and is 9/16 in. OD with an overall length of 1⅝ in. Voltage drop at rated load is approximately 25 volts and its weight is ½ ounce. Further information will be supplied by the manufacturer.

● **TV Loudspeaker.** Reduction in required distance between the picture tube and the loudspeaker in TV receivers is made possible in a new line of Rola models by means of a magnetically-enclosed motor structure. Available in sizes

ranging from 5 to 12 inches, the new speakers use Alnico V in a high-efficiency magnetic structure which permits reduced weight and consequent lowered cost. Full information may be obtained from The Rola Company, Cleveland, Ohio.

● **Soldering Gun.** An advanced note of flexibility is introduced by the Model LW Versa-Tool, an instant-heating soldering gun recently presented to the trade by Phillips Manufacturing Company, Inc., 2816 Aldrich Avenue South, Minneapolis, Minn. The two-position trigger-actuated switch closes the circuit to a concentrated light beam in its first position, thus permitting the operator to use the tool as a flashlight. The second switch position maintains a completed light circuit and closes the circuit of the heating element. Carbon element is easily replaceable.

IMAGERY

[*from page 15*]

air through a small orifice. Another type of mechanical noise is the so-called *needle scratch* or *surface noise* present in disc recordings. It is due to irregularities in the groove walls, and if heard through a *flat system*, sounds *smooth* or *satiny*, corresponding to initially *white* (flat spectrum) *noise* with perhaps some *roll-off* of the *highs*. Ordinarily, however, the character of the *surface noise* is markedly influenced by undamped resonances in other parts of the system and becomes *scratch*. With pressings of a homogenous material, such as polyvinyl chloride acetate, *clicks* rather than *scratch* are noted. *Swish* is *scratch* periodic with the rotation of the record.

Thermal noise due to electron agitation often shows up as a *background* of *tube hiss*; a poor carbon (variable resistance) microphone also contributes the more irregular *frying* or *popping* noises which have prevented its use in high-quality systems.

When dynamic devices such as limiting amplifiers and variable band-width noise suppressors are improperly used, the finite time constants of attack and release may cause a subtle form of distortion. With the latter devices, *breathing* may occur when the time constants are set too large, and the program changes its dynamic range rapidly, thus making audible the changing cut-off. However, the trouble can be obviated by the intelligent use of the suppressor.

The above terms for the most part, refer to fairly definite objective quantities for which physical measures exist. The difficulty comes in setting up scales of values with a one-to-one correspondence between the term and its physical correlate; such a refinement is not completely possible at present. These terms are listed in Table II.

TABLE II

Description of Distortion and Noise

General	Clean, dirty.
Overload	Hash-up, mush-up, hits bottom, thump.
Noise	Rattles, buzz, rub, wheeze. Background noise, tube hiss, frying, popping, sizzle, smooth, satiny.
Records	Needle talk, scratch, surface noise, clicks, swish. Fuzz, lace, kazoo, wiry, jamming.
Subharmonics	Breakup, birdies, tweets.
Intermodulation	Harsh, rough.
Cross-over	Marbles, garble.
Dynamic	Thump, breathing
Transient	Attack, hangs on, slurred.

To be concluded in September

TAPE RECORDING

[*from page 18*]

which the tape moves past the head. The faculty of recognizing sounds at various speeds must be well-developed if the tape editor expects to achieve any appreciable speed and finesse. Constant practice is required, so that the ear becomes familiar with all commonly encountered sounds.

The easiest sound to recognize—and therefore to edit—is the sound of *s* and similar sibilant sounds such as *ch, sh, ts, tz,* and so on. The hard sounds of *t, p, b* and similar sounding combinations of sounds are also quite easy to recognize. The sounds of *r*, both round and gutteral, are more difficult to determine, especially when they occur in the middle of a word. Compound sounds, such as the beginning *y* of *you* and other *y* and *u* sounds, are difficult to apprehend and sometimes are recognizable only at normal tape speed. The tyro editor would do well to practice the recognition of sounds and to exercise himself in the art of editing tape by cutting out slurred *r's, u's* and other sounds as mentioned above.

Editing of musical recordings is done in the same manner as that of voice and sound, with the exception that the editor of music should be acutely conscious of rhythm, pitch, and "overhang." By "overhang" is meant those lingering tonal beats, especially of string instruments, that are somewhat similar to reverberation. Because of these lingering overtones, it will often be difficult to edit a musical piece without the use of re-recording techniques. However, in some cases, by cutting at the beginning of a bar exactly, an acceptable job can be done.

Tape Splicing

The actual mechanics of tape editing are fairly simple. Some tape editors work with scissors and Scotch tape. Some use a patented cutting and patching mechanism similar to a motion picture film splicer. Since 1947, the author has used a cutting block which he designed and which has proved satisfactory. The final result to strive for in the mechanical process of editing is a smooth splice, with the ends of the tape abutting each other with no discernible space between. A diagonal cut which eliminates the 90-deg.-cut "clicks" has been found most satisfactory. In addition to eliminating clicks, which are very disconcerting to the listener, the diagonal cut helps to make background blending easier. The splicing block is made of a piece of brass 7½ in. long and 1½ in. wide and ¾ in. thick. A slot ⅛ in deep and .248 in. wide is machined in this block. The ¼ in. tape will then fit snugly in the block so that it can be cut accurately. In the middle of the block, a 45-deg. angle cut is made, as shown in *Fig.* 1, extending to the bottom of the tape groove, wide enough to admit a single-edged razor blade (See figure #1).

