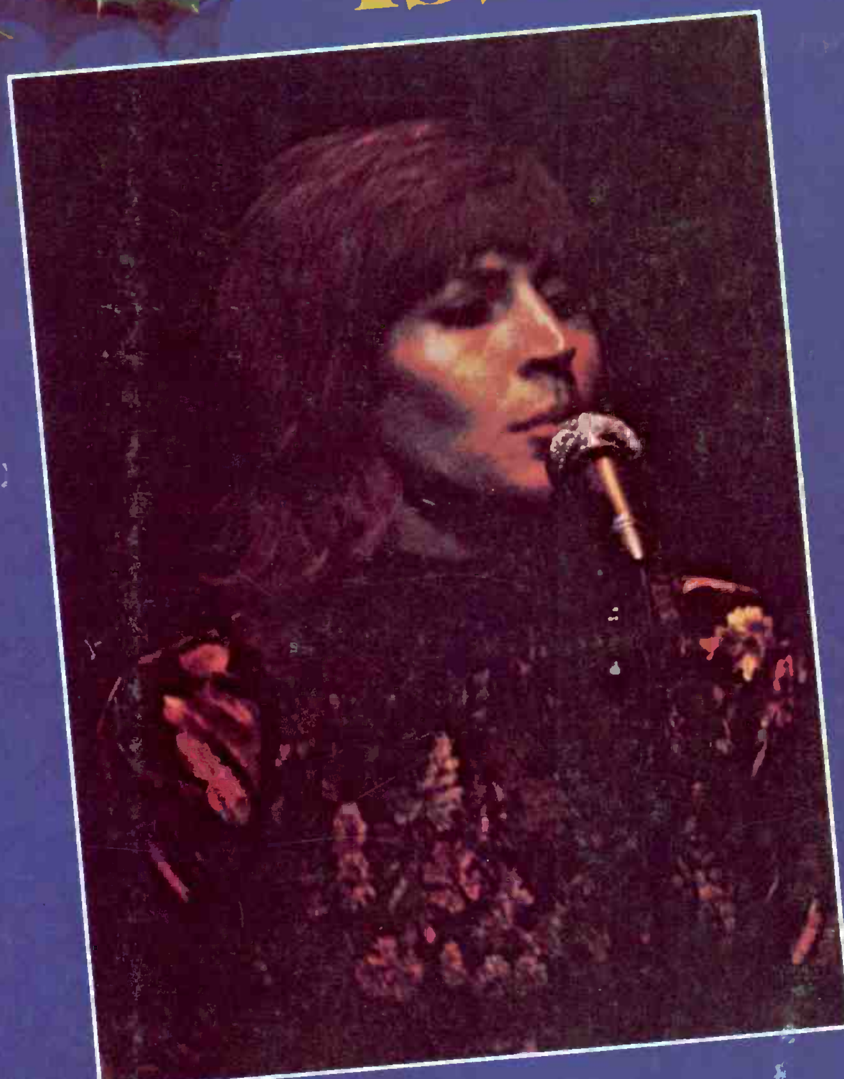
Audio

THE AUTHORITATIVE MAGAZINE ABOUT HIGH FIDELITY • DECEMBER 1973 60¢ ®

47207

Season's Greetings from Audio

SPECIAL MICROPHONE ISSUE



- Mics—Vital Link In The Recording Chain
- Recording Live In 2 & 4 Channels
- Phasing In Tape Recording

Critics acclaim...

HIGH FIDELITY: "... The performance of the SA-9100 is so exceptional and the many extras in the way of switching options, and so on, so eminently useful, that we find it the most exciting piece of audio hardware we've yet tested from this company."

HI-FI STEREO BUYERS' GUIDE: "(The SA-9100) is a powerhouse of sound level, performance and features. Works like something the chief engineer had built for his own use."

"The Pioneer TX-9100 AM/FM stereo tuner offers notably excellent performance and sound quality."

AUDIO: "You can't buy better audible performance than is achievable with Pioneer's new TX-9100 (AM-FM stereo tuner) at any price."

STEREO REVIEW: "... The TX-9100 unequivocally outperforms anything we have tested up to this time."

STEREO REVIEW: "This (SA-9100) is an essentially distortionless, bug-free, and powerful amplifier with exceptional flexibility . . . A highly complex array of electronic circuitry has been packaged into a consumer product of relatively modest price without a trace of 'haywire' or slipshod assembly. It almost seems a pity to hide internal workmanship."

Complete reprints available upon request stabilization, special electronic regulator circuits are used. Transient response is also improved with a superb damping factor of 70.

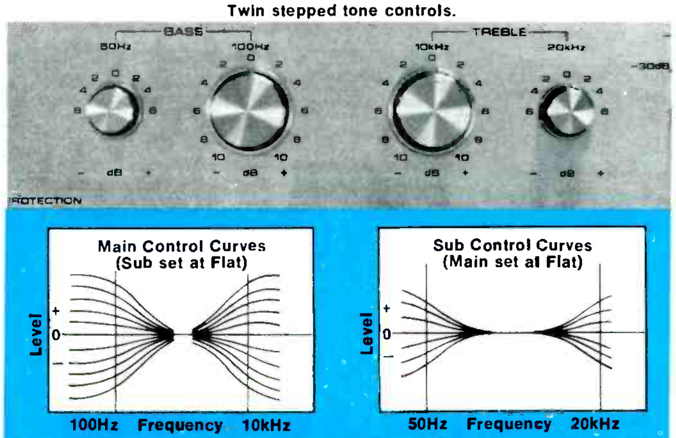
The unique equalizer amplifier

To make certain that extraneous signals do not interfere with the input signal, the equalizer amp is totally enclosed and sealed to shield it against leakage.

There's also extra assurance of precision with special low noise metal film resistors and styrol capacitors. Both are manufactured under continuous computer control to highest laboratory test equipment tolerances: ±1% for resistors; ±2% for capacitors. Until now such precision has been unheard of in hi-fi equipment. Deviation from the ideal RIAA curve is only ±0.2dB.

Since a direct-coupled SEPP complementary circuit is used in the equalizer amplifier, virtually any dynamic phono cartridge can be accommodated without overloading or distortion. For example, with 2.5 mV sensitivity, the overload at 1KHz is an unbelievable 250mV, and 1200mV at 10KHz!

Twin stepped tone controls.



Excellent frequency response curves from 100% negative DC feedback buffer amp & twin tone controls.

The control amplifier: Twin stepped tone controls custom tailor your listening.

Now you can make the most critical bass and treble adjustments with supreme ease. In fact, there are 5,929 tonal combinations to suit your listening room acoustics and to compare or compensate for component frequency response.

On the SA-9100 and SA-8100 four tone controls (two for bass, two for treble) make 2dB (2.5dB with SA-8100) step adjustments for the entire audio spectrum. Working together with the tone controls is a buffer amplifier with 100% negative DC feedback. The main bass control governs ± 10 dB at 100 Hz; the sub-bass, ± 6dB at 50 Hz. The main treble control governs ±10 dB at 10KHz and the sub-treble, ± 6dB at 20 KHz. This, plus the tone defeat control (described in the next paragraph) makes the SA-9100 the most exciting-to-use amplifier that has ever powered any hi-fi system.

New tone defeat switch

Because of the extremely wide variety (5,929) of frequency adjustments made possible by the twin tone controls, the tone defeat switch adds extra flexibility. Adjusting the tone controls to your satisfaction, you can flip the tone defeat switch. Bass and treble responses instantly become flat. When it is switched off you return to the original tone control settings.

The power amplifier

To sustain the ultra sophistication of the equalizer and control amp sections, the power amp has a direct-coupled pure complementary SEPP circuit, double differential amplifiers and two constant current loads. The combined effect is the achievement of wide power frequency range and excellent transient response. 100% negative DC feedback is supplemented by 66dB dynamic negative feedback for minimum distortion and absolute stability. The pre and power amps can be used independently with a separation switch.

Exclusive direct-coupling in all stages

Until now direct-coupling has been used only with the power amplifier. Pioneer takes it a dramatic step further in the SA-9100 and SA-8100. Direct-coupling in all stages from the equalizer amp to the control amp to the power amp. More effective? Absolutely. It achieves the finest transient response, wider dynamic range, THD and IM distortion of only 0.04% (1 watt). It's an incredible achievement.

Level set, volume and loudness contour controls adjust to listening preference

Three controls working together adjust to any degree of loudness. The level set control is the primary volume control. Its maximum loudness setting is 0dB.

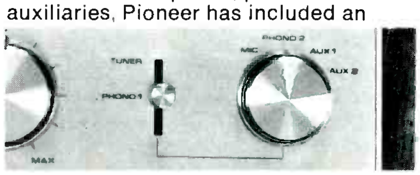
Successive settings of —15dB and —30dB result in lower gain. Once the desired volume is obtained, the volume control is used for fine adjustments within the given range. While the loudness contour boosts bass and treble, it may also be used with the level set control. The more advanced the position of the level set control, the lower the effective range of the loudness contour.

The original and positive speaker protector circuit

Since the signal is fed directly to the speakers because of direct-coupling, an automatic electronic trigger relay system is incorporated into the power amplifier. This protects the speakers against damage from DC leakage which can also cause distortion. It also prevents short circuits in the power transistors.

Maximum convenience for program source selection

While there is a multiple function rotary switch for microphone, phono 2 and two auxiliaries, Pioneer has included an additional convenience. A separate flip type lever control for instant switching between the more widely used tuner and phono 1 and any other single program source. Incidentally, both switches are shielded to protect the input against undesirable extraneous signal pickups.



Convenient program source selection switch & control lever.

Two-way tape duplicating and monitoring

There are two separate flip type switches on the front panel of the SA-9100 for tape-to-tape duplicating and monitoring. Two tape decks can be connected for recording, playback and duplicating in either direction, with simultaneous monitoring.

Level controls for phono 2, aux 2

In order to match the level of various inputs, individual level controls are provided for phono 2 and aux 2.

Speaker B control

This special control helps in the use of two pairs of speaker systems of different efficiencies. There is no sacrifice of damping or distortion when switching from one pair to the other.

Impedance selector for phono 2

An easy-to-use switch allows you to employ any phono cartridge input (25K, 50K, 100K ohms).

Two-position high & low filters

The low filter switch on the SA-9100 and SA-8100 has subsonic (below 8Hz) and 30Hz positions. The high filter switch has 12KHz and 8KHz positions.

Maximum versatility in program sources

	SA-9100	SA-8100	SA-7100
Inputs			
Tape monitor—S/N	2-90dB	2-90dB	2-90dB
Phono—S/N	2-80dB	2-80dB	2-80dB
Auxiliary—S/N	2-90dB	2-90dB	2-90dB
Microphone—S/N	2-70dB	2-70dB	1-70dB
Tuner—S/N	1-90dB	1-90dB	1-90dB
Outputs			
Speakers	3	2	2
Headsets	1	1	1
Tape Rec.	2	2	2

Consistent power for every requirement

	RMS power both channels driven 20-20KHz	RMS @ 8 ohms both channels driven @ 1KHz	RMS @ 4 ohms single channel driven @ 1KHz
SA-9100	60+60 watts	65+65 watts	100+100 watts
SA-8100	40+40 watts	44+44 watts	60+60 watts
SA-7100	20+20 watts	22+22 watts	36+36 watts

This new lineup of Pioneer tuners and amplifiers is unquestionably the most advanced available today. Yet despite this overwhelming sophistication, they're sensibly priced.

See your Pioneer dealer. He'll show you how this series of fine instruments can outperform any units in their price range. All prices include walnut cabinets. SA-9100—$399.95; SA-8100—$299.95; SA-7100—$229.95; TX-9100—$299.95; TX-8100—$229.95; TX-7100—$179.95.

While not discussed here, Pioneer is also introducing the SA-5200 stereo amplifier and the TX-6200 stereo tuner for high quality hi-fi on a low budget. Only $129.95 each, with walnut cabinet.

U.S. Pioneer Electronics Corp., 178 Commerce Rd., Carlstadt, New Jersey 07072

West: 13300 S. Estrella, Los Angeles 90248 / Midwest: 1500 Greenleaf, Elk Grove Village, Ill. 60007 / Canada: S. H. Parker Co.

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Audio

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FEATURE ARTICLES

EQUIPMENT PROFILES

RECORD REVIEWS

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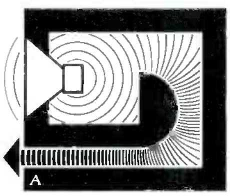
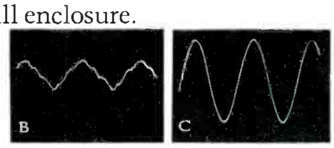
Now BIC VENTURI™ puts to rest some of the fables, fairytales, folklore, hearsay and humbug about speakers.

Fable

Extended bass with low distortion requires a big cabinet.

Some conventional designs are relatively efficient, but are large. Others are small, capable of good bass response, but extremely inefficient. The principle of the BIC VENTURI systems (pat. pend.) transforms air motion velocity within the enclosure to realize amplified magnitudes of bass energy at the BIC VENTURI coupled duct as much as 140 times that normally derived from a woofer (Fig. A). And the filtering action achieves phenomenally pure signal (Scope photos B & C). Result: pure extended bass from a small enclosure.





B—Shows output of low frequency driver when driven at a freq. of 22 Hz. Sound pressure reading, 90 dB. Note poor waveform.

C—Output of venturi coupled duct, (under the same conditions as Fig B.) Sound pressure reading 111.5 dB, (140 times more output than Fig. B.) Note sinusoidal (nondistorted) appearance.

Fairytale

It's okay for midrange speakers to cross over to a tweeter at any frequency.

Midrange speakers cover from about 800 Hz to 6000 Hz. However, the ear is most sensitive to midrange frequencies. Distortion created in this range from crossover network action reduces articulation and musical definition. BIC VENTURI BICONEX horn (pat. pend.) was designed to match the high efficiency of the bass section and operates smoothly all the way up to 15,000 Hz, without interruption. A newly designed super tweeter extends response to 23,000 Hz, preserving the original sonic balance and musical timbre of the instruments originating in the lower frequencies.

BICONEX™ horn

Folklore

Wide dispersion only in one plane is sufficient.

Conventional horns suffer from musical coloration and are limited to wide-angle dispersion in one plane. Since speakers can be positioned horizontally or vertically, you can miss those frequencies so necessary for musical accuracy. Metallic coloration is eliminated in the BICONEX horn by making it of a special inert substance. The combination of conical and exponential horn flares with a square diffraction mouth results in measurably wider dispersion, equally in all planes.

Hearsay

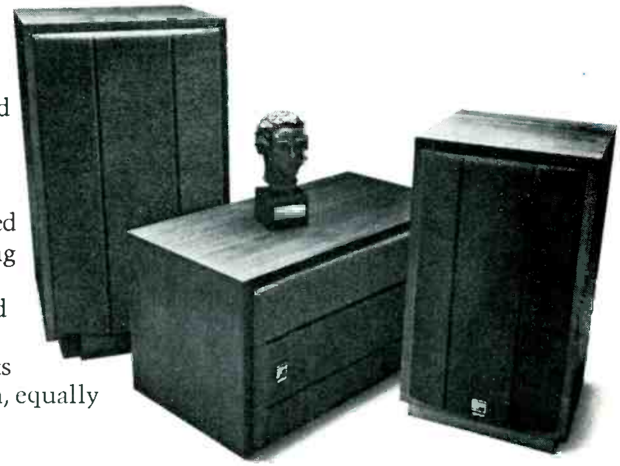
A speaker can't achieve high efficiency with high power handling in a small cabinet.

It can't, if its design is governed by such limiting factors as a soft-suspension, limited cone excursion capability, trapped air masses, etc. Freed from these limitations by the unique venturi action, BIC VENTURI speakers use rugged drivers capable of great excursion and equipped with voice coil assemblies that handle high power without "bottoming" or danger of destruction. The combination of increased efficiency and high power handling expands the useful dynamic range of your music system. Loud musical passages are reproduced faithfully, without strain; quieter moments, effortlessly.

Humbug

You can't retain balanced tonal response at all listening levels.

We hear far less of the bass and treble ranges at moderate to low listening levels than at very loud levels. Amplifier "loudness" or "contour" switches are fixed rate devices which in practice are *defeated* by the differences in speaker efficiency. The solution: Dynamic Tonal Compensation.™ This circuit (patents pending) adjusts speaker response as its sound pressure output changes with amplifier volume control settings. You hear aurally "flat" musical reproduction at background, average, or ear-shattering discoteque levels—automatically.



A system for every requirement

FORMULA 2. The most sensitive, highest power handling speaker system of its size (19¾ x 12 x 11½)." Heavy duty 8" woofer, BICONEX mid range, super tweeter. Use with amplifiers rated from 15 watts to as much as 75 watts RMS per channel. Response: 30 Hz to 23,000 Hz. Dispersion: 120° x 120°. $98 each

FORMULA 4. Extends pure bass to 25 Hz. Has 10" woofer, BICONEX midrange, super tweeter. Even greater efficiency and will handle amplifiers rated up to 100 watts. Dispersion: 120° x 120°. Size: 25 x 13¼ x 13." $136 each.

FORMULA 6. Reaches very limits of bass and treble perception (20 to 23,000 Hz). Six elements: 12" woofer complemented by 5" cone for upper bass/lower midrange; pair of BICONEX horns and pair of super tweeter angularly positioned to increase high frequency dispersion (160° x 160°). Size: 26¼ x 15¾ x 14¾." $239 each.

Sturdily constructed enclosures. Removable grilles in choice of 6 colors. Optional bases for floor standing placement. Write for brochure A-12.

Audition today's most advanced speakers at your BIC VENTURI dealer.

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IHF Receiver and Tuner Specifications—Len Feldman gives the latest word.
Quadra-Direction Discrete Compatible Stereo System—Fumitaka Nagamura, President of N. F. Farrd Systems Corp., details his firm's entry into multichannel sound.
Microphones—The Vital Link in the Recording Chain—Part II of David L. Josephson's discussion of mic use.

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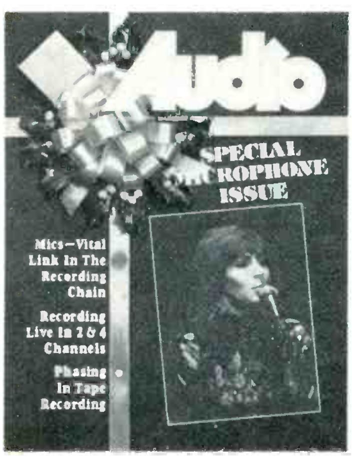


About The Cover: The microphone is the subject of our editorial coverage this month, and we could think of no better way to illustrate what mics are about than to show one in use by a really neat lady, Helen Reddy.

Audioclinic

Joseph Giovanelli

Phono Cable Capacitance

Q. How can one know if he has the proper phono input capacitance? My turntable has four-foot cables.—Name withheld.

A. Unless you can measure the capacitance of the cables or can measure the frequency response of the cartridge/tonearm combination, you cannot know the capacitance of your phonograph. Even though you know the length of cable involved, this information is not sufficient. Shielded cable is rated as having a certain amount of capacitance per foot.

Assuming that you cannot make the necessary electrical measurements, write to the manufacturer of your phonograph or tonearm and ask for the capacitance of the interconnecting cables. Also write to the manufacturer of your cartridge for his recommendations as to the optimum cable capacitance which should be used with that cartridge.

Static from an Amplifier

Q. I have a problem with my receiver and speakers. I get loud static from one speaker after the set has been operating for about five minutes. I interchanged the speakers at the receiver end of the cables. This change resulted in the static going to the other speaker. I changed speaker connectors and I also hooked the speakers up to each of the other two speaker outputs with no success.

Now, I have added a set of small, cheap, bookcase speakers. I hooked them up to the second set of speaker terminals. When playing both speaker systems at the same time, the static virtually disappears. When I play either of the speaker systems by itself, however, static returns.

Any suggestions?—Leonard J. Vieira, MSGT, USAF, Jacksonville, Arkansas

A. From the tests you have performed on your equipment, it is obvious that the "static" problem lies with your amplifier. The only conclusion I have reached is that the feedback loop is involved. When more than one speaker is loading down the output, feedback is reduced. Hence, the "static" is reduced. Perhaps there is too much feedback, causing the amplifier to be unstable.

In addition to this problem the capacitance involved with high frequency roll-off may be defective.

Microphone Phasing

Q. Is there a standard phasing of microphones as regards pins 2 and 3 of a Cannon XLR connector?—Harvey W. Kunz, Old Tappan, New Jersey

A. There is a proposed standard for mic phasing, but not all companies use it. Pin 2 of a Cannon XLR connector will be positive when the diaphragm is compressed. There is no way for you, however, to compress a mic diaphragm in order to check this out. If the instruction manual accompanying your microphone states that wiring your mic as described therein results in adherence to the "standard," you can then phase all of your other mics to that one. If you have a mixer, the "standard" mic can be connected to one input, and a mic having unknown phase connected to another input of the mixer. Raise the gain of the "standard" mic to a point where you receive a significant reading on a VU meter when speaking into it. The mic whose phasing is not known is held next to the "standard" one. You now raise the gain of the "unknown" and see if the output tends to fall off as you raise the gain. If it does, this mic you are checking is out of phase with respect to the "standard" mic. If, instead, the signal constantly increases, the two mics are in phase.

It is more important to have all of your mics in phase than to have them adhere to a standard. Therefore, if you do not have a mic known to conform to the "standard," take any mic at random and consider it to be the "known" one. Then check phase from this mic to all others. If you have a number of mics, make phase comparisons at random. If you find that most of your mics are in phase, but a few are not, consider that the group of mics having the greatest number in phase will be YOUR standard. The few which are of the opposite phase can then be wired to conform to the majority. As you buy more mics, check them out for phasing.

Be sure that all of your extension cables are correctly wired, or you could well have misleading results. An Ohmmeter check will determine the correctness of these cables.

Light and Heavy Tracking Force

Q. Can you tell me the advantages or disadvantages of higher or lower stylus force?—Jim Spellmeyer, Affton, Missouri

When two loudspeakers sound different, at least one of them is wrong. Maybe both.

Unpleasantly Distorted Reproduction

Which is better: the Rectilinear III, at $299, or a comparably priced but totally different-sounding speaker by another reputable manufacturer?

The ready answer to that question by a nice, clean-living salesman or boy-scout hi-fi expert is: "It's a matter of taste. Whichever you prefer for your own listening. They're both good."

We want you to know how irresponsible and misleading such bland advice is.