When editing on any tape machine the place to mark the tape for cutting is at the magnetic gap in the play head as in *Fig.* 2. Any sound you have heard will have passed this point. It is best, if possible, to mark both sides of an excerpt *before* cutting. Then it is only necessary to cut at both marked spots and join together. (See *Figs.* 3 and 4.)

A number of methods for splicing tape have been tried. Tape can be cemented together if overlapped, but the cement may disturb the binder in the magnetic-coating, and an overlap splice is neither as accurate nor as quiet as a butt splice. Heat-vulcanizing has been tried on plastic tape with great success, but it is not recommended where a splice might have to be removed for a change in script. Scotch tape #41, which has a minimum of "tackiness" and does not "bleed", permits quick and permanent splicing and is the favorite adhesive in the industry to date.

The simplest way to make a good splice is to use a block such as has been described. There are several good tape editors who mark their "spots" and cut *both* diagonally with scissors at the same time. However, in that case, it requires practice to keep the tape ends lined up perfectly until they are patched together.

After about a one-inch length of #41 Scotch tape has been stuck to the recording tape ends, it should be firmly pressed to the tape so that the adhesive is thoroughly engaged, as shown in *Fig.* 5. When splicing tape in a jig, be careful not to press the tape with such force that the recording surface is depressed at the splice. When this surface is pressed in it will not be in good contact with the magnetic heads and the high frequencies will be attenuated at the splice. Then the superfluous Scotch tape should be trimmed with scissors, cutting smoothly *into* the recording tape for a depth of about .002 in., as in *Fig. 6*. This undercutting is advised so that no adhesive will appear on the surface of the tape and, subsequently, on the recording and play heads. Undercutting also makes the compliance of the splice more nearly the same as that of the tape itself, thus assuring better head contact and less "skip." Care in splicing, resulting in a finished splice similar to the one shown in *Fig. 7*, pays off by making the completed show sound perfectly natural, avoiding any sign whatsoever that it has been edited.

Where it is necessary, to save time, strips of adhesive tape (#41) may be cut in advance, in widths of 3/16 in. or so, and used to make splices that are not of a permanent character. An experienced editor can make a good, permanent splice in approximately thirty-five seconds, while a temporary splice may take ten seconds less. *Figure 8* shows a tape editor at work in an NBC tape cutting room.

If the tape is to be re-used time and time again (which is one of the reasons why tape is used) it is better to make perfect splices of the permanent kind. Then, after the tape has been erased and used again for recording, there will be no embarrassing "holes" in the recording. The adhesive tape, needless to say, does not record magnetically.

Auditory Fatique in Editing

We have thus far covered editing in two of its aspects—how to cut tape and why and how to make a clean splice. The psychological aspect of tape editing becomes the next problem. You will find that the concentration required of your hearing system during an editing session is extremely fatiguing. Since, the monitor system must be set at a fairly high level in order to hear extraneous noises at low levels and soft sibilant endings of words, auditory fatigue sets in rather rapidly. Hearing-fatigue lowers the ability of the ear to detect sounds by almost 50 per cent and causes more than normal distortion in the system of hearing itself, so the reason for the above opinion is self-evident.

Editing tape is in itself a profession and like any other work, the more editing you do, the better you become at it. There is nothing that will take the place of practice and the exercise of your own acumen. You may devise methods of your own for editing that will prove to be better than those outlined. The main object is to become familiar with the workings of your equipment; the rest is practice and common sense.

STROBOSCOPES

[*from page 22*]

85 r.p.m. the same timing accuracy will give a speed determination closer than 0.7 per cent, and use of a stop watch for timing should better these accuracies by ten fold.

Table I is a compilation of the design elements for a group of easily constructed arrays (with second and third order effects) which will provide stationary basic patterns at rotational speeds from 33 1/3 to 125 r.p.m. with lamp-flash rates of 50, 100, and 120 (25, 50, and 60 cps a.c. supply). Arrays 4, 8, and 10 may be placed on one disc to provide a convenient "universal" stroboscope for record-player use, with basic stationary patterns of 78 6/23, 45, and 33 1/3 r.p.m. with 60-cps (120 flash per second) illumination; similarly, arrays 2, 6, and 9 will indicate speeds of 75, 45 5/11, and 33 1/3 r.p.m. with 50-cps (100 flash per second) lighting. These latter arrays may also be used with 25-cps (50 flash per second) illumination, giving a second-order pattern.

Lamp Requirements

The flashing lamp necessary to simple stroboscopic measurements is easily provided—an ordinary incandescent lamp (preferably of low wattage and not frosted) will serve, although the variation of intensity of light from such a lamp is not sufficient to bring out the stroboscope pattern sharply. A single-tube fluorescent lamp (not a pair—dual fluorescent fixtures are usually so designed that each tube illuminates the periods of darkness of the other) will serve nicely. A neon or argon glow lamp is probably the most satisfactory light source easily obtainable, since such a lamp will give a sharp ignition flash on each pulse of the alternating current supply. These lamps are readily available—they are often used as low-drain pilot lamps and as safety and night lights.