Think about it:

A loudspeaker is a reproducer. The most important part of that word is the prefix *re*, meaning *again*. A loudspeaker produces again something that has already been produced once. Not something new and different.

Therefore, what it correctly reproduces should be identical to the original production. And *identicalness* isn't a matter of taste.

For example, it isn't a matter of taste whether the body shop has correctly reproduced the original color of your car on that repainted fender. Nor is it a matter of taste whether your mirror correctly reproduces your visual image. Is the reproduction identical to the original or isn't it?

Okay. We know. The ear is less precise than the eye. And in the case of loudspeakers, it's usually impossible to compare the reproduction and the live original side by side. Furthermore, the speaker is only a single link in a whole chain of reproducers. But these problems only complicate the matter without changing the basic principle. *The reproduction is either right or wrong. Two different-sounding reproductions can't both be identical to the original.*

The common fallacy is to call the reproduction wrong only when it's obviously unpleasant (fuzzy or shrieky highs, hollow midrange, etc.). But what about a pleasingly plump bass, lots of sheen on the high end, and that punchy or zippy overall quality known as "presence"? Equally wrong. And, because of the seductive "hi-fi" appeal, much more treacherous.

To glamorize the original that way amounts to having a built-in and permanently set tone control in your speaker. For some program material it can be disastrously unsuitable. Like the funhouse mirror that makes everybody look tall and thin, it's great for short and fat inputs only.

At Rectilinear, we design speakers to approach facsimile reproduction of the input as closely as is technologically possible. We restrict the "taste" factor to twiddling the tone controls of our amplifier in the privacy of our home. Not in our laboratory.

The Rectilinear III is our best effort to date in this direction. And our inspiration for it was a totally different and rather impractical design: the full-range electrostatic speaker.

Any serious audio engineer will tell you that electrostatics are inherently superior to conventional speakers in producing an output that's identical to the input. This superiority is due to scientifically verifiable characteristics, such as flatness of frequency response and low time delay distortion.

The trouble is that electrostatics create tremendous problems with amplifiers, have difficulty playing *really* loud without distortion and are also somewhat deficient in bass. But—they're accurate, undistorted "mirrors" of sound.

The Rectilinear III is the first successful attempt to give you this electrostatic type of sound in a conventional speaker without any of the above problems.

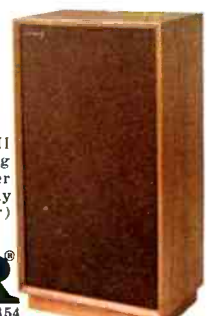
It allows you to hear what composers, musicians and record producers have created for you and not what some speaker manufacturer thinks will please you.

So, next time you're in a store and you hear another $299 speaker that sounds different from ours, you'll have an idea which of the two is wrong.

And which is the one to buy.

The Truth: Undistorted Reproduction

Seductively Distorted Reproduction



Rectilinear III floor-standing speaker (6 drivers, 3-way crossover)

RECTILINEAR®

Rectilinear Research Corp., 107 Bruckner Blvd., Bronx, N.Y. 10454
Canada: H. Roy Gray Limited, Ontario

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A. The lower the tracking force the better, up to a point. The more force which is required, the greater the amount of wear on a record. The record must move the stylus back and forth rapidly. As tracking force increases, the disc must do more work in order to produce this stylus motion. Further, the friction of the stylus against the groove walls will increase. This friction will add to the wear problem.

There are many factors which can influence the minimum recommended tracking force of a cartridge. It would be difficult to specify all of them. The stylus assembly must be flexible, readily movable by the undulations in the grooves. At the same time the assembly must be rigid enough to withstand reasonably rough handling. These two factors are mutually exclusive. The mass of the tonearm is also involved. If the arm is too massive, more force will be required to push it along, with the result that more tracking force must be used. The friction of the bearings of the tonearm must be taken into account. To some degree, the amount of modulation impressed on the disc determines the minimum force which can be used. Thus, while there is an advantage in tracking a disc at its minimum practical force, it is possible to track a disc too lightly. When tracking too lightly, contact between the stylus and groove walls will be intermittent. The stylus will slam into the walls. Wear will be added over what would occur when using heavier tracking force, once the force has fallen below this minimum.

It is not difficult to tell when tracking is too light. The distortion is obvious, especially when listening to loud musical passages.

There are various aids to help you track your discs as lightly as possible, but still be above the minimum which will keep groove contact from becoming erratic. The manufacturer of your tone arm and of your cartridge will provide some general guide lines. Force gauges are available which will allow you to measure the force. There are some test discs which are designed to let you know when you are tracking too lightly.

Note

I just want to take this opportunity to wish each of you the most joyous of Holiday Greetings.

If you have a problem or question on audio, write to Mr. Joseph Giovanelli, at AUDIO, 134 North Thirteenth Street, Philadelphia, Pa. 19107. All letters are answered. Please enclose a stamped self-addressed envelope.

expanding horizons

When a revolutionary new principle re-creates the excitement and grandeur of an original performance with a clarity and power you've never experienced before, technical arguments are unnecessary. Now, as a companion to the amt-1 ESS introduces the amt-3 "rock monitor", a speaker system that mates the unequaled Heil air-motion transformer to a unique "power burst array" low frequency system for super-tight, impactful bass.

The ESS amt-3 recreates the swift attack-time impact punch of an actual performance. You can't appreciate what high acceleration in a loudspeaker system really means until you experience the incredible transient immediacy of the ESS amt-3. The ESS amt-3 lets you break clear of the slow accelerating drive in conventional systems and expands high fidelity horizons into new areas of accuracy.

And now the dramatic ESS amt-3 and original amt-1 Heil air-motion transformer speakers can be matched to the new ESS model 200 stereo power amplifier. The elegant styling and outstanding performance of the ESS model 200 surpass demands of even the most critical installations. Don't be bogged down with yesterday's sound when these components light the way to tomorrow. Step into the future with confidence at your ESS dealer.

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sound as clear as light

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Tape Guide

Herman Burstein

Demag After Playback

Q. I would like to know whether the heads on a tape deck require demagnetizing, even though I don't do any recording. And if they do, after how many hours of playback? Do playback heads ever wear out? How does one know when they need replacing?—Jerry Meslin, Miami, Florida

A. The asymmetrical audio signal presented to the playback head in effect contains a d.c. component, which tends to magnetize the head. Therefore periodic demagnetization of the heads is ordinarily recommended, generally after about eight hours of use. At least one manufacturer, however, has recommended less frequent demagnetization.

Playback heads do wear out. How soon depends upon the quality of the head, the nature of tape tension (whether pressure pads are used), and quality of tape (how abrasive). Under the best of conditions, a conventional playback head may last 2,000 to 3,000 hours before its gap widens to the extent that treble response deteriorates significantly. Some recent heads claim a much longer life.

Amp Overload with Tape

Q. When I use my turntable as a source, the music sounds quite clear all the way to maximum volume. But when the same record has been recorded and is played back through my tape deck, the music becomes quite distorted at half volume. This is especially so in the lower and mid frequencies. Also, for the turntable volume to equal that of the deck at the 9 o'clock position, the volume control would have to be set about the 12 o'clock position. Is my tape deck faulty?—Jeffrey Peace, Marysville, California

A. From your description, your tape deck produces considerably more signal than your turntable, inasmuch as the turntable produces as much volume at 12 o'clock of the volume control as the deck does at 9 o'clock. Hence when you turn the volume up, it appears that you are overloading your audio system on the tape signal. Offhand, it does not appear that there is anything wrong with your tape deck. On the other hand, there might be some very low-frequency wow produced by the deck which tends to overload your audio system, causing distortion. Or the deck might have excessive bass boost, again resulting in a tendency to overload at high volume. See what happens if you adjust the output volume of your deck so that at 9 o'clock you obtain the same signal level on both tape and disc. If your problem doesn't then disappear, your deck may have a fault such as I have described.

Speed Conversion

Q. I have a model 7030 TEAC half-track machine. It comes from the factory set for 7½ and 15 ips, and I wish to convert to 3¾ and 7½ ips. Other than changing the capstan drive shaft, will it be necessary to have a bias adjustment?—Gus. W. Thomasson, San Luis Obispo, California

A. It will probably be necessary to change the bias. In order to obtain full treble response, manufacturers generally employ somewhat less bias than that which achieves minimum distortion. In other words, at 7½ ips the bias adjustment tends to represent a compromise between minimum distortion and extended treble. However, at 15 ips, such a compromise is little if at all necessary; bias can be adjusted for minimum distortion while maintaining treble response through the audio range. At 3¾ ips, it becomes all the more necessary to retreat from the bias producing minimum distortion, so that adequate treble response can be maintained. Consult the manufacturer for information on the specific changes in bias required in going from the faster speeds to the slower ones.

Let me add that in changing speeds, it will also be necessary to change record equalization, and it's probably desirable to change calibration of the record level indicator. And it will be necessary to change the playback equalization for the 3¾ ips speed (playback equalization is the same for 7½ and 15 ips).

If you have a problem or question on tape recording, write to Mr. Herman Burstein at AUDIO, 134 North Thirteenth Street, Philadelphia, Pa. 19107. All letters are answered. Please enclose a stamped, self-addressed envelope.

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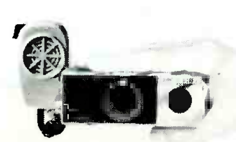

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Edward Tatnall Canby

Four for Everything

'Way back last spring, I had a temporary experience that I have to describe to you. In fact I did, but the whole thing got put aside. And so here we go again. I found myself, all of a sudden, back on two speakers. And I didn't like it.

Not voluntarily mind you. I had every intention of listening to *everything* via four speakers from thence onward until doomsday. I am by now wholly adjusted to four-way sound for all listening, even mono broadcasts. And by last spring I was so accustomed to it that the very idea of trying out a good old-fashioned two-speaker set-up would not have occurred to me. Then—my quadraphonic amp conked, with no warning. All of it. Total silence. Now if there's anything I can't stand for long, it's total electronic silence. I fear I have joined the audio fraternity in this respect, for better or worse. So—what? Back to stereo! Out with some of my old familiar equipment.

It was, I assure you, a most unexpected jolt, such as I wouldn't have believed. Phew! Only two speakers, both of them in the front of my room. After so long, I found this effect strangely unfamiliar and inadequate. I was really disturbed. The whole thing was so lopsided. All the music pushed over into one end of the room. Even when it was loud, it somehow seemed impotent; I kept turning it up too high. I was accustomed to the more gentle persuasiveness of four speakers, for more impact at *less* volume. Stereo was strident; quadraphonic purrs. The "dead" half of the stereo room really began to bother me. No speakers there! The rear of my listening space sort of dragged itself along, speakerless, like a dog with its hind legs out of commission—ugh. All sorts of nasty things kept coming to mind. No—I did *not* enjoy my return to stereo.

The fact is that four surrounding speakers, given a minimum of differentiated sound, are more versatile, more flexible, capable of a much wider variety of sound impacts, than any two-speaker system, however hi the fi. The four-way surround speaker set-up is a basic advance in home listening over stereo, as stereo was (most of us will now admit) over mono. That is the big message that dinned itself into me. Astonishing.

But let me go back a bit. Things happen so fast. Before it conked, my four-way amp was one of those big single-unit "receivers," all of a piece, and it came from the matrix side of the quadraphonic fence, equipped with the then-new logic SQ decoder. I had been listening to SQ-type discs via this machine for some time—*it* was there, *they* were there; what better reason. Also everything else, including weather reports and the news. I duly reported to CBS that, unaccountably, my SQ news broadcasts were playing tricks on me. Invariably, the announcer's first syllable, in every sentence, came from the back speakers. But just as invariably, the next syllable came from in front. Odd! Perfectly intelligible, of course, but a quadraphonic side-effect I had not quite counted upon . . . (Note: my newest "three-chip" SQ logic decoder no longer performs this curious function. The newscaster stays put very nicely.)

CD-4? At that point, nobody had been kind enough to pass me a CD-4 demodulator, though RCA's discs had been coming in month after month. They got played, natch, via SQ. What else! Sounded nice, too. Then Elektra Records, which had just taken on the CD-4 system, offered me a nice new JVC demodulator. Excellent! In no time I had it plugged into the big quadraphonic machine (this was before it conked, you see . . .), the output going into the four "discrete" inputs handily provided at the rear. Even with RCA, so to speak, feeding Columbia, I figured it ought to work. It did. And so I was set for my first truly home experience with the discrete disc system, which until then I had heard only at numerous public demos. The Audio-technica cartridge, already in use in my system, picked up the 30 kHz carriers nicely, the red JVC signal "radar" went on and the music poured out. Great! Just superb, without so much as a minute of adjustment—it simply worked, straight off. How's that?

To be sure, the sound seemed a wee bit less *discrete* than I had hoped. But then, after all, ads are ads and we should expect a bit of a minus. So I quickly forgot that small feeling and proceeded to play straight through my modest pile of RCA Quadradiscs (this was before Elektra hit the market) one after another. I was happy. Like driving a brand new car first time around the block. But that was before I had discovered what I now must disclose.

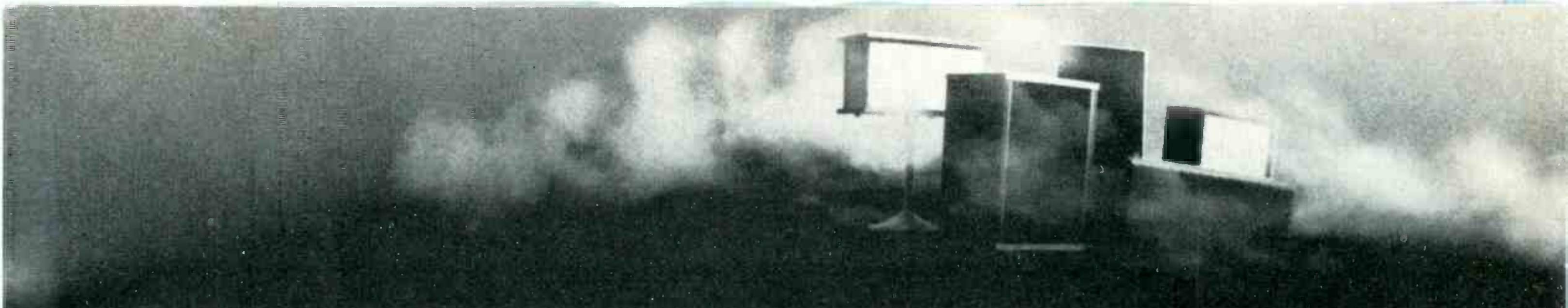
It seems that my amplifier selector switch had been screwed tight at a wrong position. I hadn't noticed. I became aware of this when, one day, I was too lazy to get out my magnifying glass, lean over double, and read the fine print under the switch. Instead, I switched by ear—counting clicks. HEY! *Wrong number of clicks.* The thing was one position off its base. In an instant the ghastly truth hit me. When the switch said DISCRETE it was actually on SQ. I had been sending my entire "discrete" record collection through the SQ decoder, after demodulation via CD-4. And so I had me a gorgeously improbable sound, SQ logic working away upon a demodulated RCA signal! That accounted for my tiny little feeling that something was vaguely less discrete than I had hoped for in all those lovely RCA discs. It also, I trust, shows you how persuasive *any* four-channel sound can be, given a good recorded performance, well microphoned.

It was soon thereafter that this big amplifier conked on me. Why? One theory you can guess. Acute hysteria due to RCA/CBS confusion.

Another more rational theory was that perhaps the ultra-wide-range Audio-technica cartridge was throwing a blast of unaccustomed supersonics into the four amp channels, via the preamp. Worth a thought, though my reasoning tells me this wasn't the case in my case. Solid-state circuitry these days is nicely transparent to supersonics, even if your ears can't hear them, and one of these new CD-4 capable cartridges could, conceivably, send a really healthy micro-wallop straight into your system up in the high Hertzes. If the preamp doesn't blow, then the amplifier might object with an inaudible squawk of horror, not to mention the tweeters, if all else holds firm. JVC has a feed-through position on its demodulator, sending the pickup signal straight into the two-channel preamplifier for standard stereo sound. Is there a filter somewhere en route? Seems to me there ought to be, these days, for safety. Worth a review, I'd say, of all present and contemplated playback equipment. The new CD-4 cartridges do send through the high stuff whenever it is there and they might indeed do damage or contribute to overloading.

Well, what actually happened to my amplifier was much simpler. We had an electric storm. Power went out. When it came back—no amp. Some sort of power surge and probably a healthy bolt of lightning (in spite of all my puny precautions). Act of God, I calls it.

And so, for weeks on end, until I went off on a vacation, I was limping along on two lonely speakers in "ordinary" stereo, like a four-cylinder buggy with two cylinders gone. Believe me,



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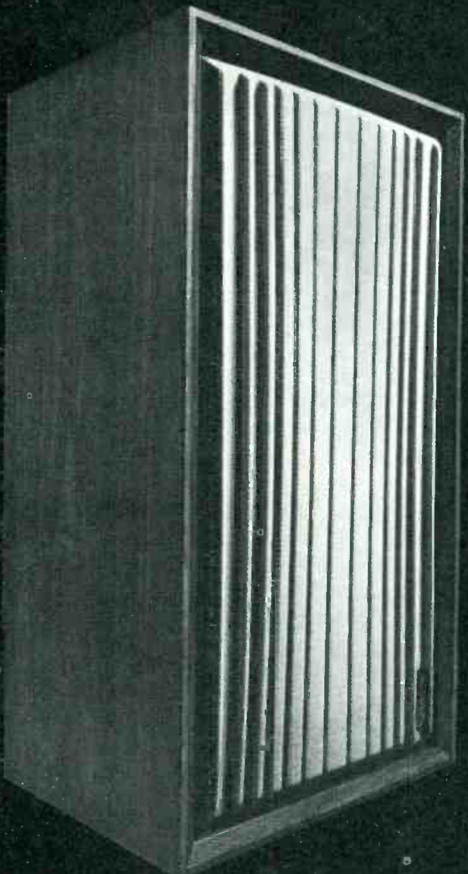

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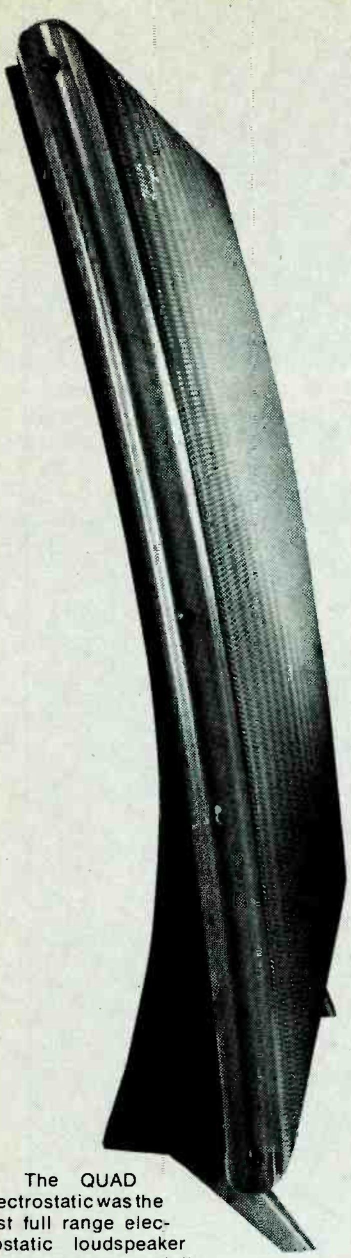


it's true. And not even the superb sound of the Crown 150 *two*-way amplifier system, pressed back gratefully into service, was enough to compensate for the lack of the other pair of speakers. That's how it was. I figure that in a few years' time all of us will begin to feel this way when we are reduced to a mere two speakers. Don't we feel it right now when we have to play through *one* living room speaker in mono? Sure, you can listen! But there is simply more information available, more aliveness, more versatility, in the quadraphonic array. You'll see. We'll learn.

Microstatic

So now I'm back in quadraphonics again, to my great relief. And I must add a postscript here that applies to all my four-way sound, whether mono, SQ or CD-4 or even home-recorded Canby-discrete via tape. Those four speakers. Just about this same time I got my first set of four identical units (I had previously used somewhat differing pairs, as most of us have to for awhile). These were the new Microstatics, full-range units incorporating a new version of the earlier wide-dispersion Microstatic add-on tweeter system to give a complete hemisphere of equal highs out in front, both sidewise and up-and-down. Wide-angle dispersion in two dimensions.

Since we've already run detailed profile information on these units, I'll only say that for my ears, unaided by measurements, they are excellent quadraphonic speakers, rather gentle, not really the hard, big-bang sort good for rock music, but excellent for a four-way blend in a nice living room environment and plenty loud enough too. What is really interesting in them is that special dispersion of the highs, which works out to be extremely useful.

The tweeter array is zany; it sticks out in front of the box (and is covered by several alternatively shaped fancy grille covers, guaranteed not to collapse when you lean against them). It *has* to stick out, in order to get its extremely wide dispersion. That's the trick. It works. With four of these, you get a smoothly uniform spread of sound from any point within the listening area, no matter where you are—as you move, you are astonishingly unaware of the individual speakers. No "beams" to walk in and out of. No special best spots. This is definitely all to the good and highly desirable.

But the nicest feature of the Microstatics, to my mind, is the separate level control for the front-facing tweeter unit (there are a number of tweeter cones, combining their coverage for the ultra-wide even spread). Turn this down, and you "blunt" the front of your sound hemisphere, the sides remaining intact. The volume is *less*, straight out in front, than it is off to the sides. You use this unusual feature if you habitually find yourself too near one speaker, hearing it too noticeably above the others. With the front turned down in this way, you can be right next to the speaker and still not hear its highs separately—unless you lean over and stick your ear almost into it. Amazing. And yet, via the continuing side dispersion at normal volume, your over-all room balance remains intact in the rest of the listening space. Simple and very ingenious, I say, and good thinking.

In view of prevailing arguments concerning methods of sound dispersion in the listening room, it's worth noting that these Microstatic speakers *do not depend on reflected sound* for their smooth, any-place-in-the-room blend. Wherever you may be, you receive direct signals from all four speakers, radiated equally over the hemisphere of space in front of each. Stereo (and quadraphonic) theory is clear enough: the stereo effect itself, whether by two channels or four, depends on interaction at the ears between signals set apart in space and coming from different directions. Reflected signals are less desirable than direct, simply because the more they are reflected, the more diffuse and, hence, uncontrolled is the stereo. A pleasant blur. Room reflection is, of course, an inevitable part of our listening and we allow for it in the art of recording; but it is never more than a passive drag on the controlled, intended stereo interaction. Real stereo—real quadraphonic—comes from direct-line hearing, speakers straight to ears.