A record player or recorder turntable may be easily equipped with a permanent speed-check stroboscope which will also serve to give warning of mechanical faults in equipment which show up as speed variations in the turntable. A strip of paper marked with properly spaced lines and attached to the periphery of the turntable where it may be illuminated by a neon lamp connected across the a.c. motor supply will furnish such a set-up.

If the turntable is to be used for several record speeds, a different band may be marked for each speed. A strip of paper, cut to the length of the turntable periphery, may be marked with the appropriate number of marks (determined from Table I or from formula 3) as shown in *Fig.* 2. The two ends of the strip count as the same mark. The values in Table I were selected to provide the most useful stationary pattern speeds consistent with ease of protractor and compass layout of the corresponding arrays. For a rim stroboscope the dividing scheme illustrated in *Fig.* 2 is equally easy of use for any whole number of marks and spaces. The whole number closest to the value given by formula 3 will give the slowest pattern drift for a given set of conditions, and may well be used to advantage. Thus, for a 45 r.p.m. rim stroboscope to be lighted by a 50-cps (100 flash) lamp:

$$n = \frac{60 \times 100}{45} = 133\ 1/3.$$

133 is the nearest whole number, and the pattern formed by an array of 133 marks will drift backward about one revolution in 9 minutes.

A little experimenting with simple stroboscopes will soon convince the user of their great versatility and usefulness. There are probably no simpler or more fascinating precision instruments that can be handmade with as little cost and technical skill.

POPS

[*from page 24*]

is or depend on the sanctity of national advertising. Eliminating the naive, there is vast evidence of the creeping paralysis induced by the technical straitjacket. I, for one, have never found the concept of specialization satisfactory on any level. There is a folkway with reference to engineers which carries an extraordinary degree of truth as well as some over-generalization. It is certainly true that a whole coterie of "audio-engineers" specializing in the theoretical and applied problems of reproducing equipment are thoroughly detached from the essential problem, which, to my way of thinking, is a musical one. Hence, the mutilated recordings of our highly sophisticated time, the expensive custom-jobs suited perhaps to the approximation of a theoretical limit but overlooking the very real problems involved in musical reproduction.

Musically, the problem is perhaps more severe. With some exceptions, the recording industry . . . and to be brutally frank, the music business in general . . . is captive to the musically inept. It is my pitiful misfortune to be extremely closely connected with our third largest industry, the music business, in an intimate relationship which breeds only the highest contempt, on the one hand, and the most bathotic sympathy on the other. For those of you who are connected with the business either in the form of technical indulgence or listening status, it would be wise tó let a little bit of reality seep through and recognize the fact that the mountain of the gods is now populated by second-rate satans.

Mass Buying

Who is to blame? YOU are! You refuse to trust yourself any longer. Willingness to accept the stereotypes of mass appeal have brought the walls crumbling down on us. The LP market is fantastic now. It is due to musical reasons? Is the LP superior (when played on the type of instrument that most of them are played on) to the good 78 r.p.m. shellac model? Decidedly not. Are records supposed to be bought and used for musical reasons? The third step of the syllogism is obvious.

What has happened in the United States during the past fifteen years constitutes more than anything else a shift in objectives. The shift could not have been accomplished if the buying public hadn't been all too willing to fall into line and accommodate the ambitions and objectives of the controlling factors in the record industry, music business, and engineering arts. The objective is clearly directed towards sales. There is no need to hash around the problem of economic motivation. What is most ironic is the fact that fifteen years ago it would have been possible to combine economic motivation with something called artistic integrity. The boom market in the record and music business indicated that quality was easily as saleable as junk.

NEW RELEASES:

From the above, it is obvious that I am hopping mad. For several months now, I have plied the charitable road. Prior to doing the column, I've gone through new release after new release, listening fairly and objectively, hoping to find just one record that I could shake hands with . . . pat it on the back and send it merrily on its way. No such luck! Some months ago, I received a card from one of this column's readers asking why I didn't review good recordings. The card raised a question . . . and since I am going to have to pan this month's batch, a word of explanation is in order.

A considerable number of mass circulation magazines have "record critics" who devote some space every week to the new "pops." With the exception of a few (and I consider George Avakian to be one of the best informed and most honest "jazz" critics around today), the monthly output gets varied bravos or insipid biographical commentaries. In my book, this represents an evasion of the job at hand. Reviews serve as buying guides in the final analysis. To review the pop items that come out daily, mention who is on the label (and I've said all this before) is a waste of time. This column is, and will continue to be, an objective guide to the situation as it stands. I am not going to sell you what I wouldn't buy myself. To make up for it, next month's column will begin an informal series of listings of things that I think are the best in pops (of any shape or variety). Sporadically, the list will be enlarged to include a basic guide for the collector. There will be a few contemporary items; most of the stuff is old. I can't vouch for availability, but with the right amount of money in hand, anything can be had.