Four channels, surrounding the listener (to get back to where I started), offer a factually greater control of the listening space than two. *Active* sound sources all around, and no passive rear area, merely reflecting what's up front. *Six* simultaneous stereo "pairs" instead of only one. (Front, rear, left side, right side, two diagonals.) And all working simultaneously. The more we keep these interacting signals direct and uncluttered by reflection, the stronger will be the quadraphonic impact. That's why I favor the sort of direct-line dispersion offered by the Microstatic speakers, as well as by other speaker systems of a similar design philosophy.

* * * *

. . . So you *like* your old two-channel stereo sound? OK! Fine! You are by now wholly used to it, comfortable with it, tuned to it; *you have learned to read it*. One does have to learn, you know. It has taken you a long time, though maybe you haven't even noticed. I'm only telling you that the same is likely to happen when you shift to four. For everything.

Behind The Scenes

Bert Whyte

THE AUDIO ENGINEERING SOCIETY must have influence in "high places." The annual New York convention of the Society was held earlier than usual this year, settling in at the Waldorf-Astoria on September 10th, and just missing a steamy, debilitating 10-day heat wave, with its concomitant power brown-outs.

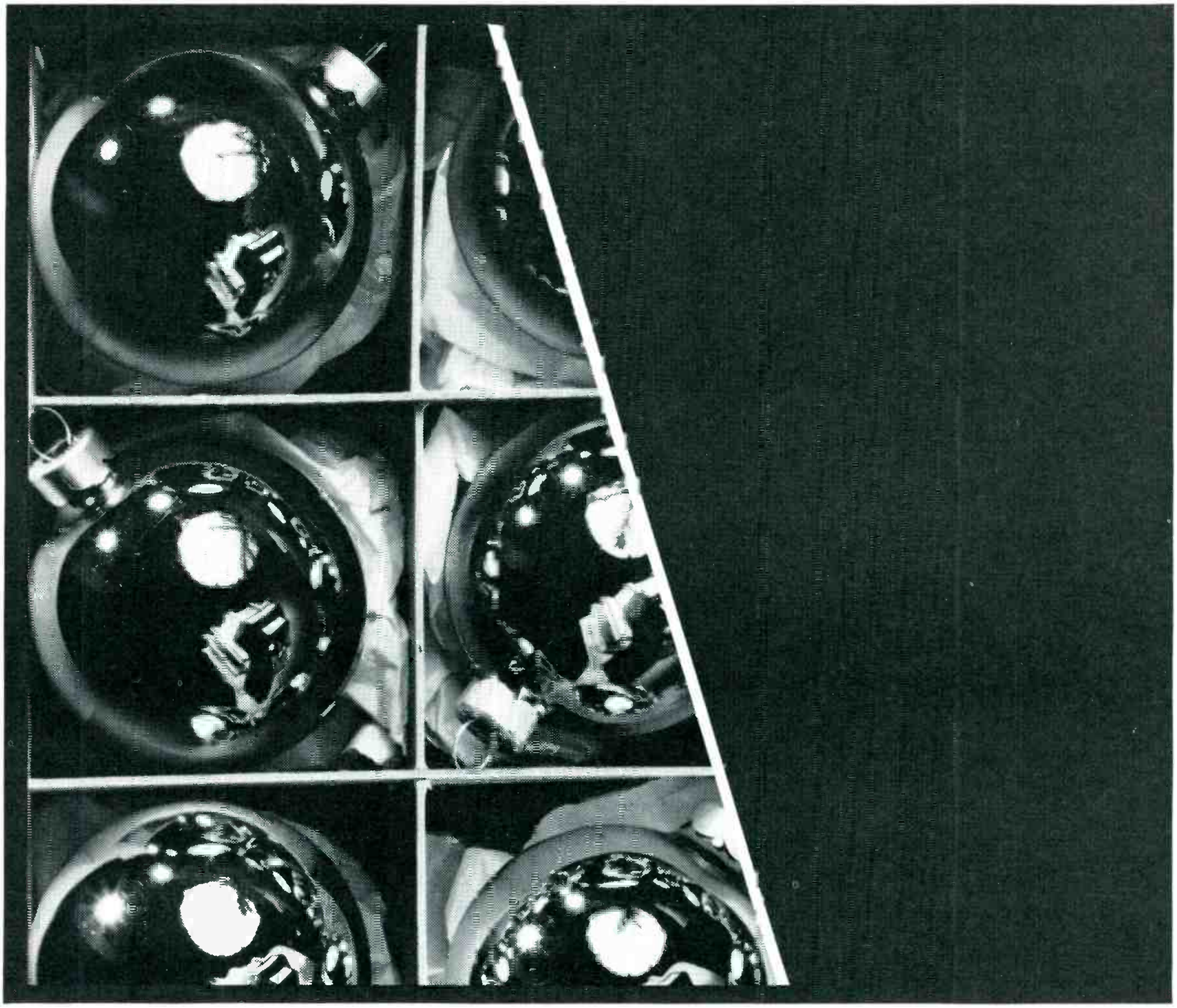
This 46th convention of the Society was the third and final one of the year, a fact that was greeted in certain quarters by sighs of relief. For the doughty technicians and engineers of the various exhibitors, charged with the responsibility of setting up a properly functioning display and then tearing down and repacking everything, it has been a "long, long trail a-winding" from Rotterdam, to Los Angeles, to New York.

As usual, the Grand Ballroom of the Waldorf was jam-packed with every conceivable kind of audio equipment. Some of the gear had been seen at the earlier conventions . . . after all, one doesn't design a new mixing console every other day! But there were plenty of interesting new items. DeWitt Morris of United Recording Electronics Industries was on hand to show us the production models of their Electronic Crossover Systems. These are active crossover networks on plug-in cards. Crossover frequencies are continuously tunable . . . the 521-L from 200 Hz to 2 kHz, and the 521-H from 1 kHz to 10 kHz. Filter characteristic is 2-pole Butterworth yielding 12 dB per octave. The cards plug into either the 521-P chassis with internal power supply or the 521-E for external powering. Cards can be combined so as to give bi-amplification, tri-amp (3-way), or four-way amplification. There is currently a revival of interest in multi-amp speaker systems. Many people are experimenting with exotic low frequency systems, such as transmission line, corner horn huge infinite baffles with 24- or 30-in. drivers or outsize acoustic suspension systems. These are being combined with various electrostatic and dome-type tweeters. The various levels of efficiency between the low and high frequency units dictate bi- and tri-amplification and hence the need for a good electronic crossover network. I expect to have one of these new UREI units before long, for use in some fairly exotic speaker configurations I have been pondering for some time.

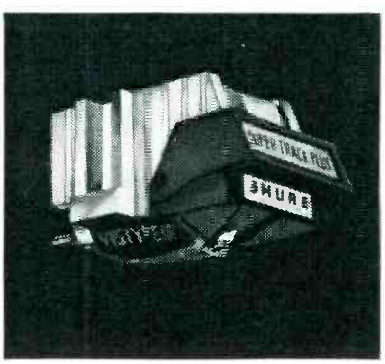
Two new tape machines in the "advanced audiophile"/semi-professional category made their debut at the convention. One from Revox was the long-awaited successor to their A-77 model. The machine had arrived just a few days prior to the show and there wasn't even literature available, so details are a bit sketchy. It has a very advanced servo-motor drive system which I gather is of the crystal-controlled reference oscillator type. A "fail-safe" logic tape-handling system is a feature as is an integral four input mixer. The tape drive is of the closed-loop type. There are much larger VU meters than on the A-77 and I believe there are peak "hold" facilities. While the present machine is available in quarter- and half-track stereo in normal and high speed (7½/15 ips) versions (there is no quadraphonic unit as such), it would appear that conversion to this format at some time in the future could be easily accomplished. The new Revox is expected to cost around $1,800, and as soon as we get more details and/or a unit to play with, we'll bring you up to date.

The other new tape machine is the British-made Ferrograph Super Seven. This 10½-in. reel machine has a host of features, some of them quite unusual. It is a three-motor/three-speed/three-head unit with variable speed on fast forward and rewind to eliminate over-tight tape wind. It has, of all things, electronic editing! To quote Ferrograph, "no clicks, no pops, new material replaces old without annoying bias transient noises." If this is what I think it is, this would seem to be a "first" in an audio tape recorder. Heretofore, electronic editing has been found only in super-expensive video tape machines. Among other goodies, there are push-button bias readings, automatic demagnetization of tape heads, and this I have to see . . . endless-loop cassette facilities! To further gild the lily, Dolby B-Type noise reduction is optionally available for a nominal $125. The Ferrograph Super Seven is available in quarter- and half-track stereo at 1⅞, 3¾, and 7½ ips, or in the high speed version 3¾, 7½ and 15 ips at no extra charge. Price with Dolby B is $1075.00.

Speaking of Dolby, at their booth Ray Dolby showed me his new Cinema Equalization unit. Dolby noise reduction for use with motion picture optical tracks is an ongoing thing. It is a project which takes time, but new developments are hastening the day



A cartridge in a pear tree.



A gift of the *Shure* V-15 *Type III* stereo phono cartridge will earn you the eternal endearment of the discriminating audiophile who receives it. What makes the V-15 such a predictable Yuletime success, of course, is its ability to extract the real sound of pipers piping, drummers drumming, rings ringing, et cetera, et cetera. Stereo Review, in a test report that expressed more superlatives than a Christmas dinner, described the performance of the V-15 Type III as "... a virtually flat frequency response ... Its sound is as neutral and uncolored as can be desired." All of which means that if you're the giver, you can make a hi-fi enthusiast deliriously happy. (If you'd like to receive it yourself, keep your fingers crossed!)

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when Dolby encoded prints will be industry standard. The object of Dolby noise reduction with film is not an improvement in the signal-to-noise ratio in the movie house as audience noise would swamp the 10/15 dB Dolby reduction. For many years motion picture sound tracks have been saddled with restricted frequency bandwidth. There exists the "Academy" or Cinema Equalization Curve, which is supposed to give a bandwidth on optical tracks from 50 to 7500 Hertz. In actual practice, they are lucky to get 80-4000 Hertz. The reasons are numerous, a combination of the optical recording process, the type of film stock, and film development techniques. Even with modern film stocks of fine grain, high resolution, and super high acutance developing chemicals, the cumulative noise still restricts the bandwidth. The use of Dolby noise reduction allows optical tracks to achieve a frequency response from about 40 to 10 kHz. This gives a less distorted, far cleaner sound with better articulation in dialogue, more natural sounding music, and more dramatic special effects (low frequency cannon fire in battle scenes, more realistic thunder). The print must be released in the Dolby "compressed" (encoded) state and in the theater played back (expanded, decoded) through the special Dolby Cinema noise reduction module. Of course, most theater sound systems are set up for the old Academy curve. The purpose of the new Dolby equalization module is to adjust the theatre sound system to the characteristics of the Dolbyized optical tracks. According to Ray Dolby, over 100 movie houses in England have installed his noise reduction modules, and there are a half-dozen films now shooting in England that will be released as Dolby prints. Film executives and engineers in this country have been impressed by a number of Dolby film demonstrations and hopefully it won't be too long before we can enjoy this improved sound in theaters in this country.

In the Waldorf ballroom, New York engineers had their first look at the imposing new 3M Series 79 tape recorders available from mono all the way up to 24 tracks. Ampex was on hand of course, and I had a fascinating demonstration of their synchro-lock system. A color TV monitor showed a picture played back from the new Ampex 7900 video tape machine. A 440 servo recorder furnished the audio track for the picture. Through headphones, you could hear the audio master in your left ear and the recorded track from the video machine in your right ear. You watched the picture for lip-sync. No matter how wildly the video recorder was deliberately started out of sync, a touch of a button on the synchro "black box" would snap picture and sound into perfect sync. You could start the audio master late, but no matter . . . sync was established in a twinkling.

A lot of action on the fifth floor of the Waldorf where the sound demonstration rooms were located. Here was where the quadraphonic action was. Sansui had an elaborate set-up to demonstrate their new VarioMatrix IC chip. They are claiming 12/15 dB of separation with this chip with possible expansion to as much as 20 dB. The A/B comparisons between master tape and decoded disc were impressive and certainly seemed to support their claims.

Columbia, not to be outdone, was playing their SQ discs through their new IC chip, which I believe combines full logic plus "variable blend." This latter addition has virtually eliminated the rear channel "pumping" and "breathing" of the earlier matrices to which some people objected. What I heard was nice clean four-channel, but I think some better records could have been chosen to demonstrate this advance.

JVC was, of course, playing CD-4 discrete discs, including some of the new Elektra titles. Separation was beyond cavil, but the sound could have been of better over-all quality had they used some higher quality loudspeakers. They were once again showing their fascinating and unique MM-4 peak and VU level meter for quadraphonic sound utilizing a "plasma film." I gave a more detailed description of this meter in my Los Angeles AES report in the August issue. It seems production on this unit has been delayed, but I still hope to have a unit for test in the next few months.

Mark Levinson had a room in which he was demonstrating his super pre-amp (of which I spoke last month) along with his JC-1 cartridge pre-amplifier. Mark was sharing his room with Jon Dahlquist, who was demonstrating his new model DQ-10 "Phased Array" loudspeaker. The speaker at first glance looks like the British Quad electrostatic unit, but in the rear is a good-sized bulge, which I would assume acts as the woofer enclosure. The speaker is a four-way dynamic system using five drivers in an acoustical configuration which is claimed to provide on-axis compensation for time-delay effects. The speaker is stated to have a response from 32 to 25 kHz, with very low IM distortion and wide vertical and horizontal dispersion. Big claims indeed, but the speaker has made a considerable impression on many people, not the least of whom is Saul Marantz who has gone into partnership with Jon Dahlquist. In the limited time I listened to the speaker, I found it exceptionally smooth, with really good transient response, a bass response hard to believe from such an odd configuration, and good stereo imaging. In short, a very clean, natural sound remarkably free of coloration. In due time I hope to have a pair of these speakers at home for more of an insight into such areas as power handling, etc.

In the Gotham Audio room, president Steve Temmer proudly showed me the new EMT 424 Flutter Analyzer. This fabulous instrument is the last word for really nailing down tape motion parameters. It is much too complicated to explain everything, but among its features is a memory hold on the meter, so you don't go nuts trying to figure a value. There is an automatic analyzer section which scans the entire frequency range between 1 and 100 Hz in 20 seconds. The results can be seen on a graphic pen recorder or on a memory oscilloscope.

At Burwen Laboratories room, Dick Burwen was playing a recording of Mahler's *3rd Symphony* made with his noise eliminator system. Very clean sound indeed. He was also showing his dynamic noise filter. I have had one of the filters at home for a while and it is a unique and interesting item on which I will report in the near future.

All in all, the 46th AES convention was a success. Many important papers were given, especially some on digital recording. The convention was also a good scene for some AUDIO Magazine people, past and present. This was the 25th anniversary of the AES, and former Editor and Publisher C. G. McProud, a charter member of the AES, was guest speaker at the banquet. Our own Ed Canby was made a Fellow of the AES, a long overdue reward. Also made Fellow was old friend and associate Bob Fine. Dick Burwen was similarly honored. My dear friend Murray Crosby, "Mr. Multiplex," having already been made a Fellow, was awarded an Honorary Membership.

Needless to say, Jack Mullin's fabulous collection of historical recording equipment was as big a hit at the Waldorf, as it had been at the Hilton in Los Angeles. Thank you, Jack!

Well, that is the AES convention activity for 1973. Perhaps we will recover in time for the Copenhagen 47th convention in the springtime! Æ

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Editor's Review

THERE WERE some names from the audio field in the news during the past few weeks, and since the events associated with these gentlemen could easily have been overshadowed by the momentous national and international political events of the period, we thought we'd better stop and take a moment to pass along the information.

"It all came out of the world of music and some of it should go back as a replacement of a personal debt, you might say, but also as a civic responsibility." Those are the words of Avery Fisher, of Fisher Radio Corp., in giving an immense sum—said to be between $8-million and $10-million—to New York's Philharmonic Hall. In appreciation, officials of Lincoln Center and the New York Philharmonic decided to change the name of the hall to Avery Fisher Hall.

The gift was described as a breakthrough in the field of arts patronage as 80 per cent of the grant will be used to help meet the hall's housekeeping expenses. In the past, such gifts have been directed by their doners for the more glamorous areas, such as new opera productions or buildings.

The remaining 20 per cent of the grant will go towards a special project dear to Mr. Fisher, who is a violinist: a fellowship program designed to give impetus to the careers of young American instrumentalists.

Dr. Peter Goldmark, chairman and president of Goldmark Communications and former director of C.B.S. Laboratories, has been presented the Golden Omega award of the Electrical/Electronics Insulation Conference. The award is presented at each E.I.C. conference to an outstanding person in science, engineering, education or industry who has made an important contribution to technological progress. The E.I.C. is jointly sponsored by the National Electrical Manufacturers Assn. and the I.E.E.E.

Goldmark is, of course, well known for his creation of the long-playing phonograph record, which is celebrating its Silver Anniversary this year. (The LP, incidently, grossed more than $2-billion in the United States alone last year.) Goldmark holds some 160 patents and is known for development of the first practical color television system and Electronic Video Recording (EVR). He was also responsible for the development of the high-resolution readout and ground recording system used in the U.S. Lunar Orbiter space program.

Goldmark, who developed the LP because he became annoyed with the constant interruptions of classical music movements with 78 rpm records, still receives courtesy copies of each new LP produced by record companies and thus owns one of the country's most complete record libraries. He describes the years of the invention of the LP and other developments in his autobiography "Maverick Inventor: My Turbulent Years in CBS," published November 1st by the Saturday Review Press at $7.95.

Hans W. Heinsheimer, executive vice president of G. Schirmer, Inc., is celebrating his 50th anniversary in music publishing. Having worked closely with such composers as Gian Carlo Menotti, Samuel Barber, Virgil Thomson, Aaron Copland, Leonard Bernstein, Bela Bartok, and Leos Janacek, Heinsheimer is credited with a significant role in shaping the concert and opera repertoire heard today.

Heinsheimer began his career in 1923, after graduation from the Univ. of Freiberg, with Universal Edition in Vienna—at no salary. In 1925, as director of the firm's opera department, he arranged for the premiere of Alban Berg's *Wozzek* and in 1928 for the premiere of Kurt Weill's *Threepenny Opera.*

Heinsheimer came to the United States in 1938 and, after a nine-year association with Boosey & Hawkes, he joined G. Schirmer, Inc., in 1947 as director of symphonic and operatic repertory. He was named director of publication in 1957, elected vice president in 1971, and attained his present position in April of this year.

New York City Watts

Consumer Protection Law Regulation 36, covering power output disclosures on home audio equipment, went into effect October 17 in New York City, after its original publication in August. While there were a few changes from the originally published version, the amended regulation is unchanged in substance. Disclosure is not mandatory under the regulation, but when it is made must meet the following standards: (a) show watts per channel with all channels driven; (b) at 8 ohms impedance; (c) across a power bandwidth not less than 60 to 10,000 Hz, and (d) with THD less than 1 per cent from 250 milliwatts to rated power. (The original low limit on THD specification was 0 watts.)

We are, of course, glad to see that the regulation is going into effect. It will reduce the consumer's confusion about power ratings and should prove to be no hardship on the industry, as all are placed on equal footing by the regulation. *E.P.*

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Microphones– The Vital Link in the Recording Chain

David Lane Josephson

ARE YOU REALLY satisfied with the quality you're getting in your live recordings? The amateur recordist's main problem seems to be selection and placement of mics for the best sound pickup. While there aren't any hard and fast rules one can follow to get professional sounding tapes, here are a few ideas about mics that should help.

What is a microphone anyway? A microphone is a sound-actuated transducer; a device which accepts sound waves (air vibrations) and changes them to electrical impulses which may be amplified and recorded. The electrical impulses, according to the *accuracy* of the microphone, correspond more or less to the shape of the sound waves striking the microphone. Various factors—mass of the microphone's moving parts, magnetic fields, friction sources, materials used, physical construction—all affect the final accuracy of the microphone. This degree of accuracy—no mic is perfect—determines the way any given mic should be used.

There are two basic variables in the conditions that affect the quality and accuracy of any given sound pick-up: 1) the characteristics of the microphone(s) used, and 2) the position of the microphone(s) in respect to the sound source(s). Understanding the characteristics of the various microphones available is a lot easier if one knows how they all work.

Types of Microphones

In common recording use today, there are three different types of microphones: dynamic (or moving coil), capacitor (or condenser), and velocity (or ribbon). All three types can produce high fidelity recordings in the conditions they are best suited to.

A dynamic microphone is basically a speaker in reverse. The diaphragm, a basic element of any microphone, is attached to a coil of wire. This coil is suspended by the edges of the diaphragm over and around a small permanent magnet. When sound strikes the diaphragm, it makes the coil move back and forth over the magnet, thus inducing an electrical current in the coil.

Capacitor microphones (also known as condenser microphones, after the older name for capacitors) are pressure devices like dynamics, but the means used to generate the output signal are entirely different. The diaphragm in a capacitor microphone is very similar to that of a dynamic, except that it is usually flat instead of convex. It may be either thin metal foil or metallized plastic. The diaphragm is suspended about 1/1000 of an inch from a fixed metal plate, which is insulated from the microphone case. In the conventional capacitor microphone, a polarizing voltage of between 45 and 200 V. is applied between the back plate and the diaphragm. When sound strikes the diaphragm, the spacing between it and the back plate changes, changing the capacity between them. This *change* from one value to another changes the current flowing through the load resistor. Since the air space between the diaphragm and the back plate represents a very high impedance, the amplifier

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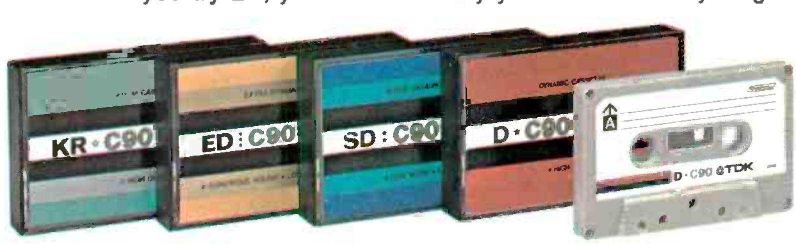

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more about TDK's circle of tape performance

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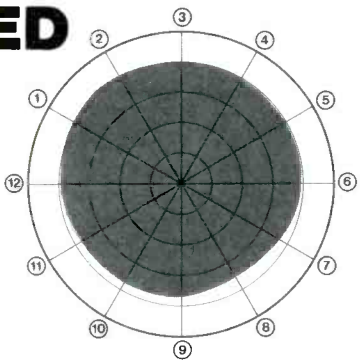
Compare TDK's well-balanced characteristics with those of the two leading so-called "hi-fi" competitive cassettes and a typical conventional tape. Judge for yourself which provides the best characteristics for true high fidelity performance.