Alec Wilder Octets
Mercury MG 25008

I'm particularly fond of Wilder's stuff. I'm not certain whether it should be reviewed in a pop column or not despite the beat. At any rate, the facile composer-arranger has a knack when it comes to handling wind instruments . . . always featured in the octet arrangements. This is, again, a 10-inch LP, nicely done. Hard stuff to push . . . because you either like it or not. Titles, as always, are cute and therefore should be listed . . . The Children Met the Train; Remember Me to Youth; They Needed no Words; Jack, This Is My Husband; Little White Samba; The Amorous Poltergeist, etc. To those fearful ones, Frank Sinatra is not conducting.

James P. Johnson **Decca DL 5190**

Not much to be said here. I don't like the piano recording, and being an old J.P.J. fan from way back, I return to objections mentioned above. I don't want anybody to select my evening's pleasure for me via LP. Any well stocked jazz shop has the stuff on this baby . . . despite the fact that the originals weren't well recorded either.

POT LUCK:

One of the best pop tunes of the past ten years was the luscious "Bewitched, Bothered and Bewildered." The past couple of months have seen a revival in numerous lush arrangements. No need to review them, because they all do a good job of murdering a wonderful pop. For those of you who must have it, go back to the original Goodman version on Columbia. Helen Forest did a tasteful vocal and the orchestration is just right . . . one of Benny's best straights. For that matter, another word to the wise. Since Disc Recording Co. left this world, a lot of their jazz recordings have been awfully hard to lay a hand on. There are still a few floating around. If possible, track down the Charlie Ventura Trio recording of "Body and Soul" and "Stompin' At the Savoy," both on a 12-in. 78. Recorded at Town Hall, Krupa is on drums in a neat, neat recording. This is a gem in my books (despite an occasionally noisy audience). Recording is very good, despite the hall and audience. Ventura is brilliant . . . buy, buy, buy. If you can't get any copies, drop me a note and I'll try and track them down for you.

RECORD REVUE

[*from page 24*]

the usual ½ mil of many machines to the fabulously small size of ¼ mil. This, as technical experts will understand, allows for the recording of a wider range of frequencies at the usual speeds.

Don't ask me details on how the thing is done—though it was explained to one of my ears, only to dribble out of the other one. Don't ask me how the serious difficulties encountered with such tiny gaps have been met—as clearly Ampex must have met them, unless the company is putting itself on a very long and shaky limb. You might try pumping Walter Selsted of Ampex, who did the development work—or if Mr. Selsted quite correctly clams up, then you may tackle the Veeps and the Prexies of Ampex Electric, who may or may not be ready to confide.

It's enough for this column that here we have, presumably in an advanced stage of preliminary development, a basically new thing in tape recording, with some very interesting implications. Let us, for now, take it as granted that the Ampex development will prove sound, bug-free, and as good or better than as claimed. A fairly reasonable assumption. What then, may be the consequences of the doubling of recording efficiency here achieved?

Equipment Available

By the time this is in print (it is being written earlyish so that our editor may take his much-deserved vacation in peace and editorial security) there will no doubt be a further announcement from Ampex, of a model 400 (a complete recorder-playback unit) to supplement the presently-announced model 450 playback machine. My unofficial impression is that this machine is a kind of feeler model to test out the possibilities inherent in the improved efficiency of the central mechanism. There are two major fields in which tape machines incorporating this sort of improved efficiency may be expected to operate.

Record Releases

Erna Sack sings Opera Highlights and Song Favorites — **Mercury LP MG 10044**

Ellabelle Davis sings Negro Spirituals (with orchestra, piano) — **London LP LPS 182 (10")**

Here are two phenomenal voices that have one thing very much in common: both have that consummately accurate sense of exact pitch and of beautiful phrasing that one in a hundred "great" vocal artists are lucky enough to be born with. A subtlety, you may say—but listen hard, and judge for yourself. There's nothing like it and even a tin plated ear can catch on, after a few notes.

The Mercury Sack record, the third reissue, is an example of a good and well justified pot-pourri of older recordings; for Sack is surely one of the most astonishing voices of all time, both in its extraordinary range and (more important) the musicianship, above-mentioned, behind it. These are technically of good pre-war quality, quite wide range but with some distortion in the high end and a fair amount of surface interference. Acoustically the recordings vary greatly—in some she is close, others at a distance; levels differ and orchestral sound differs. The operatic arias are useful in giving an idea of Sack's wider musical range.

The Ellabelle Davis Spiritual arrangements—some for piano accompaniment, some for fancy orchestral background—are straightforward conventional corn; but the Davis voice and sense of pitch make one immediately forget the background. This is perhaps the only time I have ever enjoyed listening to commercially "arranged" spirituals—and it is all Davis' work. Gorgeous wide-range recording, the voice very close, with beautiful sibilants.

•

Bartok, Sonata for Two Pianos and Percussion.

Wm. Masselos, Maro Ajemian, pianos. Saul Goodman, Abraham Marcus, percussion. **Dial LP #1**

Alban Berg, Lyric Suite

Pro Arte String Quartet **Dial LP #5**

Dello Joio, Ricarcari for Piano and Orchestra.

Concert Hall Symphony, Swoboda; Germaine Smadja, piano **Concert Hall LP DL 6 (Lim. Ed.)**

Milhaud, Concertino de Printemps; Violin Concerto #2.