ED



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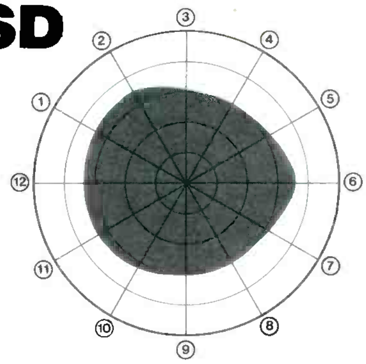

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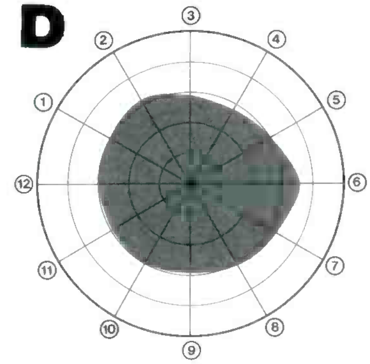
D



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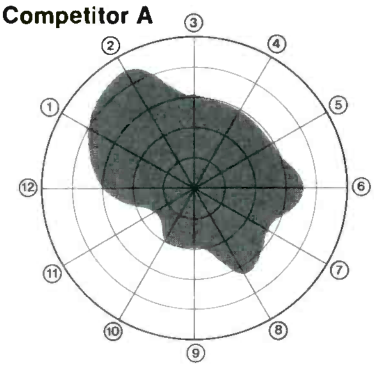
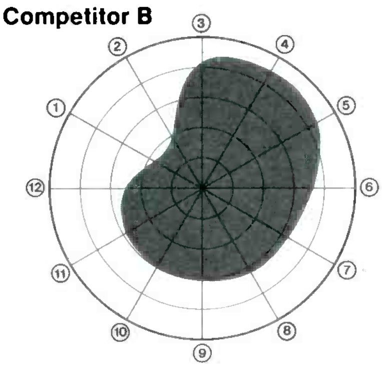
2-Sensitivity @ 333Hz
3-Sensitivity @ 8kHz
4-Sensitivity @ 12.5kHz
5-MOL @ 8kHz
6-Erasability
7-Bias Noise
8-Print-Through
9-Modulation Noise
10-Output Uniformity
11-Uniformity of Sensitivity
12-Bias Range

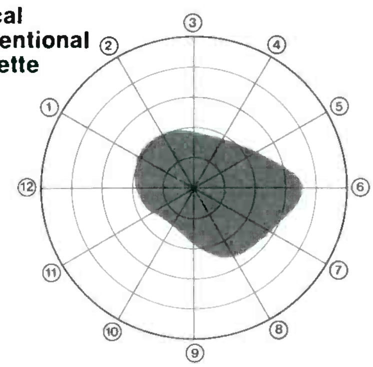
Competitor A



Competitor B



Typical Conventional Cassette



ED'S EXCLUSIVE NEW "STAGNETITE® COATING

TDK EXTRA DYNAMIC is the world's only tape with a magnetic coating of "Stagnetite". The coating consists of microscopically fine particles of stabilized magnetite in a special binder. Magnetite is a material with magnetic properties which make it ideal as a recording medium, except that in its natural state it is not sufficiently stable. TDK discovered a way to permanently stabilize magnetite particles; the result (Stagnetite) is a perfect coating material for magnetic recording tape, contributing to ED's unrivaled "real-life" sound reproduction capabilities.

THE IMPORTANCE OF HIGH MOL

TDK's EXTRA DYNAMIC tape has the highest MOL values of any cassettes on the market today. MOL means maximum output level, and is perhaps the most important single characteristic of a recording tape. MOL is the output signal level resulting from an input signal which produces 5% distortion in the output. A tape with high MOL can be recorded at higher input levels without audible distortion on playback. High MOL lets you faithfully reproduce all the complex transient phenomena, subtle overtones and important harmonics that give the original sound its natural warmth, richness, depth and feeling.

for this type of microphone must be located inside the microphone body—or at least not more than a foot or so away. Because of the extremely high input impedance this amplifier must present to the microphone element, these amplifiers were previously exclusively tube units. Vacuum-tube capacitor microphone amplifiers have now been almost entirely replaced by field-effect-transistors (FETs) which can present as high an impedance as most any tube. These have vastly decreased the size and cost of capacitor microphones today. The one remaining problem is that of getting the polarizing voltage to the capacitor element. This has been solved recently by the use of an *electret* element rather than the usual capacitor unit. In the electret capacitor microphone, the diaphragm is plastic and has a static electricity charge implanted in it during manufacture. The only power supply required then is the 1.5 V. or so to power the FET. Another solution to this polarizing voltage problem in extensive use before the electret was developed for capacitor microphones (the electret principle is not new) was the r.f.-excited or FM capacitor microphone. In this system, still used by some manufacturers, the varying capacitance of the microphone element is connected in the grid or base circuit of an r.f. oscillator. As the sound waves strike the diaphragm, the frequency of the oscillator is varied, producing an FM signal. This is then detected by a conventional discriminator, just like that used in FM receivers, and an audio signal is produced.

Capacitor microphones always have some amplifier circuitry inside the microphone case which must be supplied with power. Numerous techniques have evolved over the years to get this power to the electronics. Perhaps the most simple is to mount a battery directly in the case. With electret mics, all that is required is a single 1½-V. penlight cell. Conventional capacitor mics usually use two 22½-V. "B" batteries in series. Another method is to simply run extra wires in the cable between the mic and the power supply to carry the power. This was common practice for tube powered capacitor mics which required filament voltage and B+ for the tubes as well as polarizing voltage. The two other common methods involve simplexing the power for the mic onto the cable carrying the audio back to the power supply. The widely used system is known as "phantom" powering, where the two audio leads carry the positive side of the power and the cable shield returns the negative to the power supply. The commonly used voltage is 48 V. The other system, still being used by some manufacturers, is the powering voltage applied directly between the two audio leads. One lead carries the positive while the other carries the negative. While this system preserves the balanced conditions necessary for r.f.-powered mics, it can add noise and precludes the use of dynamic or velocity mics on the same mic jack since such mics would present a direct d.c. short across the power supply. This system generally operates on 12 V.

Velocity or ribbon microphones operate on an entirely different principle from the dynamic and capacitor units. The diaphragm is a thin duraluminum ribbon, about a quarter of an inch wide and two to four inches long, suspended between the poles of a strong permanent magnet. When sound strikes the ribbon, it moves back and forth in the lines of flux of the magnet, cutting them and inducing an electrical current in the ribbon. The velocity or speed of the sound waves determines the output rather than the pressure. Because of the extremely low impedance (usually equal to the d.c. resistance of the ribbon, or less than 1 ohm) of the mic, a step-up transformer must be mounted in the microphone case. Velocity mics were the mainstay of almost all commercial recording and broadcast pickups, in spite of their weight and fragility, until high quality dynamics became widely available about ten years ago. One strong cough or puff of wind can tear a velocity mic's ribbon to shreds.

Characteristics and Specifications

The first element in the characteristics or personality of a given microphone is its directional pick-up pattern. This is the relative sensitivity of the unit to sounds arriving at different angles on a horizontal plane the same as the one the microphone is in. Certain types of microphones have certain distinctive directional characteristics, but all can be modified through the use of various phase-cancellation devices.

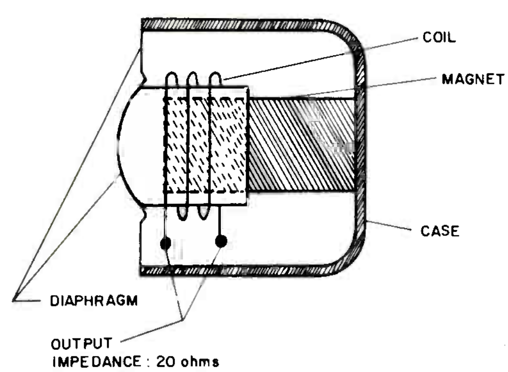


Fig. 1—Dynamic microphone construction.

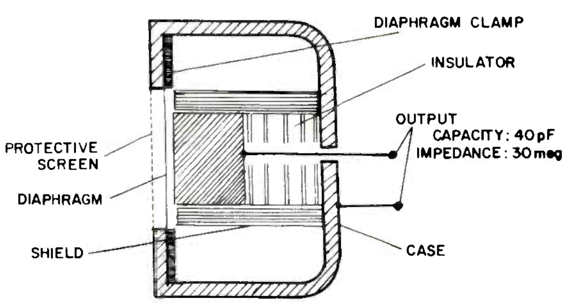


Fig. 2—Capacitor microphone construction.

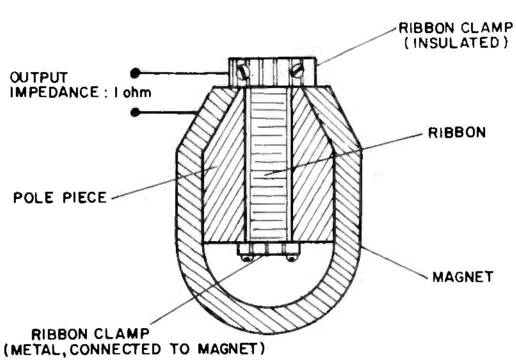


Fig. 3—Velocity microphone construction.

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Pressure microphones are by their nature *omnidirectional*. This means they pick up equally well from all directions. Velocity microphones may be made omnidirectional by attaching an acoustical labyrinth at the back of the ribbon. This changes the velocity microphone to a pressure unit, since the ribbon is now responding to pressure differences and can be pushed only toward the back of the microphone case.

Pressure microphones may be made *unidirectional*, or tending to pick up from the front only, by the addition of tubes and ports from the diaphragm to the rear of the mic case. In a simplified way, this produces a unidirectional effect merely by cancelling the sound waves arriving at the rear. Velocity microphones may be made into unidirectional units by dividing the ribbon into two sections and converting one section to omnidirectional as described above. The remaining half of the ribbon operates as a velocity unit. When a sound wave arrives from the rear of the microphone, it reaches the velocity section at the same time as it reaches the pressure section. Because the velocity section produces a negative voltage (because the ribbon is being pushed toward the front of the case) and the pressure section produces a positive voltage (because any sound striking the pressure unit will produce a positive signal), the two voltages, being equal and opposite, will cancel each other out and the net output will be zero. In capacitor microphones, the unidirectional pattern may be produced by either of the ways described above; there may be two elements, one for the rear and one for the front, or there may be just one element with tubes and ports to the back of the microphone. Because the actual directional pattern of most unidirectional microphones is not truly one-directional but rather heart-shaped, unidirectional mics may also be referred to as *cardioid* mics.

Fig. 4—Microphone pick-up patterns.

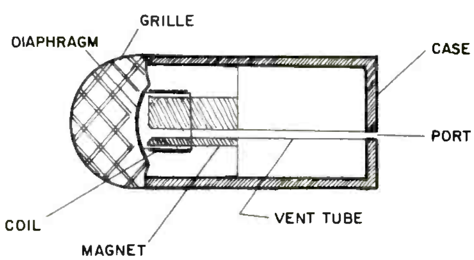

Fig. 5—Typical unidirectional microphone construction. Sound waves arriving from the rear of mic enter the port and reach the diaphragm through the vent tube at the same time the rest of sound wave reaches the front of the diaphragm. Sound from the vent tube pushes the diaphragm out, while sound from the front pushes the diaphragm in, resulting in no net movement.

Fig. 6—A capacitor version of the inline superdirectional mic, the Sennheiser MKH 415, shown on a desk stand.

Even the best unidirectional microphone still has quite a bit of pick-up from the sides. This is sometimes advantageous, but there are times, such as the pick-up of a single person or group from a great distance, when a more selective pick-up is desired. This, too, may be accomplished in a number of ways. The first idea was to place an omnidirectional pressure unit in the focus of a parabolic reflector. This produces a pick-up angle of about 80°, somewhat better than the 180° or so produced by a good unidirectional mic. Perhaps the most practical super-directional microphone, and today the most common, is the *inline* or *interference* mic. This uses a standard omnidirectional pressure mic at the end of a long single tube with slots in it. The principle of operation is that sound arriving from the rear of the mic is going to take longer to reach the diaphragm than sound arriving from the front. Since the sound from the rear is going to go in the front just as much as the sides, all of these sound waves will be reaching the diaphragm at different times, even though originating from the same sound wave. They produce a cancelling effect, and the net output for sounds arriving from the sides and rear will be nearly zero. The angle of pickup for this type of mic is between 40 and 80 degrees, but is free from the resonance effects common to parabolic mics.

The last common microphone pick-up pattern is *bidirectional* or figure-eight. Velocity microphones, by virtue of the physical plane of the ribbon itself, are inherently bidirectional. Most capacitor microphones can be made bidirectional by the use of two separate microphone elements connected out of phase with each other.

All three directional characteristics may be combined in one microphone, sometimes known as a *polydirectional* unit. This may be either a capacitor or velocity mic. In a capacitor mic, two omnidirectional elements are used back-to-back. For an omnidirectional pickup, only one element is switched in. A unidirectional pattern may be had by connecting one element at a different phase from the other, by changing the polarity of one element's polarizing voltage. A bidirectional pick-up is made by connecting the two elements out of phase with each other. Typical polydirectional capacitor microphones are the Neumann U-87 and KM-86 (shown), the PML TC-4V and the AKG C-412. All of these pattern changes require no mechanical alterations to the microphone at all. A velocity mic may be made polydirectional by dividing it into two sections as described in the unidirectional section above. If the acoustical labyrinth for the pressure section of the unidirectional pattern is provided with an adjustable flap over a hole drilled in it, the pressure section may be opened and converted back to a velocity section and its

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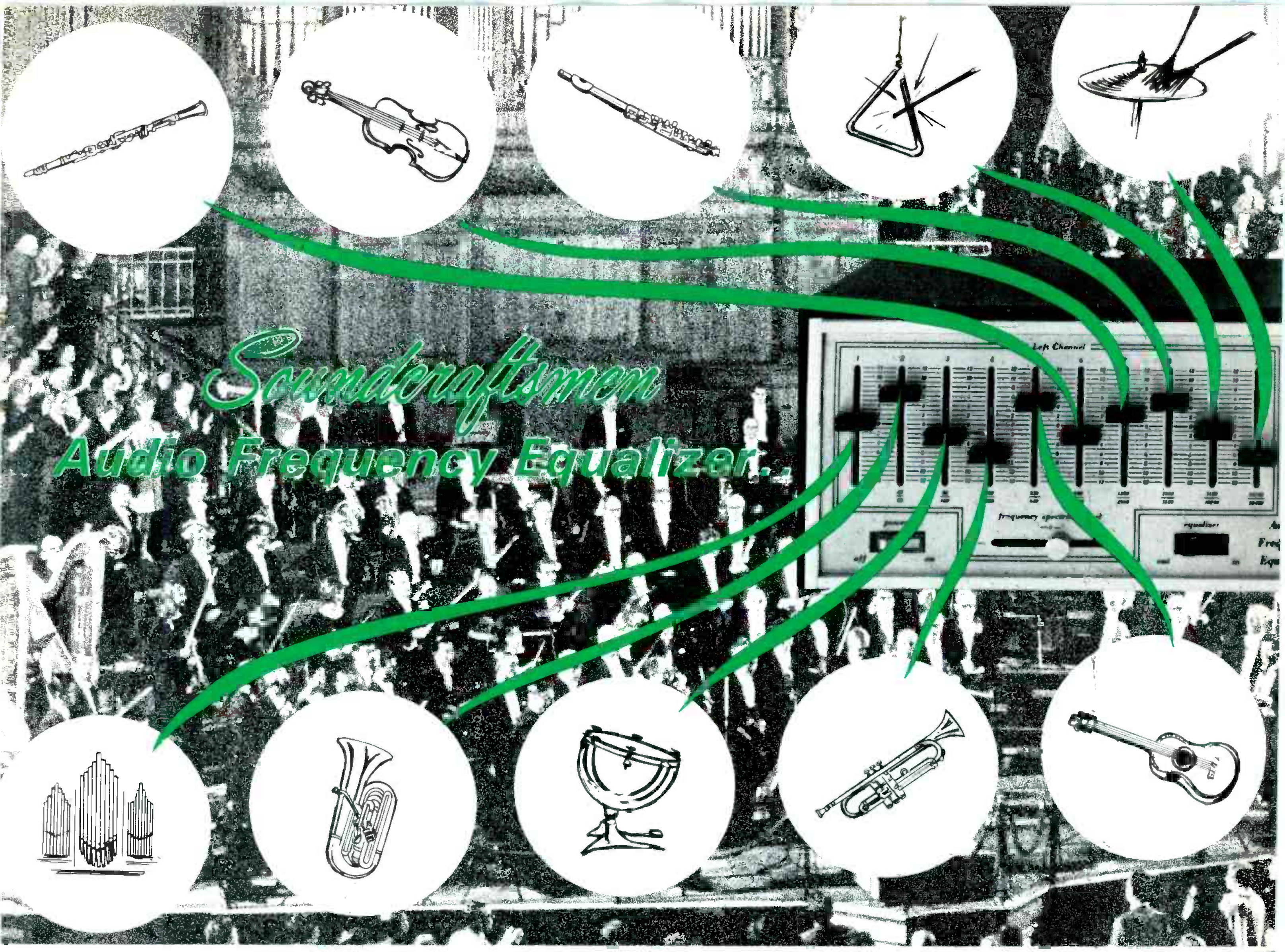

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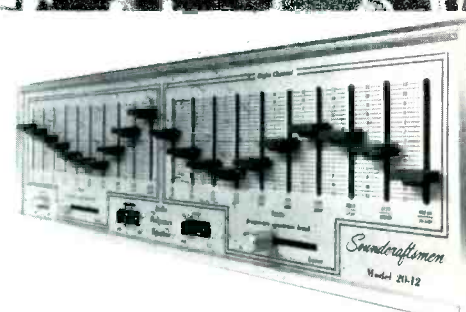

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normal bidirectional pickup. If the flap is closed, the unit becomes unidirectional, and if the velocity section is disconnected, only the pressure section is used and an omnidirectional pattern results.

Microphones are available which produce a full stereo or quadraphonic pickup with one single mic. These units usually contain two or four unidirectional elements in a single case. Typical of the stereo variety are the Neumann SM-69 FET and the AKG C-24. Bang & Olufsen some years ago came out with a stereo mic using two small velocity units in the same case. This was distributed in the U.S. by Dynaco and may still be available on the used market. Neumann has recently announced a *quadraphonic* microphone producing a complete quadraphonic signal with one mic unit. This mic, the QM-69, contains four separate unidirectional capacitor mic elements in a case very similar to the SM-69 FET. The four outputs are available at the power supply.

Fig. 7—A typical poly-directional capacitor mic, the Neumann KM-86. Pick-up pattern may be switched to omni-, bi-, or uni-directional. A 10-dB attenuator switch is provided to prevent overloading distortion in high sound-pressure-level pick-up situations.

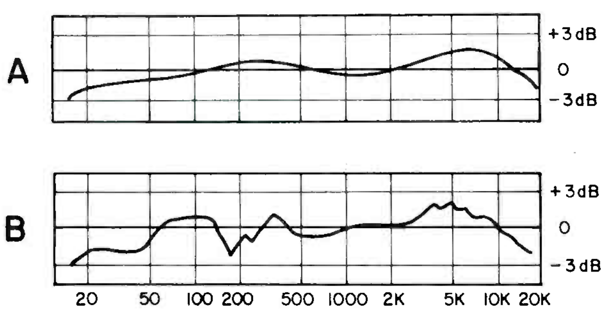

Fig. 8—Comparison between two microphones with the same numerical frequency response specification: 20-18,000 Hz, ±2 dB. Mic A exhibits a very smooth response within those limits, having no sharp resonances or dips. Mic B has a very sharp resonance at 5 kHz and a 2 dB dip at 180 Hz. If used with a PA system, mic B would be much more prone to feedback, which would occur at 5 kHz.

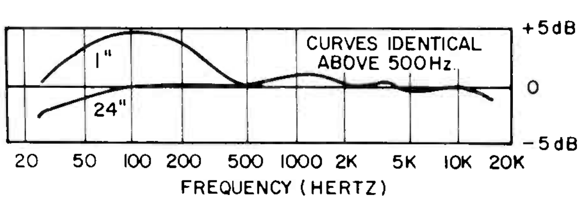

Fig. 9—Frequency response of a typical unidirectional dynamic microphone with sound source at one inch and two feet.

Frequency response is the tonal accuracy of any given audio equipment. In microphones, this means the relative voltage output across a wide band of frequencies for the same sound input with respect to a level at a set mid-band frequency (usually 1,000 Hz). As with all other audio gear, a frequency response rating of, say, 50-15,000 Hz is meaningless unless a specific range of tolerance (i.e. plus or minus so many dB within the range) from the level at the reference frequency is mentioned. Theoretically, one could say that any microphone would have a frequency response of 50-15,000 Hz—but the difference in output between a 15,000 Hz signal and the reference (1,000 Hz) might be as much as 60 dB. The main thing a recordist must be aware of in selecting a microphone from frequency response figures is the *smoothness* of the response between the numerical limits. For instance, two microphones might be rated as having a response of 20-18,000 Hz±2 dB, but one would sound far better than the other. Figure 8 shows why. Some microphone manufacturers have taken to supplying individually run frequency response curves for each microphone shipped. In most cases, however, the average response (a curve of a typical unit, taken off the assembly line) will give a fair indication of the flatness of a given model of mic. Sometimes these curves are included in the spec sheets for new mics.

Proximity effect is the extreme accentuation (boosting) of lower frequencies (below 200 Hz) as the sound source moves closer to the microphone. Sometimes this effect is desired, as it imparts a filling, radio-announcer quality to the voice being miced—but it definitely is not an advantage for accurate pick-up of non-voice signals. Proximity effect is much more pronounced with unidirectional mics—and because of this, many have bass rolloff switches to compensate for this accentuation. Omnidirectional mics are relatively free of this phenomenon until the sound source comes to within three inches of the microphone grille. Velocity mics are extremely sensitive to proximity and begin to show bass accentuation when the sound comes any closer than two feet. Proximity effects in conventional unidirectional mics are primarily caused by sensitivity to extreme pressure differences produced by close low-frequency sources. This problem has been suppressed to some extent by using a series of tubes and ports, one for each band of frequencies, or one large tube from the rear of the diaphragm with a continuous series of slots producing a theoretically resonance-free tube and port system. Electro-Voice calls these methods Variable-D and Continuously Variable D®, respectively.

Perhaps the most misunderstood microphone characteristic is *distortion*. Partly because there are no accepted standards for measuring all types of distortion to be found in pickup units such as microphones, this aspect of a microphone's specifications usually goes unwritten. The most common form of microphone distortion is poor transient response. Transient response time is the time taken for a microphone's output to rise to 90 per cent of its peak value when a pulse of d.c. is applied to it as sound. Most capacitor mics take around 15 microseconds—dynamic mics usually take around 40 μsec. Velocity mics are somewhere in between the two. This may help explain the characteristic "clean capacitor sound" most capacitor mics have.

Some capacitor mics are rated with a percentage distortion figure for a given sound pressure level (SPL). This is the distortion of the mic *amplifier only* when fed with a signal that approximates the level of a signal put out by the element at that SPL.

The construction and circuitry of any microphone determine how *noisy* it is. Noise may be of any number of kinds—wind noise, breath pops and hisses (sibilance), handling noise or electronic noise. In dealing with various external noise sources, it is well to remember that any movement of the diaphragm in a microphone is caused by one condition: an instantaneous difference in the pressure between the front and back of the diaphragm. When both sides of the diaphragm have equal pressure on them, the diaphragm cannot move. Wind and breath noises are caused by direct air pressure changes between the front and the back. Both may be reduced to a great extent with *windscreens*, structures of plastic foam or rigid frameworks covered with cloth. These windscreens simply resist rapid changes in air pressure by requiring that the air slow down before reaching the mic itself. Some mics are inherently less wind and pop sensitive than others due to the inclusion of windscreens in the microphone itself or the particular mic's design. Omnidirectional mics tend to be less sensitive to wind and pop noises--primarily because the sealed air space behind the diaphragm acts to oppose any violent changes in air pressure. Unidirectional mics are more sensitive to noise of this sort, since the only opposition to diaphragm movement are the ducts and ports leading to the rear of the microphone. Handling noises are basically a function of the internal design of the microphone. If the microphone element is mounted directly to the case, with no shock mounting, vibrations and noises originating on the case will be much more easily transmitted to the diaphragm than if it were isolated from the case. Electro-Voice, among others, has developed a mic-within-a-mic design, covering an ordinary mic (usually an omnidirectional dynamic) with foam rubber and installing it in another case. This seems to be very effective in reducing case and handling noises.

Sibilance is a hard hissing noise, often with distortion and quite annoying harmonics, that appears in the output when some microphones are spoken into with "S" or "Z" sounds. Some people have extremely sibilant voices, which will produce this type of distortion with any type of mic—while others will not sound sibilant at all. Most sibilance problems can be eliminated by installing a windscreen and/or speaking across the microphone rather than into it.

Electronic noise is almost entirely limited to capacitor microphones and is caused by noise in the capacitor microphone element, or, more commonly, in the very high impedance and low level amplifier circuitry.

Impedance is the ohmic value of load which, when placed across a microphone output, will result in the most efficient transfer of power from the microphone to the load. Common figures for microphone impedance are 50, 150-200-250, and "high" (around 50,000) ohms. Most older home tape machines using vacuum tubes are meant for high impedance mics, and most current solid-state gear should be used with low impedance mics. The main operational difference between low and high impedance mics is in the length of cable that may be used. Up to two or three thousand feet of cable may be used with low impedance mics, but if high impedance mics are used, the high frequency response (above about 5 kHz) drops off drastically as the cable is made longer than 20 feet. This is because the cable acts as a shunt capacitor across the microphone. High impedance cables also pick up considerably more hum and noise than do low impedance ones.

Low impedance mics are usually supplied in a "balanced" configuration. Technically, this means that each side of the output (three wires are used, two signal and one ground) has an equal impedance to ground as the other lead. For instance, the impedance from one lead of a 200-ohm balanced mic to ground would be 100 ohms. The impedance from one lead to the other would be 200 ohms. The advantage to going to all this "balance" trouble is that one signal conductor, being the equal and opposite of the other, will be 180° reversed in phase. When an extraneous signal is picked up by the cable, the common mode rejection that occurs in the amplifier cancels the noise out. Most, if not all, professional recording and broadcast installations used 150-250 ohm balanced mics exclusively. When the microphone matches the equipment in impedance, then there is no mismatch. A low impedance microphone may be used with high impedance equipment at a sacrifice in signal level, but a high impedance mic should never be used with low impedance gear, or overloading, distortion and level loss will result.

It has been this writer's experience that in microphones, if in nothing else in audio, the old adage of "you get what you pay for" applies almost universally. The market in this country is crammed with just about every conceivable type, style, color, and brand name of microphone possible. There are a few units which appear to be worth much more than their price and a few that are definitely overpriced.

Used microphones can present the best value, as mics which have been used by professionals can sometimes be bought at less than half their original selling price. Microphones that come with tape recorders are too often poor quality, and, in fact, most home decks and all professional studio machines now come without mics.

Part two of this article will deal with how these microphones can best be positioned and mounted for accurate and pleasing stereo recording.

(To be continued)

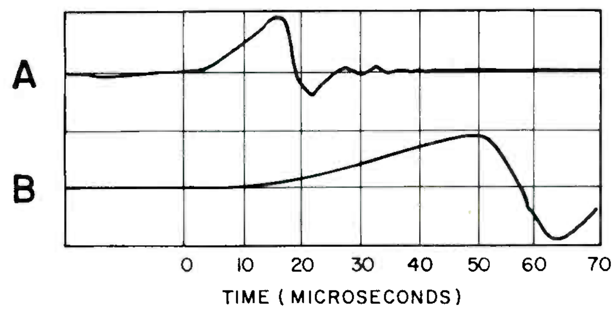

Fig. 10—Comparison of transient response time between two microphones. Mic A is a good quality capacitor mic, while mic B is a good quality dynamic. Note that A takes about 15 μS to reach 90 per cent of its peak output, while B takes 40 μS to reach 90 per cent, with both having the same d.c. pulse input.

Fig. 11—Rigid frame and cloth windscreen on a Sennheiser MD-211 omnidirectional dynamic mic.

Recording in 2 and 4 Channels

Jim Gordon

EXPLANATIONS OF STEREO recording are frequent, but there seems to be little about practical microphone use. Here are some suggestions:

For basic two-channel stereo, our ears want to hear some left information, some right information, and some information common to both channels. Suppose we record two acoustic guitars playing together, each on its own separate track, basically two mono signals. Playback of two mono signals sounds OK on speakers, because some of the sound from each speaker reaches the opposite ear. But listening to the two mono signals with earphones is uncomfortable and sounds unnatural. Now suppose we record a third guitar, playing in sync with the first two, on its own separate track. Then we play it back in the center, that is to both left and right speakers, along with the first two guitar tracks. Adding this center mono signal common to both sides satisfies our ear's desire for sound common to both channels. It sounds good on both speakers and earphones.

Some might say that this isn't "real stereo," only three mixed mono sources. I'd like to answer this by saying that different styles of micing are only different tools. You wouldn't use a screwdriver to pound a nail or a hammer to turn a screw. Whatever type of micing that sounds best to you is right; there are no hard and fast rules.

Two Channels

Suppose you're recording two sound sources, a singer and a piano. You might place a microphone close to each, making basically two mono recordings. Or you could put the mics closer to each other, so that upon playback, each ear hears some sound common to both. Our ears want some of that, remember. Recording this way would have less stereo separation, but might be aesthetically more pleasing. More toward "real stereo." But in the first case on the piano, you could use a mic best for recording the piano. And the same with the singer. The closer you get to "real stereo," the more two matched microphones of the same kind are necessary.

The simplest way to record stereo is to set two cardiod mics in front of the sound source, just as you would sit in front of two stereo speakers. This is a good way to record where the principal sounds or performers tend to arrange themselves in a straight line, as on a stage or bandstand.

Try this: (Fig. 1) Draw line LR between the extreme right and left *front* sound sources (not the edges of the stage). Make an equilateral triangle so that LR = LM = RM. Bisect LM and RM, and at those spots put two cardiod mics facing straight forward. Don't angle them. You'll get a recording that has good stereo effect, no hole-in-the-middle, *and reproduces the original balance.* It's important to measure the set-up carefully; if you just estimate the dimensions it won't work very well. Hang the mics from the ceiling if you like. Use the same formula and do your measuring on the floor. Aim the mics straight ahead and angle them down toward a point mid-way between the front and back of the stage.

Sometimes it's desirable to put both mics on one stand. Atlas makes a TM-1 "twin-microphone mount" that supports two mics on one stand. For most situations use two cardiods at a 90° angle to each other (Fig. 2).

To record a stage performance (Fig. 3), draw line LR between the extreme right and left sound sources. Bisect LR, at M. Draw perpendicular line MX equal to ½ LR. Put your mics at X.

If the sound source is within a foot or two of the microphones, you may get a hole-in-the-middle, so angle the microphones in a bit. If you can monitor with earphones, snap your fingers or jingle car keys back and forth while you're "angling" to eliminate the hole-in-the-middle. If the sound source is a very large distance away, you may want to angle the microphones outward, although at large distances both mics tend to receive the same sound. Monitoring with earphones again helps.

Four Channels

One simple way to record four-channel sound (on a two-channel recorder) is to use a stereo mic made of two bi-directional sections, such as a Bang & Olufsen BM-5. This mic consists of two bi-directional ribbon elements. If you

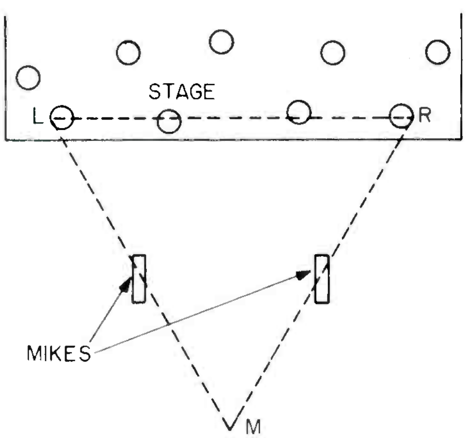

Fig. 1—Recording a stage performance with two cardioids.

Fig. 2—Two E-V RE-16s in Atlas TM-1 mount.

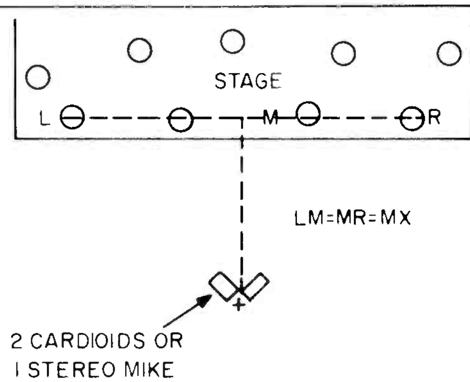

Fig. 3—Recording a stage performance with two cardioids or one stereo mic.

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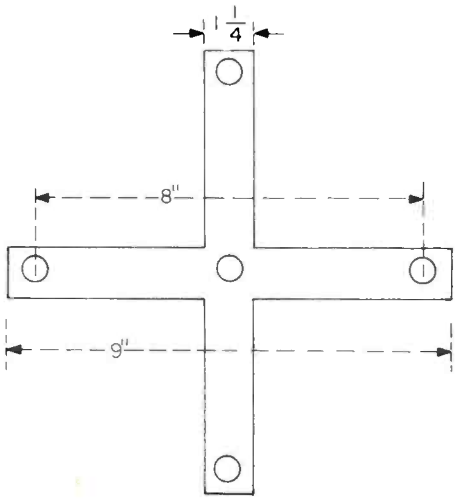

Fig. 4—Four-channel mic fixture.

Fig. 5—Four Sony ECM-21s on four-channel mic fixture.

set the two sections 90° apart, sounds from in front and back of the mic will be in phase, while sounds from the sides will be out-of-phase, producing matrixed four-channel recording. Ideally, it should be played back thru a Dynaco-type decoder, but other types will work well too.

To record a stage performance, place the microphone as shown in Fig. 3. Set it to 90°. Aim the 45° mark on the mic toward the stage. What if your sound sources have no "front line," like a string quartet? Place the mic in the middle, 6 to 8 feet in the air if possible.

If you have a four-channel recorder, you can use four mics close to the sound sources. This is basically four mono signals. The "real stereo" equivalent may be more desirable. You'll need a fixture to mount four mics together. Figures 4 and 5 show one made of ⅛-in. aluminum. A local machine shop made this one for me. The holes have ⅝"-27 threads. The upright pieces are Atlas AD-7 3-in. tubes. Use four cardiods at 90° angles to each other. To record a stage performance, use the set-up shown in Fig. 3.

Additional Notes

It goes without saying that your microphones should be in phase. They should be the same make and model, unless you're just recording simultaneous mono sounds. It's a good idea to balance your levels on the recorder before recording. A cheap portable FM radio can be a handy tool here; tune the radio in between stations to get the white-noise "rushing" sound. Set the radio volume to a level comparable to what is to be recorded, if possible. Put the radio midway between the mics, so that they both receive an equal amount of sound. Set the mic level controls on the recorder so that the VU meters read the same. Æ

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Fundamentals of Loudspeaker Design

Michael Lampton and Lee M. Chase

THE LOUDSPEAKER is, to many people, the most mysterious part of the modern sound reproducing system. Each year, a few manufacturers introduce "totally new" loudspeaker systems and claim extraordinary performance achievements; often, they boast of applying new principles unknown to their competitors. In fact, the fifty-year-old electrodynamic loudspeaker is capable of excellent performance, but a speaker system (the loudspeaker and its enclosure) does have limitations. One purpose of this article is to remove the mystery of loudspeaker design and show just what the design limitations are. Another purpose of the article is to dispel a number of untruths which have grown up in this field: that a bigger woofer is always better; that a sealed enclosure always outperforms a vented enclosure (it is, in fact, a special case of the vented design); that a bass-reflex should always be tuned to the free-air resonance of the loudspeaker. A third purpose of this article is to provide the reader with some definite, quantitative engineering data in the form of graphs, which can be applied to existing or planned loudspeaker systems as a guide to their improvement.

II. The Theory of Loudspeaker Performance

In this section, we'll take a look into the theory of "direct radiator" (hornless) electrodynamic loudspeakers. A more complete treatment is given in the Appendix and in the references.

The theory of the frequency response of a loudspeaker can be boiled down to one simple formula:

'em 'radResponse =

$$\text{Response} = \frac{r_{em}\, r_{rad}}{|r_{em} + Z|^2}$$

In this formula, r_{em} represents the electromagnetic driving power of the magnet and voice coil; this factor is constant with respect to frequency. The quantity r_{rad} is the so-called "radiation resistance" which describes the useful acoustic load on the cone's motion; it increases as the square of the frequency until the frequency reaches the speed of sound divided by the cone's diameter. At higher frequencies r_{rad} becomes approximately constant. Finally, z represents the total mechanical impedance of the speaker's moving parts. The important thing to remember about z is that, throughout the speaker's frequency midrange, z is proportional to the frequency. So, its square is proportional to the square of the frequency, and the response throughout the midrange is flat! This happy cancellation of the f^2 factors, then, requires two conditions:

(1) r_{rad} must vary as f^2. As we have seen, this condition is met at low and medium frequencies; it fails at high frequencies.

(2) z must vary as f. This is termed "inertia controlled" motion (see ref. 1) and is a good approximation at the middle and high frequencies. It fails at low frequencies.

Due to these requirements, a loudspeaker has two limitations to its response: at the high end, requirement #1 fails; at the low end, requirement #2 is not satisfied.

The high frequency limitation occurs as a result of the short wavelengths of high frequency sounds. The wavelength corresponding to a frequency f is given by $\lambda = c/f$ where c is the speed of sound, 343 meter/sec or 1130 feet/sec. A 1000 Hz tone thus has a wavelength of about one foot. At frequencies high enough that the wavelength is smaller than the loudspeaker's cone, sound is not radiated in all directions (as it is at lower frequencies) but becomes strongly beamed in the forward direction. Furthermore, the total amount of sound generated starts to diminish at increasing frequencies, owing to the radiation resistance losing the battle against the steadily increasing inertial impedance. (Olson [ref. 4] describes some ingenious ways around this problem in his discussion of wide range loudspeakers.) Since these problems set in at above about 1000 Hz for 12-in. speakers, tweeters are usually employed which are designed to cross over in the neighborhood of 1 kHz. Tweeters are designed according to the same rules which govern woofers; the dimensions, of course, come out much smaller owing to the higher operating frequency.

The low-frequency limitation on loudspeaker performance is not due to a wavelength effect. It is due instead to the forces acting on the loudspeaker's cone which are not inertial. These include things like the speaker's suspension stiffness, the electro-dynamic driving forces, and above all the pressure of the air in the speaker's enclosure. Each of these quantities can, to some extent, be minimized, and in designs where extreme low frequency response is required, it is essential to minimize all of them. There are, unfortunately, practical limits to these force-reducing measures. For example, very high compliance loudspeakers have very flabby suspensions which are prone to causing distortion and bumpy response resonances; weak electrodynamic drive will cause low overall efficiency and hence distortion and voice coil heating problems; and to achieve low enclosure air-compression forces requires the use of very large enclosures. As a result, the design of loudspeaker systems is a process of making compromises between three basic quantities:

(a) the volume of the enclosure, V.
(b) the efficiency of the system, E.
(c) the low frequency cutoff, f_c.

It has been shown (ref. 9) that any sort of enclosed loudspeaker system (air suspension, bass reflex, folded horn, or what-have-you) can be assigned a figure of merit, which represents the capabilities of that type of system with regard to this three-way compromise. The figure of merit is simply:

$$\text{figure of merit} = \frac{E}{f_c^3 V}$$

where E is the loudspeaker's midrange efficiency. The useful feature of this figure of merit is that its value doesn't depend upon how small or large or efficient a system of a given type is; it depends only on the type and on certain details of its tuning. With E measured in percent, f_c in Hertz, and V in cubic feet, the values of the figure of merit for some popular loudspeaker types are given in Table I.

TABLE I
Figures of Merit for Loudspeaker Systems

Type	Figure of Merit, %/Hz^{3}ft^3
Air suspension, air filled	4×10^{-6}
Air suspension, glass wool filled	5.6×10^{-6}
Bass Reflex, air filled	10×10^{-6}
Bass Reflex, glass wool filled	14×10^{-6}
Exponential Horn, air filled	$14 \times 10^{-8} \times E$

From the table, we note that an exponential folded horn can show as good a figure of merit as a reflex design, if its efficiency is kept high enough (70% or more). Horns have an additional advantage with respect to low distortion; however, they are much more difficult to construct than the other systems listed in the table. In the event that a high figure of merit is not needed, an air suspension system is a practical alternative; such systems are very easy to build since no tuning is required. In the remainder of the article, we'll concentrate on the design of bass-reflex systems.

In Fig. 1, we show the range of possible compromises between the three basic design quantities listed above. Here, we have assumed a figure of merit of 10×10^{-6} which represents the performance of which a properly tuned bass-reflex system is capable. An additional 40% improvement is possible, which can be obtained by filling the enclosure with loosely packed glass wool; this has the effect of making the enclosed air more compressible and is equivalent to a 40% increase in effective volume (for details, see section V on tuning).

We now have some idea of what the capabilities of loudspeakers are. At this point, we shall turn to the problem of creating a design which satisfies a set of given requirements.

III. Measurements for Design

The first step in a design procedure is to understand and measure the quantities like electrodynamic drag and suspension stiffness which are sprinkled so liberally throughout the previous section and the Appendix. Many of these quantities are strictly under the control of the speaker manufacturer's magnet builder and cone maker; nonetheless we shall have to know their values if we are to do a good job in making the system perform well. Some manufacturers respond promptly to requests for complete data; others do not. We'll outline here how to go about measuring everything needed to evaluate a loudspeaker.

Stiffness. All that is needed to find the stiffness of a speaker suspension is a known weight and a ruler. Lay a straightedge across the front of the speaker mounting plane, and gently prop a ruler against the straightedge with the bottom of the ruler resting on the cone. Avoid any contact with the center dome of the speaker as this part is very fragile; the strong part of the cone is where the front of the voice coil is glued to the cone. Use a nonmagnetic ruler, since there is a powerful magnetic field in the vicinity of the voice coil. Read the ruler where it touches the straightedge, and then read again with a (nonmagnetic) weight resting on the cone. The stiffness, s_i, is just the ratio of the applied force (in newtons; one newton is 102 grams) to the difference of the ruler readings (in meters). Compliance is $1/s_i$, and low compliance speakers have stiffnesses of 2000 to 3000 newtons per meter. High compliance speakers show stiffnesses of about 1000 newtons per meter.

BL Product. This quantity is a measure of the power of the electrodynamic motor which operates the loudspeaker. B represents the strength of the magnetic field in the gap, and L the length of the wire in the voice coil. B and L need not be separately measured. A much easier measurement, which gives the BL product, requires only a battery and a milliameter. The test is carried out as described above: Read the ruler with zero current and read again with a known current on the order of 0.1 amp flowing in the voice coil. The BL product is then BL = force/current = (cone displacement) $\times s_i/I$ where the current I is expressed in amperes. Small speakers typically have BL products in the range of 5 to 10 newtons per amp; large high efficiency woofers usually lie in the range of 15 to 20 newtons per amp.

Free-Air Resonance. This quantity is best measured with an audio oscillator and an a.c. voltmeter. Connect the oscillator to the voice coil and measure the voltage there with the speaker sitting face up on a table or chair. As the frequency is varied, you'll notice a large peak in the voltage and cone motion at the free-air resonant frequency. Also note the width in frequency of this peak, which is a measure of the open-circuit Q factor, Q_0: $Q_0 = f_i/\Delta f$, where f_i is the resonant frequency and Δf is the width of the resonance peak, measured at the 3 decibel down points. The quantity Q_0 is a measure of the suspension friction, r_i, since $r_i = s_i/(2\pi Q_0 f_i)$. The suspension friction usually lies in the range of 1 to 3 newton seconds/meter. The free-air resonant frequency is used to find the effective mass of the cone and its air load, from the formula $m_i = 0.0254\ s_i/f_i^2$ kilograms. Typical values of f_i are 20 and 30 Hz for large woofers and 40 to 60 Hz for smaller wide-range speakers. Masses are typically 0.04 to 0.06 kilograms for large woofers and 0.01 to 0.02 kilograms for the smaller speakers.