French Nat. Radio Orch., Milhaud. Louis Kaufman, violin. **Capitol LP P 8071**

If you want to know what LP is doing for today's music—and for us listeners in making new music more easily understood try this brief cross-section of dozens of very interesting new releases. The tape-LP combination is unbeatable in the contemporary music field—where in ye old days, when we got anything at all on records it was more than usually a blurry mess of dreadful distortion.

The Bartok, though not as tight and authoritative a performance as Vox's reissue of Bartok's own playing (with his wife) on a pre-war broadcast, is one of the best percussion-piano records to date. I disagree with some who say that this is better than Capitol's recording of the similar Bartok work, the Music for Strings, Percussion and Celesta—but this is good, very good. Terrific percussion sounds—xylophone, all sorts of drum sounds, etc. The two pianos are fine, though perhaps not quite big enough in the balance compared to a stage performance I heard of the music. This makes an unusual test-demonstration record.

Berg's Lyric Suite is extremely dissonant and extremely romantic—a combination that perhaps you may not have imagined as possible! Try it and see—the fine recording again makes this not at all difficult to listen to on a good outfit. Try the wiry, snarling third movement. Dello Joio's Ricarcari (that's plural) are three related movements in a good humored, rather brassy orchestral style with a quicksilver piano, expertly fluent. A couple of plays should make you enjoy it—but you have to subscribe; it's Limited Edition.

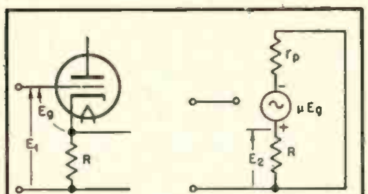
Milhaud, already an almost-elder statesman of French music, has some delightful music for you in the "Concertino de Printemps"—a burbling, gurglingly joyous little piece for a nice collection of close-up, beautifully recorded instruments. Sounds like spring! The Violin concerto is heavier stuff but not really difficult at all the fine recording makes it easy to listen to. Note that the Dial company, making only LP's (like almost everybody but the major outfits) is recording *only* contemporary music, and in excellent performances musically. One of the best things to have come out of LP.

AUDIANA

[*from page 21*]

Feedback Stages

Feedback amplifiers have been discussed at length elsewhere, and all that will be done here is to indicate the general equivalent circuits for voltage and current feedback, and for the general solution. This is done in *Figs*. 6, 7, and



$$\mu E_g = I_p(R + r_p)$$
$$E_g = E_1 - I_pR$$
$$\mu E_1 - \mu R I_p = I_p(R + r_p)$$
or
$$\mu E_1 = I_p[r_p + (\mu + 1)R]$$
$$I_p = \frac{\mu E_1}{r_p + (\mu + 1)R}$$
$$E_2 = I_pR$$
$$K = \frac{E_2}{E_1}$$
Therefore
$$K = \frac{g_mR}{1 + g_mR\frac{\mu + 1}{\mu}}$$
Where
$$\mu \gg 1$$
$$K \approx \frac{g_mR}{1 + g_mR}$$
$$R_{out} \approx \frac{R}{1 + g_mR} = R(1 - K)$$

Figure 8

8. The last circuit is the special case for the cathode follower, and if the input capacitance due to Miller Effect is computed it will be found to be very low. The output impedance also has been reduced through the use of this circuit.

For the solution of acoustical problems using equivalent circuits, it is only necessary to draw the circuit using electrical symbols and converting the values to appropriate units through the use of dynamical analogies. The circuit may then be handled as any electrical circuit.

Use of equivalent circuits and the network theorems provide simple, easily handled solutions to many complex circuits. However, it is always necessary to keep in mind the major limitation of equivalent circuit theory, where linear operation of all circuit elements is *assumed*.

AUDIO PATENTS

[*from page 6*]

Changes in the average bias caused by changes in input amplitude are offset by the coupling of the grid return to the output point—the plate. Because R_2 is so large, it, with C_1 forms an integrator circuit to prevent any feedback of the square wave itself, but it allows unidirectional current to flow from the plate to counteract the charging of C_1 due to grid current, and maintaining average bias just about in the middle of the tube's characteristic. As a result, square-wave symmetry is maintained over large variations of input voltage.

The inventors gave the values listed on the diagram and said that they had satisfactory operation from 2,000 to 5,000 cps at amplitudes of 20 to 200 volts. The parenthesized values in the figure were those I used in experiments, with a 6SJ7 instead of a 6SH7. From 25 volts upward the square waves remained unchanged after R_2 was initially adjusted for symmetry. (The final setting left approximately 2.5 megohms in the circuit.) Within the limits of the available amplifiers and oscilloscope, operation appeared satisfactory from 10 through 20,000 cps.

Musical Instrument

Believing there is considerable interest in electronic music, we present another music circuit. Invented by T. J. George (Patent No. 2,483,823), it provides both flute- and string-type tones and has delayed keying to provide a soft attack and decay.

The tube is a triode with one or two diodes in the envelope. The triode elements are connected in any standard oscillator circuit, and a diode plate is used for keying and output. The diagram in *Fig*. 2 shows suitable values for use with middle C.