Area. The piston area, A_i, is the area of a circle which extends as far as the midpoint of the suspension annulus. For the usual type of cloth roll suspensions, the area of a 15-in. frame diameter speaker will be about 0.085 square meters; 12-in., 0.050; 10-in., 0.032; and 8-in., 0.018. Very high compliance speakers may have somewhat smaller effective areas for their frame sizes, due to the greater area taken up by the suspension surround.

D.C. Resistance. Anyone equipped with an ohmmeter can measure the d.c. resistance of a voice coil. In systems where a crossover network is to be used, the d.c. resistance of this network must be included in R. The output resistance of a modern feedback power amplifier is usually negligible. Most loudspeakers of recent manufacture have voice coil resistances

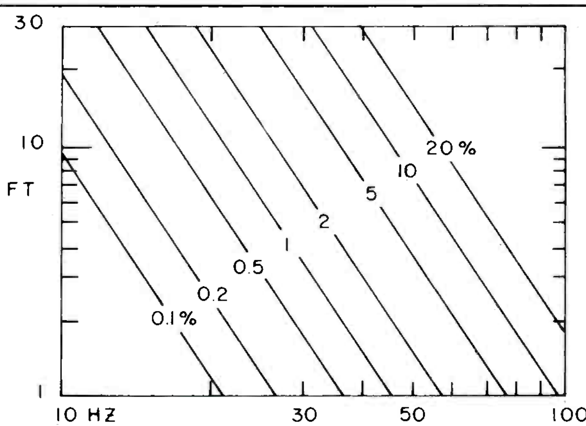

Fig. 1—An illustration of the relationship between the low frequency cutoff (Hz), enclosure volume (cubic feet), and system efficiency (%), when the figure of merit is equal to 10^{-5} %/ft^{3}HZ^3.

of about 6 ohms; they are called 8-ohm speakers because of the extra impedance encountered in the crossover network and the excess impedance appearing in the form of inductance at the higher audio frequencies. With the measurement in hand, several important quantities can be calculated. First, the electrodynamic drag, r_{em}, is the mechanical resistance offered by the piston when the voice coil is short circuited (or connected to a low impedance amplifier output). This quantity shows up in the equations for the response and the efficiency. It is calculated from the formula $r_{em}=(BL)^2/R$. Small speakers usually have values of r_{em} in the range of 5 to 10 newton seconds per meter, while larger ones give 20 to 30 ns/m. The efficiency of the loudspeaker is then Efficiency = $0.0556\ r_{em}A_1^2/m_1^2$ percent. The short circuit Q factor of the loudspeaker is obtained from the formula $Q=\sqrt{s_1}\sqrt{m_1}/(r_{em}+r_1)$. It is this quantity which has an extremely important effect on the choice of the optimum enclosure for a given speaker. It is a ratio of the reactances of the speaker's cone to the damping forces and so dictates the best tuning of the final design. Typical values of Q lie in the range of 0.2 to 0.5—not a large range, all considered, but as we shall see, Q is a rather critical quantity for systems in which flat response is needed.

The measurements and calculated quantities summarized above are the data needed to characterize a given loudspeaker. For purposes of comparison, we have tried to give the ranges of values found for popular speaker types. In section IV we shall discuss the enclosure and speaker requirements needed to create a system having given properties. Before doing this, however, we'll look into the properties of the enclosure itself.

Enclosure Air Stiffness. When a chamber containing air is compressed, it exerts pressure greater than its static barometric pressure on the piston doing the compressing. If the area of the piston is A_1, the force per unit displacement is $s_2 = 142{,}000\ A_1^2/V$ where V is the volume of the chamber in cubic meters (a cubic meter is 35.3 cubic feet). The constant in this formula is the product of the sea-level air pressure, 102,000 newton/square meter, and the adiabatic factor for air, 1.4. In small enclosures, this air stiffness easily dominates the stiffness of the speaker suspension. Since this stiffness is an important limitation in achieving a low system-cutoff frequency, it is desirable to find ways to minimize this quantity. It is clear from the formula that a small speaker will have a great advantage in this regard, especially is the enclosure must be small. Another technique for diminishing s_2 is to pack the entire interior of the enclosure with fiberglass wool, which adds thermal inertia to the compressible air inside and reduces the adiabatic factor to close to 1.00. The resulting stiffness is then approximately $102{,}000\ A_1^2/V$.

Vent Air Mass. This mass, which we shall abbreviate as m_2, is essentially the mass density of air times the volume of the duct. Two corrections to this identification are necessary, however: first, it is necessary to take into account the fact that the piston velocity and vent air velocity occur with differing flow cross-sectional areas which requires a factor of $(A_1/A_2)^2$; the other correction takes into account end effects. The correct formula for the effective mass of the air in the vent is $m_2 = 1.2\ A_1^2\ (L + \sqrt{A_2})/A_2$ kilograms, where L is the length of the duct in meters and A_2 is its cross sectional area in square meters. This formula can be inverted to give the duct length if the desired mass and area is known: $L = 0.83 m_2 A_2/A_1^2 - \sqrt{A_2}$ meters. If this comes out negative, use a larger duct cross section. If it comes out approximately zero, you don't need a duct behind the vent; just cut a hole of area A_2.

Strictly speaking, careful design should also take into account the effects of resistance in the vent. This resistance arises from the acoustic radiation of the vent, and also from the viscous frictional force acting on air passing through a hole. As was pointed out by Novak (reference 5), these forces are substantially smaller than the other losses in the system and can be ignored. We recommend that all damping material used in the enclosure be kept away from the vent to keep this approximation valid.

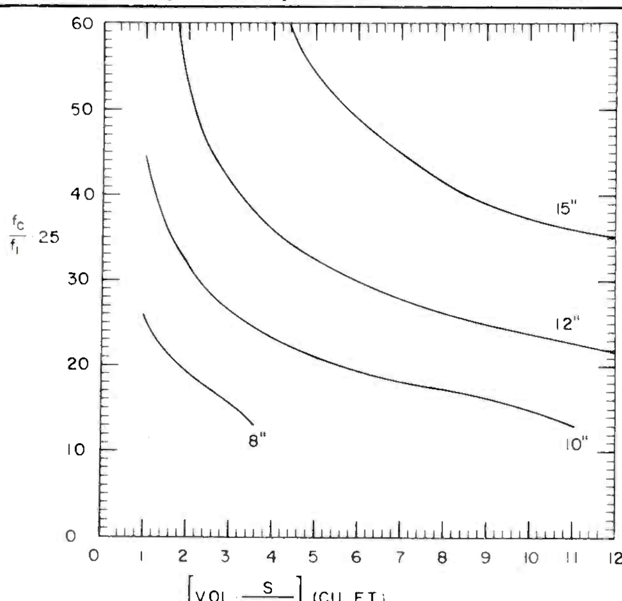

Fig. 2—These curves are used to determine the properties of a speaker that will meet the desired low frequency cutoff and enclosure volume requirements as shown in the design illustrations.

IV. Choosing a Loudspeaker

In this section, we shall present a straightforward method for designing a speaker system which meets requirements specified by the user. The designer will have to start by determining his specifications in the following three areas:

(a) the allowed enclosure volume, V;
(b) the required efficiency, E, and
(c) the low frequency cutoff, f_c.

Cost is usually also an important limitation but it cannot be handled very well theoretically. Distortion is another quantity in this class; generally, distortion is minimized by choosing the largest diameter woofer compatible with the other design objectives.

The designer cannot independently specify all three of the parameters listed above. Specifying any two of them fixes the third, as we have seen in section II. Figure 1 provides a handy guide for reaching a satisfactory compromise with regard to these quantities. Figures 2 and 3 illustrate the detailed relationship between these quantities, in terms of the properties of the woofers capable of satisfying the design goals. By means of Figs. 4,5, and 6, we shall give three design illustrations which show how a satisfactory woofer is chosen. Finally, in Figs. 7, 8, and 9, we'll show how the enclosure should be tuned to provide the performance needed.

System Performance. Figure 2 illustrates how the low frequency 3 dB cutoff, f_c, is affected by enclosure size. To use this curve, you must know the suspension stiffness, s_1, and the free-air resonant frequency, f_1, of the speaker. If, for example, the stiffness is 1000 newton/meter, then the horizontal scale reads the enclosure volume directly in cubic feet. If the free air resonance is 25 Hz, then the vertical scale reads the cutoff frequency directly in Hertz. Suppose, however, that you have a 12-in. speaker with $s_1=2400$ n/m and f_1 = 50 Hz. In addition, suppose you wish to investigate

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the use of a 4-cu. ft. enclosure. Then, the cutoff frequency is found as follows: the horizontal scale point is

$$\text{Vol.} \times s_1/1000 = 4 \times 2400/1000 = 9.6$$

From the graph for 12-in. speakers, we read off

$$f_c \times 25/f_1 = 24$$

Since $f_1 = 50$, we have $f_c = 48$ Hz. Thus, the proposed system can be expected to provide smooth response down to 48 Hz. The efficiency of the system can be determined from Fig. 1 or Fig. 3. In Fig. 3, the abscissa is again 9.6; on the 12-in. speaker curve we obtain

$$E \times (s_1/1000) \times (25/f_1)^3 = 1.45,$$

so that $E = 4.8\%$.

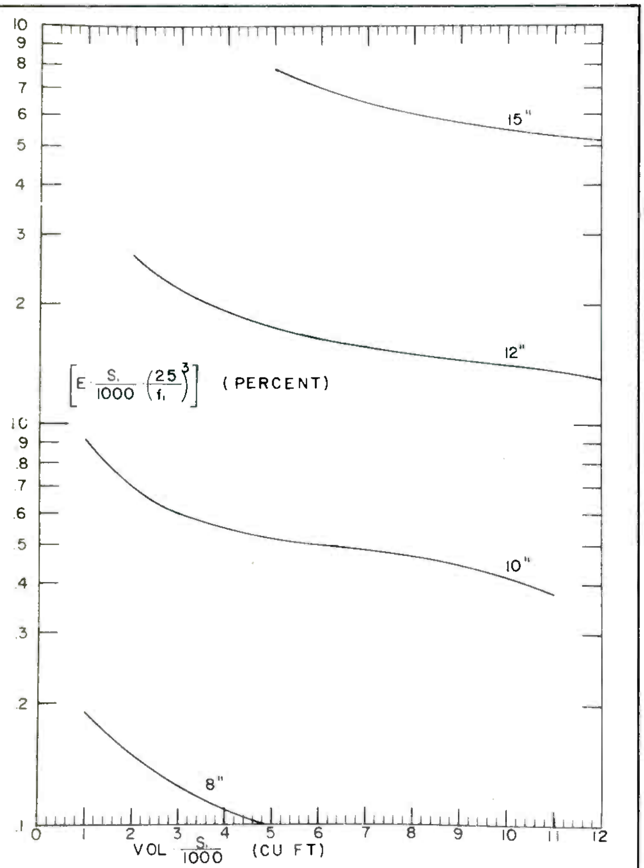


Fig. 3—These curves are used to determine speaker properties required to meet a given efficiency specification.

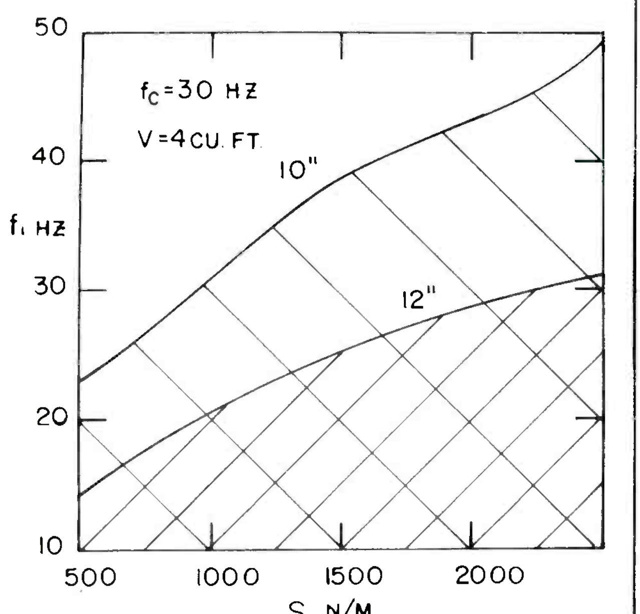


Fig. 4—The range of speaker free-air resonances and suspension stiffnesses that will meet or exceed the requirements set forth in design illustration 1.

In this illustration we specified only one of the three design parameters (the enclosure volume) since the properties of the speaker were given. Ideally, however, we would like to use the curves to find out what speaker(s) will meet the system specifications. Furthermore, from a practical point of view we should like to have the speaker requirements come out such that the system can be built with speakers now available. We shall adopt the rule of thumb that suspension stiffnesses between 800 and 2500 newtons/meter and free air resonant frequencies between 20 and 60 Hz are reasonable, and that speakers with values outside this range will be difficult to find.

Design Illustration #1: Deep Bass, Moderate Size. In this illustration we shall specify that:

$$f_c = 30 \text{ Hz or less,}$$
$$V = 4 \text{ cu. ft.}$$

There are a large number of combinations of suspension stiffness and free-air resonance that will permit us to meet or exceed the requirements. First consider speakers with $s_1 = 1000$ n/m; for these, the abscissa of Fig. 2 will be 4 cu. ft. From, say, the 10-in. curve, we find that 10-in. speakers with

$$(f_c/f_1) \times 25 = 23$$

will meet our requirements if $f_1 = 33$ Hz. If f_1 is less than 33 Hz we shall be able to exceed the required specifications. Similarly a 12-in. speaker with $s_1 = 1000$ n/m will enable us to exceed the requirements if f_1 is less than 21 Hz. (The efficiencies in these cases will be less than or equal to 1.1%.) Now consider speakers with $s_1 = 2000$ n/m; the abscissa is now 8 cu. ft., and from the curves in Fig. 2 we learn that a 10-in. speaker with f_1 below 43 Hz or a 12-in. speaker with f_1 below 29 Hz will suffice. By continuing this process for various other values of s_1, we can plot the acceptable combinations of s_1 and f_1 which allow the requirements to be met. Figure 4 shows the plot for this design example. Any 10-in. speaker whose specifications fall within the shaded region will permit the system requirements to be met. Similarly, any 12-in. speaker which falls in the cross-hatched region will also meet the requirements.

By constructing such a graph, we can tell from a glance at the manufacturer's data (or our own measured data) whether or not a speaker will be satisfactory in a given application.

Design Illustration #2: High Efficiency, Moderate Bass. Let us specify for this illustration

$$f_c = 40 \text{ Hz or less,}$$
$$E = 5\% \text{ or more.}$$

To approach this problem, start by considering speakers with $f_1 = 40$ Hz. The appropriate point on the vertical scale in Fig. 2 will be

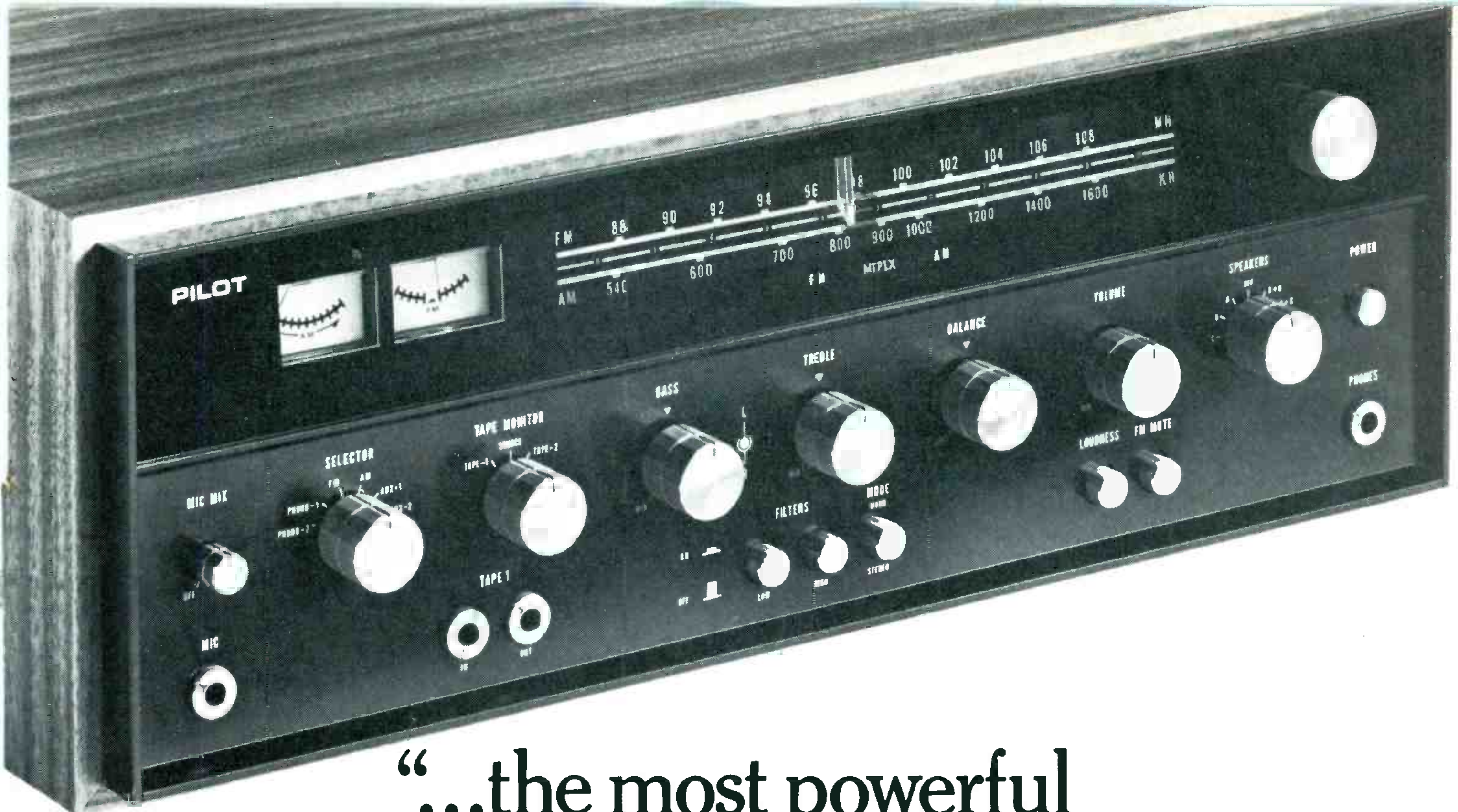
$$(f_c/f_1) \times 25 = (40/40) \times 25 = 25.$$

From the (say) 12-in. speaker curve, we find the required value on the horizontal scale to be 9 cu. ft. Using this value on Fig. 3, we learn that

$$E \times (s_1/1000) \times (25/f_1)^3 = 1.5$$

so that to meet or exceed the 5% efficiency requirement, the stiffness s_1 must be less than 1240 newtons per meter. The corresponding enclosure volumes will be larger than 7.3 cubic feet.

As in example #1, we repeat this speaker determination at other values of f_1. For example, if $f_1 = 30$ Hz we find that satisfactory 12-in. speakers will have s_1 less than or equal to 620 n/m. By gathering other points in the same way, we



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arrive at the plot in Fig. 5 which allows the range of satisfactory loudspeaker parameters for this design example.

Design Illustration #3: High Efficiency, Small Size. Let us suppose that we require

$$E = 5\% \text{ or more,}$$
$$V = 3 \text{ cubic feet.}$$

Consider first speakers with s_1 = 1000 n/m. We again use Fig. 3 to fix the needed efficiency; for (say) 12-in. speakers we have

$$E \times (s_1/1000) \times (25/f_1)^3 = 2.2$$

which is satisfied only if the free-air resonance is above 33 Hz. Similarly, if s_1 = 2000 n/m, then the free-air resonance must lie above 45 Hz for 12-in. speakers. Figure 6 shows the ranges of speaker characteristics which can be used in systems meeting the requirements of this design example. For all these systems, the 3 dB cutoff frequency will lie at or above 57 Hz.

Designing Your Own System. To design your own system, the following procedure should be used:

1. Write down your definite requirements, following the guidelines given at the beginning of this section.
2. Construct a graph of acceptable speaker specifications, following the procedure in the appropriate design illustration above.
3. Purchase a loudspeaker which meets the requirements found in step 2.
4. Build and tune an enclosure following the procedure given in the next section.

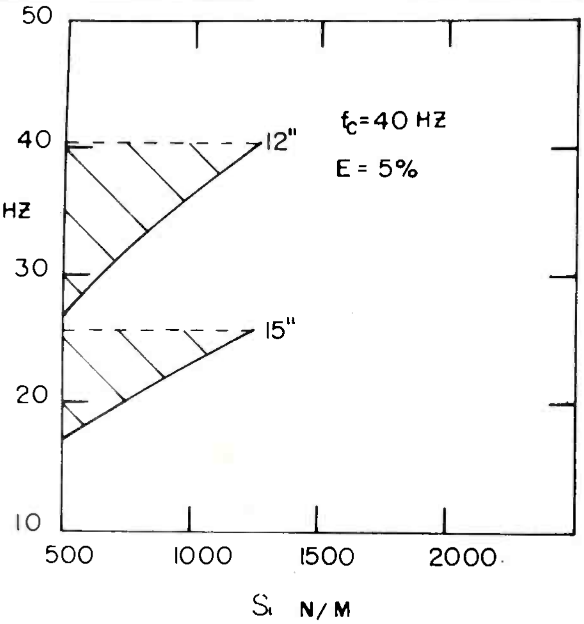

Fig. 5—The range of speaker free-air resonances and suspension stiffnesses that will meet or exceed the requirements set forth in design illustration 2.

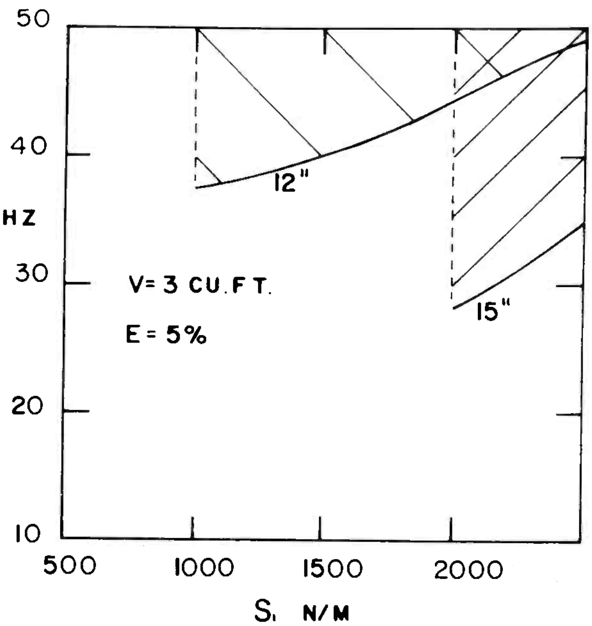

Fig. 6—The range of speaker free-air resonances and suspension stiffnesses that will meet or exceed the requirements set forth in design illustration 3.

V. Tuning the Speaker System

The previous section showed how to find a loudspeaker capable of delivering the required performance. In this section, we'll show how to set up the correct enclosure reactances and loudspeaker damping, so that the desired performance can be obtained. At this point it is a good idea to measure the properties of the loudspeaker you have obtained, as described in section III of this article.

Enclosure Volume. If the enclosure volume is not one of the specified design parameters, it must be obtained from Fig. 1 or 2 and from your other requirements. In our design curves, we have assumed that the entire volume of the enclosure was filled with adiabatically compressible air. However, the walls of the enclosure should be covered with a sound absorbing material such as fiberglass wool, to avoid problems with internal sound reflections in the enclosure. This part of the interior is then approximately isothermally compressible air. The appropriate volume to use with the design curves is then Design Volume = Adiabatic Volume + 1.4 × Isothermal Volume. Thus, a small enclosure can be made effectively larger by using more insulating material. The actual internal volume of the enclosure is, of course, just the adiabatic volume plus the isothermal volume.

Mass Ratio. The mass ratio of a speaker system is (see ref. 7) the ratio of the effective vent air mass to the effective

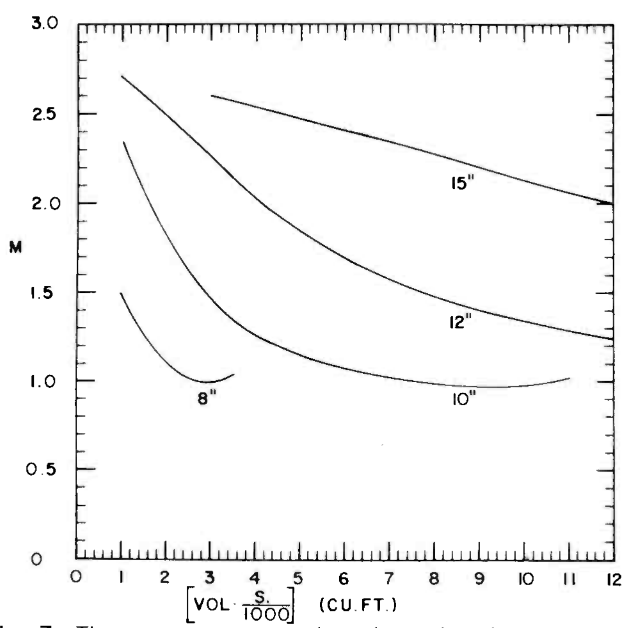

Fig. 7—These curves are used to determine the proper duct-to-cone-mass ratio for a specified enclosure and speaker.

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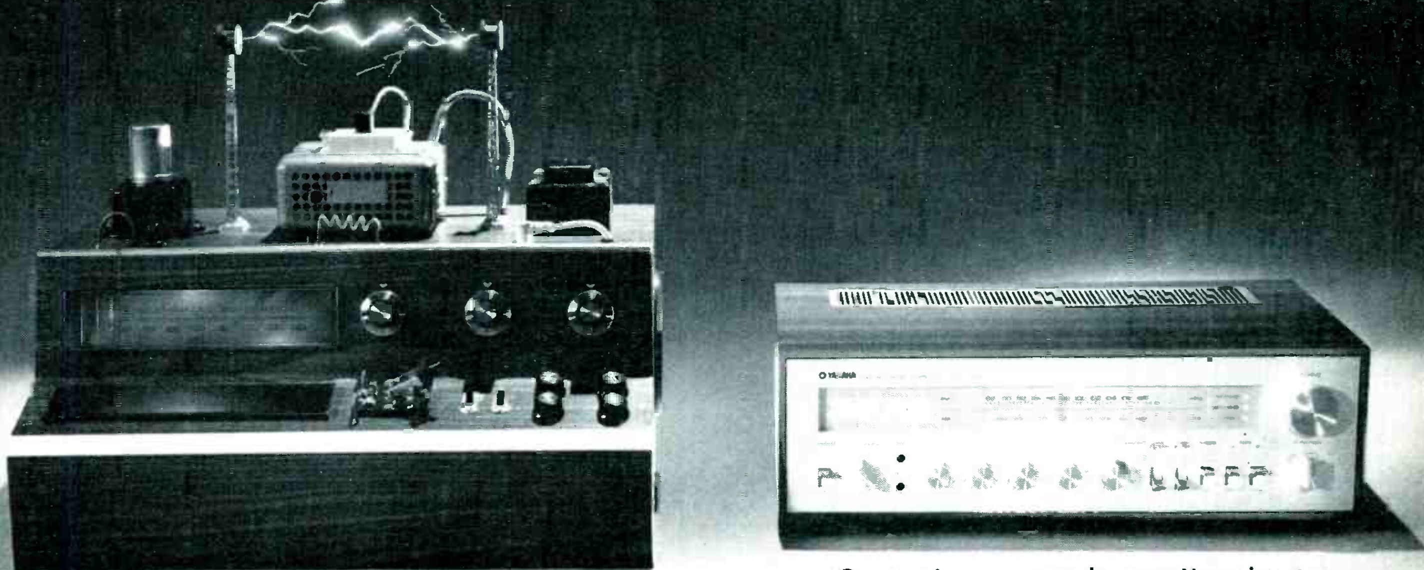

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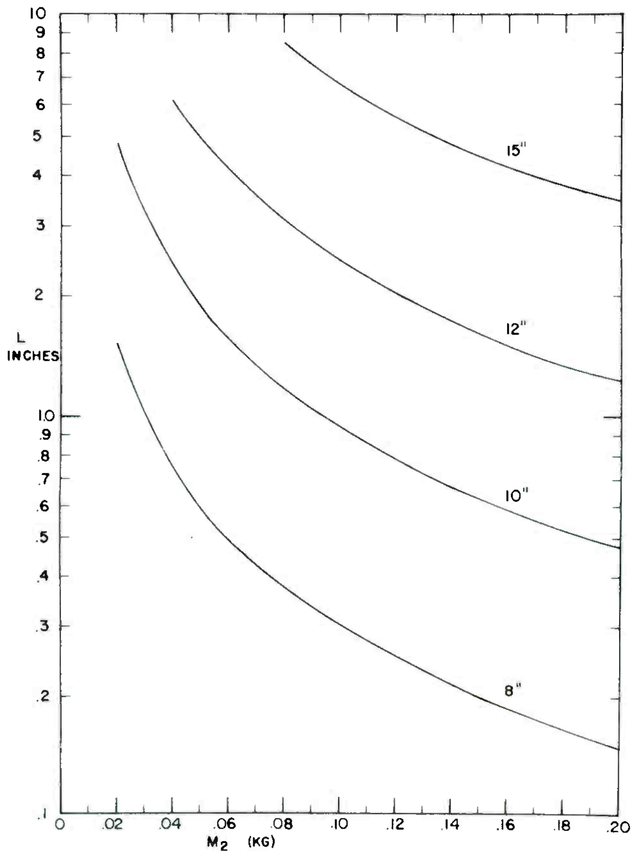

Fig. 8—Duct length for a given duct air mass is given in these curves, if the duct area is the square of the duct length. Otherwise use the formula given in the text.

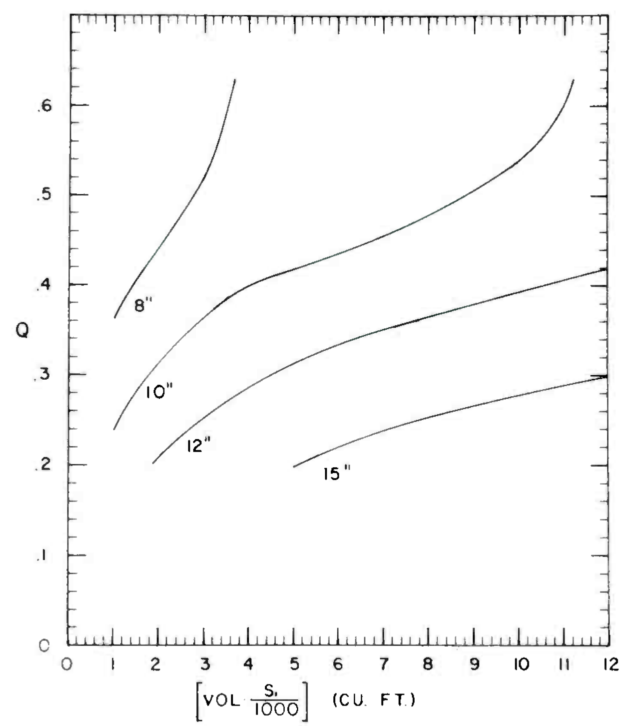

Fig. 9—Required speaker Q for a given enclosure volume and speaker suspension stiffness.

speaker cone mass. We shall abbreviate this ratio as M; so

$$m_2 = M \times m_1$$

where

$$m_1 = 0.0254 \times s_1/(f_1)^2$$

The proper mass ratio M for tuning the enclosure can be obtained from Fig. 7. Since by this time you will already know the value of the loudspeaker's mass, m_1, the proper value for m_2 follows from the definition of M. The actual length of the duct can be obtained from the formula given in section III; alternatively, the plot in Fig. 8 can be used provided that the area of the duct, A_2, is kept equal to the square of the duct length obtained from Fig. 8. The shape of the duct's cross section is unimportant; only the area is of concern.

Speaker Q. The optimum Q value for your speaker is an important quantity, since it governs the damping of the entire system. Too low a Q factor corresponds to too much damping and will give a system deficient bass response. Too high a Q factor means that the system is underdamped and leads to boomy bass; that is, the resonator part of the system will have more efficiency than the speaker alone, and so the output in the neighborhood of the enclosure's resonant frequency will be greater than the speaker's midrange output. In Fig. 9 we show a plot of the optimum Q factors for loudspeakers in a variety of systems. Recall now that the Q factor of a loudspeaker is given by the formula

$$Q = \frac{\sqrt{s_1}\,\sqrt{m_1}}{r_1 + (BL)^2/R}$$

where R is the total d.c. resistance in the voice coil circuit. It is likely that the Q value of the speaker you have chosen will not be the exact optimum value. Note, however, that Q is affected by the total d.c. resistance in the voice coil circuit, so that by adjusting the total resistance you have a handle on Q. The formula shows that adding external resistance in series with the voice coil acts in the direction of increasing Q from its short circuit value, i.e. in the direction of decreasing the damping and decreasing the midrange efficiency. So, if Fig. 9 tells you to increase the speaker's Q, you need only connect an external ballast resistor in series with the voice coil to make up a *total* resistance given by

$$R = \frac{(BL)^2}{\sqrt{s_1}\,\sqrt{m_1}} \cdot \frac{Q\,Q_0}{Q_0 - Q} \text{ ohms.}$$

If, however, the chosen loudspeaker has insufficient damping, the total d.c. resistance must be decreased. This is a more difficult task than the previous case. A method for decreasing the total resistance by means of a negative output impedance amplifier will be the subject of a future paper. In the meantime, we recommend staying away from insufficiently damped speakers, unless the discrepancy is small (say, less than 30%). A Q error of 20% will usually correspond to a response peak in the neighborhood of two to three decibels.

VI. Construction Hints

Constructing a bass reflex enclosure is one of the easiest tasks that can be undertaken in the home workshop. The basic enclosure is a rectangular box. The dimensions of the box must be such that its internal volume is the value obtained above. Do not include the duct volume as part of the internal volume. The proportions of the box are relatively unimportant, provided that there is at least three inches of clearance behind the duct.

The box should be sturdily constructed of a dense material such as ¾-in. thick plywood or particle board. Most lumber yards will cut the wood to your specified size for a nominal

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charge. Armed with a screwdriver, drill, and a saber saw, you can build a thoroughly satisfactory custom enclosure. Although we don't recommend it, we have built reflex enclosures in sizes up to 11 cu. ft. in the living room of a one bedroom apartment.

The joints of the enclosure must be reasonably air tight and above all must be strong. To get this strength, use 1 × 1-in. blocks, plenty of white glue, and screws at all edges. The duct and speaker are usually both mounted on the front panel. You will need a saber or keyhole saw to cut the holes for the speaker and vent. The duct, if needed, should be made of a stiff material which won't vibrate. Although stiff cardboard will often do, plywood is better.

Naturally you will want your enclosure to look as good as it will sound. We find it convenient to use plywood that has a prefinished veneer surface. Another method is to use ordinary unfinished plywood and to apply a hardwood veneer to the completed enclosure. This is not as difficult as it sounds and has the advantage that you need not be concerned about the wood's surface during the construction. The final touch is to use a loosely woven cloth to cover the front panel.

Appendix: Basic Engineering Formulas

1. Just as in electrical engineering, we shall take all alternating forces, velocities, currents, and voltages as being proportional to the (complex) quantity $e^{i\omega t}$ where "i" is the unit imaginary quantity equal to the square root of minus 1. Also, ω is the radian frequency given by $2\pi f$ with f the frequency in Hertz.

2. The mechanical impedance, z, of an object is the ratio of the applied force, f, to the resulting velocity, v, of the object. The basic unit of resistance, the mechanical ohm, is one newton per meter per second. As in electrical engineering, real impedances are called resistances; imaginary impedances are called reactances. The impedance of a mass is $f/v = ma/v = i\omega m$. Similarly, the impedance of a spring with stiffness, s, is $s/i\omega$. Note the important fact that if several forces act on an object, the associated impedances add together to produce an effective impedance. We shall use this concept in discussing the motion of a loudspeaker cone subject to several types of force simultaneously.

3. An electrical conductor of length L meters, moving sideways in a magnetic field of B webers per square meter with a velocity of v meters per second, will create an induced voltage V given by the formula $V = BLv$ volts. One weber/meter^2 is 10,000 gauss.

4. A current of I amperes flowing in the above conductor causes a force on it equal to BLI newtons.

5. Power is equal to the product of a force times the velocity with which the load moves. If the load is a mechanical resistance, r, then the power $p = fv = r\,v^2$. When the load is a vibrating piston, its motion produces sound. The acoustic power generated can be thought of as being due to "radiation" resistance, with

$$\text{acoustic power} = r_{rad} v^2 \qquad \text{(i)}$$

Later we will use a simple formula for r_{rad} to calculate the amount of sound radiated by a loudspeaker system. To avoid confusion, we shall use capital letters to indicate electrical quantities and lower case to indicate mechanical quantities.

6. Let's consider for our first step the electrical part of the problem: a power amplifier develops a voltage, V_0, which is applied to the terminals of the voice coil. Let the total electrical resistance of the voice coil circuit be denoted R. Then by Ohm's law, $IR = V_0 - V_1$ where V_1 is the induced voltage caused by the voice coil's motion. Recall that this current, I, causes a force on the coil and cone equal to $f = BLI$, and that the cone velocity $v_1 = V_1/BL = f/z_1$ where z_1 is the mechanical impedance of the cone. From these formulas, we calculate the electrical impedance of the system:

$$Z = V_0/I = R + V_1/I = R + (BL)^2/z_1 \qquad \text{(ii)}$$

We can also solve the equations for the cone motion, and obtain

$$v_1 = V_0 \frac{BL/R}{z_1 + (BL)^2/R} \qquad \text{(iii)}$$

7. An important characteristic of any speaker system is its frequency response, by which is meant the frequency dependence of its acoustic power output for a constant amplitude driving voltage. When the radiation comes from the cone alone (no vent in the enclosure), we can simply apply equation (i) with the velocity given in equation (iii). Specifically, we calculate

$$\text{Response} = \frac{\text{acoustic power}}{V^2_0/R} = \frac{r_{rad}\, r_{em}}{|2_1 + r_{em}|^2} \qquad \text{(iv)}$$

This dimensionless number is a measure of the amount of sound radiated for a given amount of driving voltage. In the technical literature it is often referred to as "efficiency," which is something of a misnomer since the denominator is not exactly the electrical power input—it is rather the power that would be fed to a flat resistor R at the same voltage. Because amplifiers generate an input-determined voltage, it is the response in equation (iv) that we shall be interested in. The response is a function of frequency because r_{rad} and (especially) z_1 depend on frequency. When you have obtained formulas for these quantities, we shall be able to calculate a system's response.

Vented systems have, in addition to the cone motion v_1, motion of air in the vent. We shall use the symbol v_2 to represent this motion, with $v_2 = (A_1/A_2) \times$ vent air velocity. The factor A_1/A_2 is the ratio of the area of the cone to the area of the vent, and puts v_2 on an equal footing with v_1; such a definition will simplify some of the subsequent math. Again, the response can be obtained from equation (i), but now we have two velocities which contribute to the sound and their vector sum must be used. Define the vent factor $F = (v_1 + v_2)/v_1$; then

$$F = \frac{r_{rad}\, r_{em}}{|z_1 + r_{em}|^2} \times F^2 \qquad \text{(v)}$$

8. The mechanical impedance of a roomful of air, driven by one side of a piston whose area is A_1 square meters, is a complicated-looking sum of Bessel functions. At frequencies low enough that a wavelength is larger than the piston, however, the expression can be greatly simplified. This approximation is warranted because, as was explained in section II, direct radiator performance is much degraded at higher frequencies and must be rolled off. Thus we are primarily interested in the long-wavelength-approximation performance.

In this limit, the impedance has two terms. First, there is an imaginary term which is proportional to frequency; it represents the inertia of the speaker's air load, given by 0.576 $A_1^{3/2}$ kilograms. The second term is real and is proportional to the square of the frequency; it represents the radiation resistance r_{rad} and is equal to 0.022 $A_1^2 f^2$ where f is the frequency in Hertz.

9. The only remaining quantity in our equations is the mechanical impedance of the piston. This piston possesses a mass, m_1, and is connected to the (hopefully) stationary enclosure wall by its suspension, whose spring stiffness is s_1. It is also acted on by its suspension friction r_1, its radiation resistance r_{rad}, and, of course, by the pressure of the air in the enclosure. The enclosed air stiffness will be abbreviated s_2 and can be evaluated from the form given in section III.

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In the simple case of the unvented box, $v_2 = 0$ and the impedance z_i is easily obtained:

$$z_i = i\omega m_i + r_i + r_{rad} + \frac{s_i}{i\omega} + \frac{s_2}{i\omega} \qquad \text{(vi)}$$

In this formula, m_i includes the mass of the cone, voice coil, and the mass of the air load associated with the cone's motion.

For the vented case,

$$z_i = i\omega m_i + r_i + r_{rad} + \frac{s_i}{i\omega} + F\frac{s_2}{i\omega} \qquad \text{(vii)}$$

where the vent factor F is given by

$$F = \frac{v_i + v_2}{v_i} = \frac{r_2 + i\omega m_2}{r_2 + i\omega m_2 + s_2/i\omega} \qquad \text{(viii)}$$

Note that the sealed enclosure is a special case (F = 1) of the general formulas (v) and (vii).

By comparing formulas (vi) and (vii), you will see that it is the factor F which distinguishes the sealed enclosure systems from those having a vent, i.e. from bass reflex systems. In the vicinity of the reflex enclosure's resonant frequency, the factor F becomes very large and so does z_i. A large value of F indicates that most of the sound comes from the vent. It also means that, unlike the sealed enclosure case, the loudspeaker sees a *high* impedance at the bottom of its frequency range. It can consequently produce lots of radiated sound with only a small cone excursion. This fact explains why a well-designed reflex enclosure has less low frequency distortion than a well-designed air suspension system for the same sound output.

10. A useful quantity which describes the midrange response of a loudspeaker is its "asymptotic efficiency" which can be obtained from the above formulas in the limit that $z_i = i\omega m_i$:

Asymptotic efficiency $= 0.0556\, r_{em} A_i^2/m_i^2$ percent. (ix)

11. All the formulas discussed above pertain to the analysis of some (perhaps hypothetical) existing system. For design purposes, however, we want to work the problem the other way: we wish to specify the performance of a system, and then find out what ingredients are required to achieve that performance. This process, usually termed synthesis, is much more difficult than analysis of a given system. A mathematical relationship between Q, S, and M has been discovered which when satisfied guarantees that the response curve will be as flat as possible for a given value of Q. (See ref. 6 and 7.) In addition, a maximally flat response curve was found to result from choosing Q = 0.383, S = 1.414, and M = 1.414.

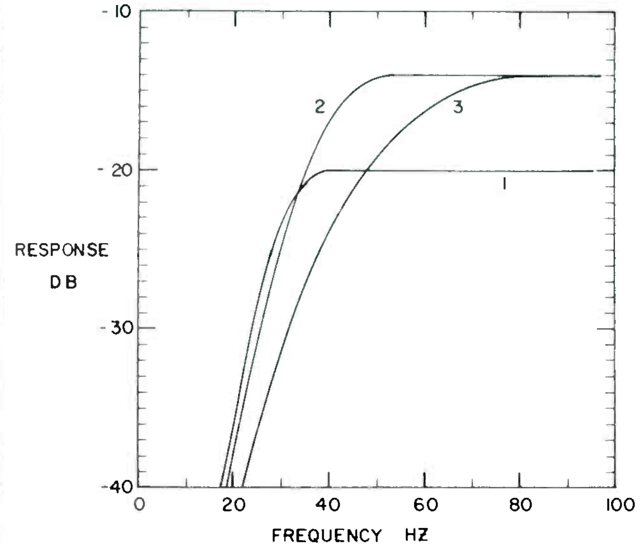

Fig. 10—Frequency response curves for the speaker systems designed in illustrations #1, #2, and #3.

These findings have been verified by computer analyses of systems designed according to the guidelines presented in this article. (See ref. 8.) The results of these studies have been used in preparing the design curves in Fig. 2, 3, 7, and 9. In Fig. 10, we show computer-generated response curves for the systems arrived at in design illustrations 1, 2, and 3.