A 9-volt negative bias is permanently fed to the diode plate. This is higher than the peak signal appearing from cathode to ground so that the diode does not conduct and nothing appears in the output. When the key is pressed, 100 positive volts from a power-supply bleeder is fed to the diode plate through a time-constant network. Gradually the plate conducts, making for a musically desirable slow attack. If the output were a sine wave, the waveform during the attack buildup would vary, but the addition of C_3 makes output essentially sawtooth in shape, so there is not much variation.

The sawtooth waveform contains harmonics of the fundamental with gradually decreasing amplitudes. The inventor makes use of this complexity to obtain two basic tone qualities from the device. To create a flute-type tone, R_1, R_5, and C_4, a low-pass filter, remove most of the harmonics. To get the string or reed effect, C_5, C_6, and R_6 act as a high-pass filter to get that "buzzy" quality.

One triode oscillator is required for each pitch in the instrument, but if it has two manuals, each can use one of the two diodes in the tube, with a circuit similar to that shown following each diode and each keyed by one of the manuals. The string outputs of all the generators are common, and so are the flute outputs. The common flute and string busses may then be mixed together in whatever proportions the designer needs to get various total tone qualities and the resultant may then be passed through tuned circuits to create formants, which imitate the mechanically resonant structure of an acoustic instrument and help give each instrument its characteristic tone quality.

When the key is released, C_3, which is now charged positively, must discharge through R_2 before the diode ceases to conduct. That takes care of the gradual decay required for good musical effect.

Electronic music patents are fairly plentiful these days, but it is a good idea to describe them only if there is sufficient interest. We would like very much to hear from readers about that. Should we keep on writing about interesting music patents or stick to the more conventional circuits and devices? Any other comments?

A copy of any patent may be obtained for 25¢ from the Commissioner of Patents, Washington 25, D. C.

NEW LITERATURE

• **Cleveland Electronics, Inc.,** 6611 Euclid Ave., Cleveland 3, O., is now distributing Catalog 127-M, listing the complete Cletron line of replacement loudspeakers for TV, auto radio, and home radio. All models are clearly illustrated, described, and priced. The catalog will be supplied free to members of the trade.

• **The Polymer Corporation,** Reading, Pa., has issued a technical bulletin covering various processes and procedures for the machining of nylon bar stock. Sawing, turning, drilling, centerless grinding, threading and tapping are all given treatment both in text and through illustration. In writing, request Bulletin No. 8.

• **Magnetic Recording Division,** Armour Research Foundation, 35 W. 33rd St., Chicago 16, Ill., has compiled and is offering for free distribution a bibliography on magnetic recording. In addition to offering a comprehensive listing of reference material, the bibliography contains a reprint of what is believed to be the earliest statement on magnetic recording.

• **Technology Instrument Corporation,** 1050 Main St., Waltham 54, Mass., has available the first issue of its Laboratory Report No. 1. This report is the result of extensive research on the measurement of phase-angle difference between two electrical signals, and is titled "Low Frequency Characteristics of the Type 320-A Phase Meter." Copies of the paper may be obtained by request in writing.

PROFESSIONAL DIRECTORY

● **British Industries Corporation**, 164 Duane St., New York City, N. Y., is now distributing The International Radio Tube Encyclopedia, edited by Bernard B. Babani. Price is $6.50. It is unique in that it is the most inclusive volume of this kind yet to be published. Over 14,500 tubes are described, considerably more than have been covered in comparable texts. Included are tube types used by the Armed Services of the U. S., Europe and Great Britain, in addition to normal civilian patterns. Tube base connections are shown in continuation columns immediately following tube characteristic columns, thus eliminating the need for repeated reference to other sections.

● **General Cement Manufacturing Company**, 919 Taylor Ave., Rockford, Ill., is now releasing to jobbers a new 64-page catalog which includes listing of over 5000 radio and television products and service. In writing request Catalog G-C 154.

LETTERS

[*from page 2*]

facturers to stress the audio end of their receivers.

The future of telecine may hinge on such a standard, for if a material increase in audio fidelity is accomplished by a general improvement in TV receiver audio design, the live portions of telecasts would stand out much more than they do now.

Frank E. Sherry, Jr.,
Sound Engineer,
Gerdes Sound Pictures,
Victoria, Texas

Postcards

Sir:

Congratulations on your May editorial on the need for identification when writing to manufacturers.

The engineer who writes us on a postcard, in pencil, will receive only a single sketchy description of our equipment, for we have no way of distinguishing his inquiry from the hobbyist's. Therefore, we say to engineers —as strongly as we can: If you want your letter treated with the deference due a professional inquiry, write like a professional! If your company makes it difficult for you to get catalogs and you want to write, at least write a *letter* and identify yourself.

Mr. Gera's letter in the June issue is somewhat in error—the hobbyist is a good market only for amplifiers, pickups, loudspeakers, components, and transformers. In the instrument field, his purchases are nil.

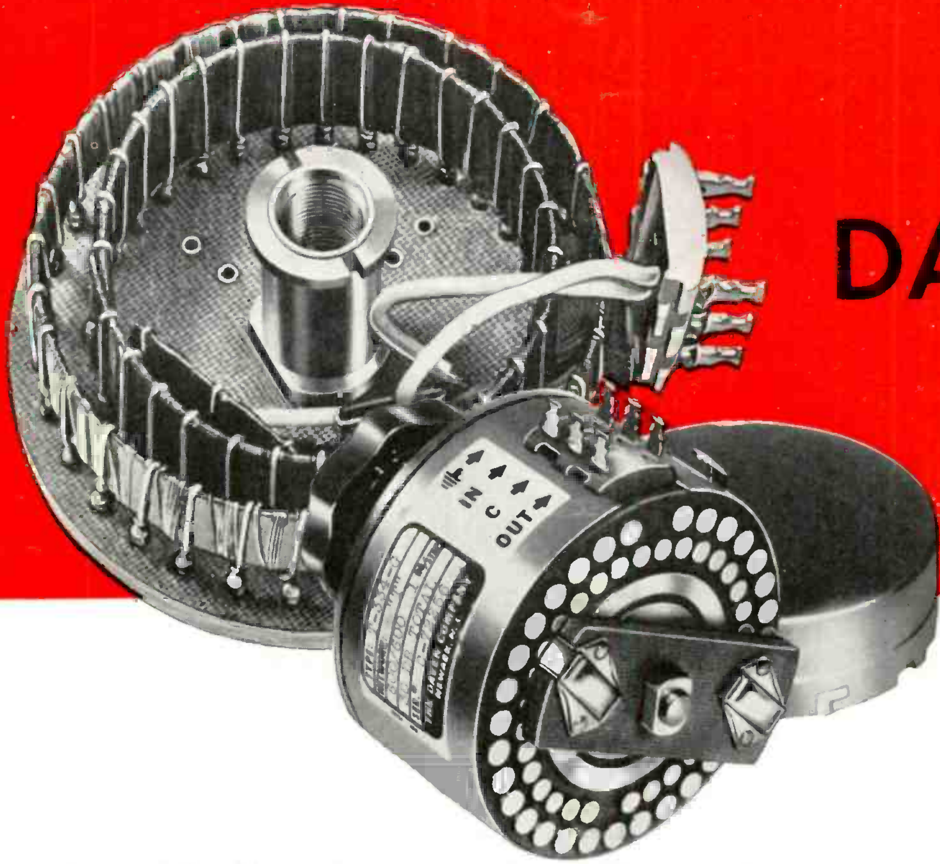
Instrument Sales Manager,
New York City

ADVERTISING INDEX

TWENTY YEARS OF ATTENUATOR PROGRESS

BY

DAVEN



As one of the oldest and most progressive manufacturers of attenuators, we take pride in presenting our recent contribution to the users of fine volume controls . . . the *"Knee-Action Switch.*"* This revolutionary type of rotor is now being offered on Daven attenuators and switches at no additional cost.

For longer life and uninterrupted performance, we offer a switch with the following advantages:

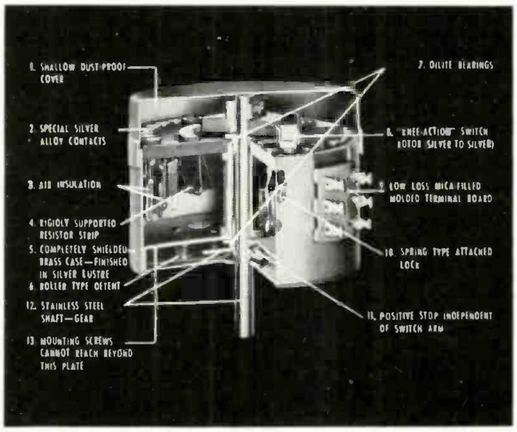
★ Multiple wiping blades of the *"Knee-Action Switch"* are enclosed in a tamper-proof housing.

★ Each blade conductor is individually spring loaded, giving a perfect balance to the entire conducting surface.

★ Uniform pressure on the contacts and slip rings is assured, resulting in low, even contact resistance, over the life of a unit.

★ The considerably shorter rotor arms result in lower over-all switch resistance, due to the reduced conducting path.

* PATENTED



For Further Information Write to Dept. A-6

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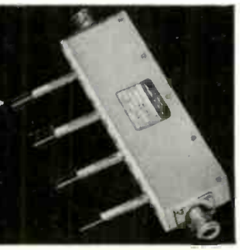
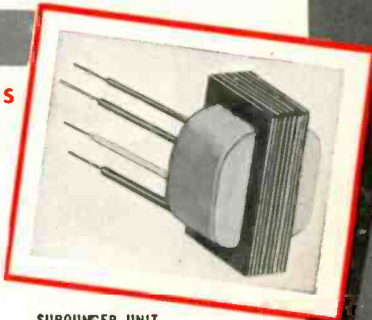


MINIATURE COMPONENTS FROM STOCK...

SUBOUNCER UNITS

FOR HEARING AIDS...VEST POCKET RADIOS...MIDGET DEVICES

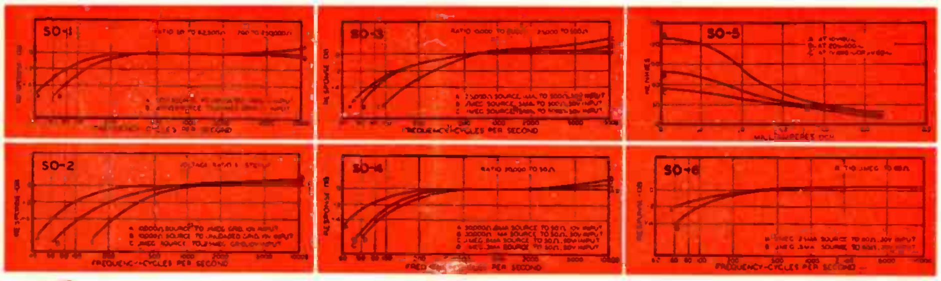


SUBOUNCER UNIT
Dimensions....9/16" x 5/8" x 7/8"
Weight .... .03 lb.

UTC Sub-Ouncer units fulfill an essential requirement for miniaturized components having relatively high efficiency and wide frequency response. Through the use of special nickel iron core materials and winding methods, these miniature units have performance and dependability characteristics far superior to any other comparable items. They are ideal for hearing aids, miniature radios, and other types of miniature electronic equipment. The coils employ automatic layer windings of double Formex wire ... in a molded Nylon bobbin. All insulation is of cellulose acetate. Four inch color coded flexible leads are employed, securely anchored mechanically. No mounting facilities are provided, since this would preclude maximum flexibility in location. Units are vacuum impregnated and double (water proof) sealed. The curves below indicate the excellent frequency response available. Alternate curves are shown to indicate operating characteristics in various typical applications.

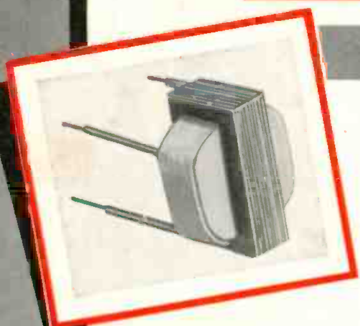
Type	Application	Level	Pri. Imp.	D.C. in Pri.	Sec. Imp.	Pri. Res.	Sec. Res.	List Price
*SO-1	Input	+ 4 V.U.	200 50	0	250,000 62,500	16	2650	$5.60
SO-2	Interstage/3:1	+ 4 V U.	10,000	0	90,000	225	1850	5.60
*SO-3	Plate to Line	+ 20 V U.	10,000 25,000	3 mil 1.5 mil.	200 500	1300	30	5.60
SO-4	Output	+ 20 V.U.	30,000	1.0 mil.	50	1800	4.3	5.60
SO-5	Reactor 50 HY at 1 mil. D.C. 3000 ohms D.C Res.							5.10
SO-6	Output	+ 20 V U	100,000	.5 mil.	60	3250	3.8	5.60

*Impedance ratio is fixed, 1250:1 for SO-1, 1:50 for SO-3. Any impedance between the values shown may be employed.



SUB-SUBOUNCER UNITS

FOR HEARING AIDS AND ULTRA-MINIATURE EQUIPMENT

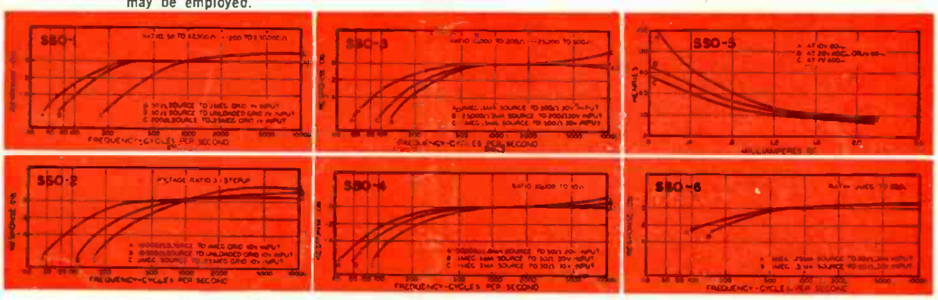


SUB-SUBOUNCER UNIT
Dimensions....7/16" x 3/4" x 5/8"
Weight .... .02 lb.

UTC Sub-SubOuncer units have exceptionally high efficiency and frequency range in their ultra-miniature size. This has been effected through the use of specially selected Hiperm-Alloy core material and special winding methods. The constructional details are identical to those of the Sub-Ouncer units described above. The curves below show actual characteristics under typical conditions of application.

Type	Application	Level	Pri. Imp.	D.C. in Pri.	Sec. Imp.	Pri. Res.	Sec. Res.	List Price
*SSO-1	Input	— 4 V.U.	200 50	0	250,000 62,500	13.5	3700	$5.60
SSO-2	Interstage/3:1	+ 4 V.U.	10,000	0	90,000	750	3250	5.60
*SSO-3	Plate to Line	— 20 V.U.	10,000 25,000	3 mil. 1.5 mil.	200 500	2600	35	5.60
SSO-4	Output	+ 20 V U.	30,000	1.0 mil.	50	2875	4.6	5.60
SSO-5	Reactor 50 HY at 1 mil. D.C. 4400 ohms D.C. Res.							5.10
SSO-6	Ouptut	— 20 V.U.	100,000	.5 mil.	60	4700	3.3	5.60

*Impedance ratio is fixed, 1250:1 for SSO-1, 1:50 for SSO-3. Any impedance between the values shown may be employed.



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