Annotated Bibliography

1. "Notes on the Development of a New Type of Hornless Loud Speaker," by Chester Rice and Edward Kellogg, *Transactions of the American Institute of Electrical Engineers*, Vol. 44, p. 461, 1925. The invention of the moving-coil-and-cone loudspeaker was announced in this fascinating paper. The authors described their invention as having many advantages over the other types of reproducers with which they had experimented, including electrostatic, throttled jet, "talking arc," and eddy current induction speakers. The need for a baffle for hornless loudspeakers was discussed, and the possibility of getting flat response from inertia-controlled pistons was recognized.

2. "The Theory of the Loudspeaker and Vibrating Systems," by Hans Roder, *Radio Engineering*, Vol. 16, #7, p. 10; #8, p. 21; #9, p. 24; and #10, p. 19, 1936. Here, a thorough mathematical development of the properties of electrodynamically driven pistons is given.

3. "The Magic Voice," by C. O. Caulton, E. T. Dickey, and S. V. Perry, *Radio Engineering*, Vol. 16, #10, p. 8, 1936. These authors describe how loudspeaker performance can be improved by (a) putting a back panel onto the loudspeaker's enclosure and (b) adding a vent to the resulting sealed box. Basically, then, these authors describe the invention of the bass reflex or "phase inverter" enclosure.

4. *Acoustical Engineering*, by H. F. Olson, D. van Nostrand, Princeton, 1957. This very important reference book gives a thorough treatment of a vast number of acoustical systems.

5. "Performance of Enclosures for Low Resonance High Compliance Loudspeakers," by J. F. Novak, *IRE Transactions on Audio*, Vol AU-7, #1, p. 5, 1959. In this excellent paper, Novak shows mathematically and experimentally how adding a vent to an enclosure lowers the amplitude of the cone motion at low frequencies and so reduces distortion.

6. "Loudspeakers in Vented Boxes," by A. Neville Thiele, *Proc. I.R.E. Australia*, Vol. 22, p. 487, 1961, and reprinted in *J.A.E.S.*, Vol. 19, No. 5, p. 382, and No. 6, p. 471, 1971. In this landmark paper, Thiele analyzes bass reflex systems from the standpoint of the filter engineer. At low frequencies, lumped constant circuit theory is applicable to loudspeaker systems. A great variety of response curve shapes are derived, together with the data needed to create the actual hardware.

7. "The Theory of Maximally Flat Loudspeaker Systems," by Susan Lea and Michael Lampton, accepted for publication in *IEEE Transactions on Audio & Electroacoustics*, 1972. This rather mathematical paper shows that the shape of the response curve of a bass reflex system depends only on Q, S, and M and that the flattest possible curve is obtained with Q = 0.383, S = 1.414, and M = 1.414.

8. "Program WOOF: A Numerical Evaluator of Loudspeaker Systems," by M. Lampton, *IEEE Trans. Audio & Electroacoustics*, 1972. This note describes a computer program which evaluates woofer/enclosure designs.

9. "The Theory of Bounded Ripple Loudspeaker Systems," by M. Lampton, *IEEE Transactions on Audio & Electroacoustics*, 1972. This paper develops the idea of the figure of merit of loudspeaker systems and analyzes the relationship between smoothness of response and the figure of merit. Æ

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"Phasing" in Tape Recording

Herman Burstein

In the July 1973 issue of the Tape Guide, Michael Caponera asked how he could achieve what he called: ". . . a special effect. It is a whirling, swishing sound that affects the total sound. . . . The sound seems to rise, dip, and then 'null out' and start all over again. I have heard this called 'rephasing' and 'phasing out.' How is this sound produced?"

Since then a number of readers have most helpfully written in to suggest how one can achieve "phasing." From the volume of such letters, it appears that "phasing" is of interest to a considerable number of persons. Following, therefore, are excerpts from several representative letters. Those who have taken the trouble to write but are not quoted here will, I trust, accept my thanks nevertheless.

Mr. David Josephson, ARE P.O. Box 191, Middletown, Calif. 95461 writes: "Here is how it's done, with home equipment. Take three tape machines. Put the master tape on one machine and make simultaneous dubs onto the other two machines. Keep the dubs made on a particular machine *on that machine*. Now cue up the two dubs on their machines and start both machines at exactly the same time, with the outputs connected to left and right channels of a stereo amp (machine A's L&R outputs to L of amp; machine B's L&R outputs to R of amp). Now to produce the phasing, you must slow down one machine *for an instant*, then return it to normal speed, then slow down the other machine, and keep rocking back and forth. Some machines have variable speed controls, but I have found that pinching the capstan works better. The output of the stereo amp is then fed back into the third tape machine for a final dub (or the amp can be left out altogether). Basically you have two audio signals, equal in amplitude but differing in phase by a continuously variable amount. This procedure can also be used to make some very weird sounding echo effects."

Mr. W. Lloyd Piper, 5628 Walnut St., Mentor, Ohio 44060 writes: "I have achieved this effect with a stereo tape deck and a variable speed turntable. The information is first recorded on one track of the tape. After careful cueing, the music is then recorded on another track; with practice, one can speed up and slow down the turntable while recording this second track. The new track is alternately ahead of and then behind the undoctored track. When the two tracks are played back monophonically (that is, both tracks combined), the "phasing" effect can be heard. When this is done in stereo, the music moves from channel to channel, demonstrating the brain's ability to localize a sound source, based on small time differences between left and right ears. . . . The most difficult feat is to insure that music from both the tape (undoctored) and from the disc start simultaneously when one is making the recording of the second track at varying speed."

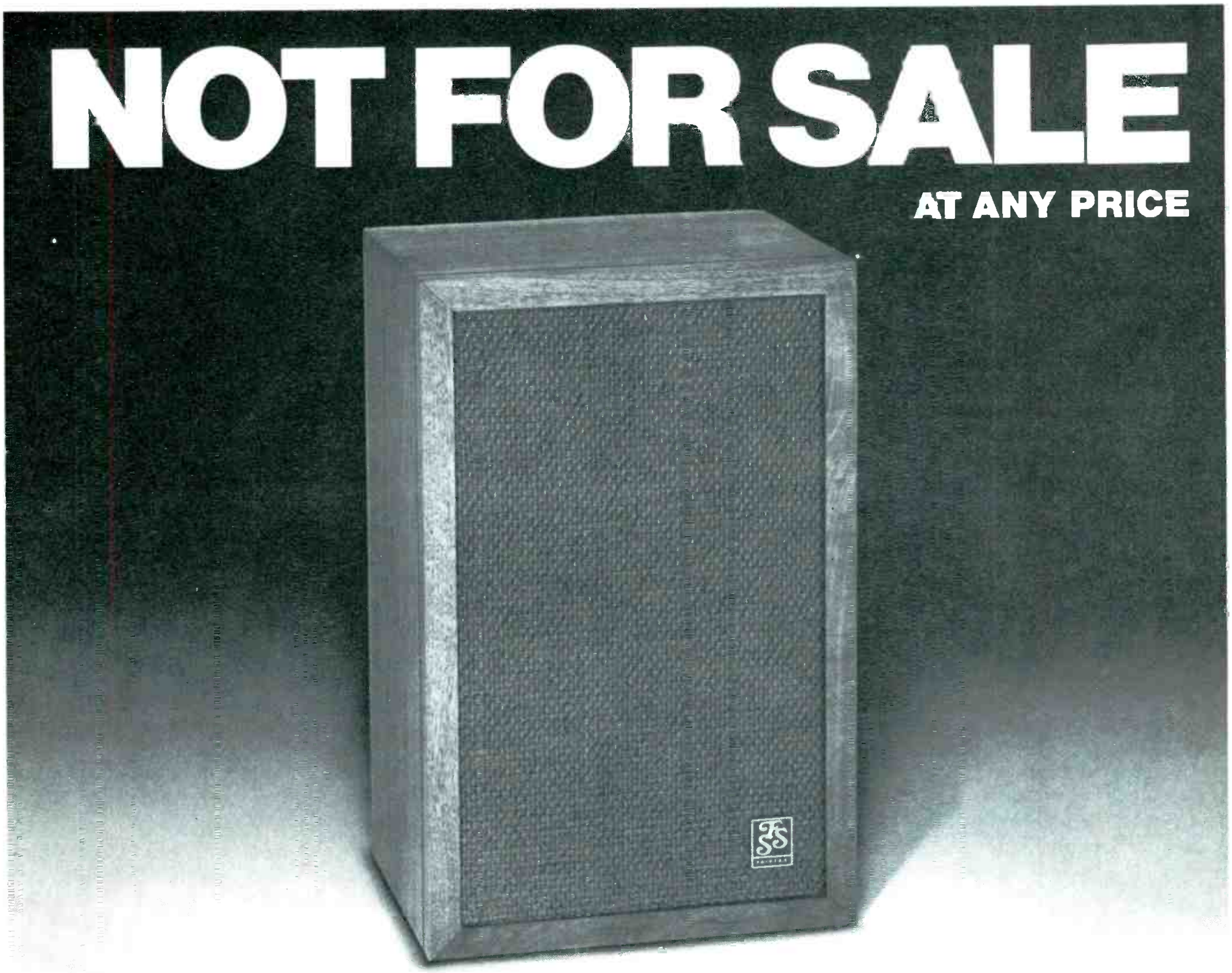
Mr. Jim Dever, 82 Fairfield Avenue, Erie, Penn. 16509 writes: "The heterodyne effect is accomplished by combining two identical sound sources, such as a recording, slightly out of sync. The heterodyne effect can be achieved in stereo, with the use of a stereo mixer, but for beginning experimentation, it is best to start with a mono effort. One track is recorded on one track of a stereo tape machine with the stereo amplifier in the mono mode. This track is then played back while recording the identical record on another track, using your finger to speed the record or slow it, and consequently take the record in and out of sync with the previously recorded material on the first track. Professional engineers use variable-speed tape transports to achieve the same effect." Mr. Dever adds, "This effect produces a jet plane-like sound which professional recording engineers have employed on some popular recordings in recent years. Perhaps the most noticed of these was the 1960 hit *The Big Hurt* by Toni Fisher."

Mr. Dan Thibault, Lafayette Radio, Syracuse West, N.Y. writes that an effective way to achieve "phasing" is as follows: "Take the left tape recording output of your amplifier and 'Y' it into the left inputs of two separate tape decks. Do the same for the right channel, feeding it into the right inputs of these two decks. Now 'Y' the line outputs of the decks together, left to left, right to right, and feed these to the line inputs of a third deck, for dubbing and catching the effect on tape. Listen to the output of the third deck via tape monitor. On the first two decks, input levels should be as closely matched as possible, for maximum effect. By touching the capstans of the machines gently, first one, then the other, you can regulate the rate or intensity of the effect. Borrow a couple of decks and try it the way the studios do it! You will blow nothing but your mind."

Mr. Thibault notes further that ". . . the Maestro Corporation markets a 'phase shifter' which produces almost the same effect. It has three rocker switches that can be combined for different speeds. It is primarily intended for live performances, but works great on tape, too."

Mr. Fred Goldberg, 120-172 Alcott Place, Bronx, N.Y. 10475 informs us that the reader interested in "phasing" should look into the Surf Synthesizer, #3711K, which is in the catalog of PAIA Electronics Inc., P.O. Box 14359, Oklahoma City, Ok. 73114. Mr. L. G. Newton, President of Tempo Audio Industries Limited, 2 Thorncliffe Park Drive, Toronto, Ontario, Canada 354, states that phasing equipment is made by "Eventide Clockworks in New York . . . and by Carl Countryman Associates in Palo Alto, California."

A brochure by Countryman contains, in part, the following information: "The Countryman Associates Phase Shifters are all-electronic time delay



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devices, useful for creating special effects on audio signals. . . . The phase cancellation effect called reel flanging is often obtained by recording the same audio signal on two pieces of tape, which are then played back simultaneously on two tape recorders. The outputs of these recorders are combined at equal levels in a mixer or audio console. . . . The speed of one tape recorder is then varied by dragging one's hand on the supply reel flange in order to slow it down (hence the term 'reel flanging'). As the time delay of one relative to the other increases, some frequencies in the signal from one recorder will become exactly out of phase with the corresponding frequencies from the other recorder, and will cancel out in the mixer. The subjective effect produced is a sort of audio 'turning inside out' as was used in *The Big Hurt* and *Itchycoopark*. A slightly different effect can be achieved by reversing the phase of one signal using an inverting amplifier or a phase inverting patch cord. The same effects can be produced using the variable time delay of a Countryman Associates Phase Shifter. . . . Reel flanging effects can be added to a signal without completely cancelling any frequencies by feeding the delayed output from a phase shifter back into its input in or out of phase at an appropriate level . . . the amount of phase cancellation can be controlled by varying the level of the feedback signal, producing more melodic effects than normal reel flanging."

Based on the foregoing, it appears that, using one, two, or three tape machines, plus care and ingenuity, the experimental tape recordist can carve out a new dimension for himself. Use of one machine would involve a phono disc as the source, so that the same source could be used first to record one track and then, at variable speed, a second track. If a tape is to be the source, then a minimum of two machines is required. Using either one or two machines, it might be helpful to have a recording deck with what is known as the "Sel-Sync" or "Simul-Sync" feature, which allows one channel of the record head to be used for playback; this permits synchronization between playback of one track and recording of another track. Alternatively, in the absence of this feature, one could record in sound-on-sound fashion, with the second sound being alternatively speeded up and slowed down by exerting appropriate pressure on the takeup or supply reel. With three machines, the problem of synchronization is reduced. Æ

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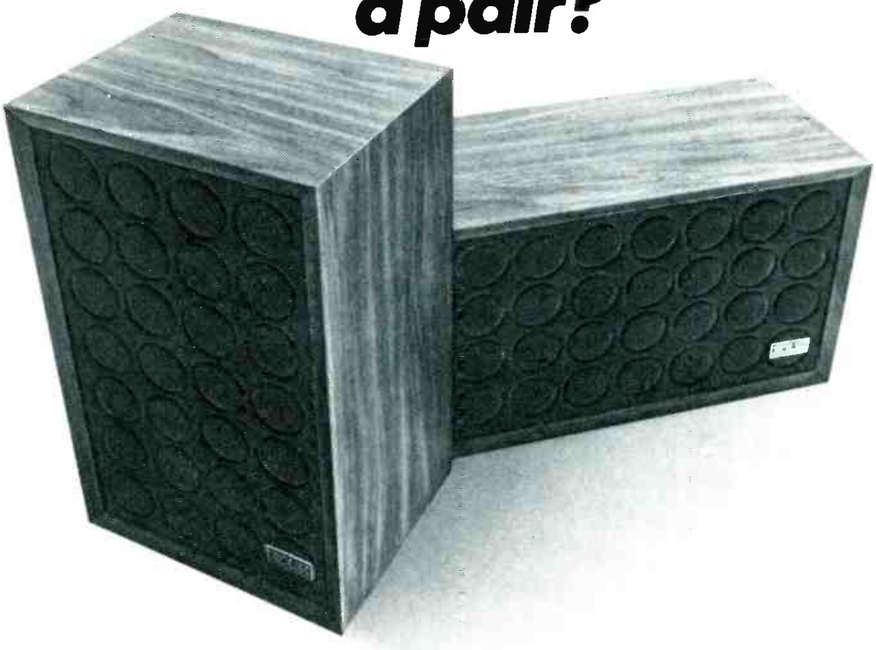

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Equipment Profiles

Kenwood KR-6340 "Two-Four" Receiver

MANUFACTURER'S SPECIFICATIONS

FM Tuner Section:

IHF Sensitivity (Mono): 2.0 μV. **S/N Ratio**: 63 dB. **THD**: Mono, 0.5%; Stereo, 0.8%. **Selectivity**: 50 dB. **AM Suppression**: 60 dB. **Capture Ratio**: 3.0 dB. **Image Rejection**: 60 dB. **IF Rejection**: 90 dB. **Spurious Response**: 90 dB. **Sub-Carrier Rejection**: 45 dB. **Frequency Response**: 20 Hz to 15,000 Hz ± 1.2 dB.

AM Tuner Section:

IHF Sensitivity: 25 μV. **S/N**: 45 dB. **Image Rejection**: 45 dB. **Selectivity**: 30 dB. **IF Rejection**: 35 dB.

Amplifier Section:

Continuous Power Output: 4-Channel Mode, 20 watts/channel @ 1 kHz; 15 watts/channel, 20-20,000 Hz, 8 ohm loads; 2-Channel Mode,: 50 watts/channel @ 1 kHz, 40 watts/channel, 20-20,000 Hz, 8 ohm loads. **Rated THD**: 0.8%. **Rated IM**: 0.8%. **Power Bandwidth**: 20-40,000 Hz. **Damping Factor**: 20. **Input Sensitivity**: Phono, 1.5 mV; Aux, 150 mV; Tape Play, 150 mV. **Hum and Noise**: Phono, −60 dB; Aux, −75 dB; Tape Play, −75 dB. **Frequency Response**: Phono, RIAA ± 1 dB; Tuner, Aux, Tape, 20 Hz to 20,000 Hz ± 1 dB. **Tone Control Range**: ± 10 dB @ 100 Hz; ± 10 dB @ 10,000 Hz.

General Specifications:

Maximum Power Consumption: 320 watts. **Dimensions**: $21\frac{7}{8}$ in. w. x $6\frac{5}{16}$ in. h. x $14\frac{3}{16}$ in. d. **Weight**: 33 lbs. **Price**: $489.95 (Optional CD-4 Demodulator Plug-In Unit, Model KCD-2: $79.95).

If you've been concerned about the possibility of degraded performance in the new breed of quadraphonic receivers because of pricing and circuitry considerations (a four-channel receiver, after all, has so many more circuits, controls and features compared to a stereo receiver), fear no more! If Kenwood's model KR-6340 is any indication of the quality to be expected from their entire series of "2-4" receivers (there are four announced thus far, with the top-of-the line Model KR-9340 promising to be a real powerhouse), that company should have nothing to worry about.

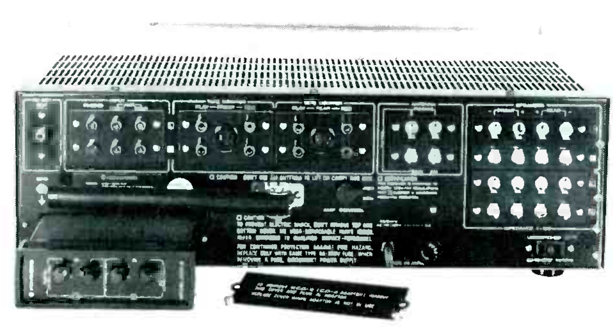

Fig. 1—Rear panel.

The KR-6340, as pictured above, is actually somewhat smaller than competitive four-channel receivers we have examined to date. A giant of a dial-scale area occupies more than half of the panel surface at the left end of the panel and, besides the well calibrated, almost linear FM scale and AM scale, the area contains a signal strength meter, indicator lights to tell you whether the set is being operated in the two-channel or four-channel amplifier mode, lights that tell you what kind of programming has been selected (SQ, RM, Discrete), lights that tell you when a CD-4 record is being played, plus the usual stereo-FM indicator light, when a stereo FM station is received. In addition, the dial pointer lights up in bright red when the selector is switched to either AM or FM.

Below the dial area are a power on-off push-button and speaker selector buttons for one or both quartets of speakers. Quadraphonic headphone jacks are provided—one for front and the other for rear channel connection. Additional push-buttons along the bottom of the panel include an FM muting switch, a loudness control switch, and a tape monitor switch. At the upper right of the panel are the tuning knob, the program source selector switch and a dual-concentric friction pair of volume controls—one for front channels, one for rear. If turned as a single control, volume to all four channels is altered uniformly. Below these controls are four somewhat smaller knobs, the first of which selects the mode of operation (MONO, 2-CH, RM, SQ, and DISCRETE). Dual bass and treble controls also employ dual knobs, so that tonal settings for rear channels can be set differently from front channels if desired. Mid settings are cleverly defined by a "click-stop" action built into the controls, insuring flat response when the knobs are set to the easily defined click position. The pair of dual-concentric balance controls (one knob for rear left-right balance, the other for front) at the extreme lower right of the panel is also equipped with this mechanical "click-stop" arrangement for easy balancing (assuming all signal sources

The rear panel of the KR-6340 is shown in Fig. 1. In addition to the usual input and output jacks for phono, aux (four of these, of course), tape out and tape in, there is an FM detector output jack, in anticipation of an as yet to be approved system for discrete four-channel FM broadcasting. Well-separated screw terminals—enough for two full sets of quadraphonic speaker arrays (eight speakers in all) are located at the right, in the photo, and similar terminals are used for connection of either 75 ohm or 300 ohm FM transmission line and an external AM antenna, if required. A pivotable AM ferrite bar antenna is included, as is an unswitched convenience outlet for record changer connection, etc. An "amp control" located at the center of the back panel is used to change amplifier mode from four-channel, to paralleled or "strapped" two-channel operation. This control does *not* duplicate the function of the front panel control (mode) discussed earlier. In other words, it is possible to leave this rear control in the four-channel setting and still select 2-channel operation by means of the front-panel mode control. Sound would then be heard from the front speakers only, but at a power level corresponding only to the per-channel rating in quadraphonic use. Only if both controls are set to "2-Ch" will the higher power rating per channel be realized.

A plastic cover plate, located at the lower left in the photo of Fig. 1, can be removed by loosening two screws. The slot that is then disclosed is intended for the KCD-2 CD-4 (Quadradisc) adaptor which Kenwood makes available separately. We were supplied with this demodulator for our tests and promptly inserted it in the beckoning slot. The nice thing about this arrangement (which is carried over into Kenwood's next more expensive receiver, the KR-8340) is the fact that it can be added at any time in the future, permitting the purchaser to economize somewhat at first if he is not prepared to spend another $80.00 (plus the cost of a new CD-4 cartridge) at the time he purchases the receiver. The demodulator unit plugs in—connections are made by simply pushing the module all the way into the slot, where its printed circuit board connector engages a properly oriented matching connector automatically.

Ordinarily, with separate demodulators previously offered, the user would end up with a *separate* accessory box and the need to handle controls on the main receiver as well as on the demodulator. Kenwood worked things out so that all controls (other than initial calibrating controls which are adjusted to match the CD-4 cartridge used) are on the receiver's front panel. This makes good sense and other manufacturers who plan to offer receivers with and without demodulators "built in" would do well to follow Kenwood's example. This bit of magic is accomplished by equipping the front panel selector switch with what amounts to two phono settings. The first, labelled PHONO is used for playing stereo records or matrix four-channel discs. With the switch set to CD-4, the phono input jacks are transferred over to the inputs of the demodulator module, the outputs of which are then simultaneously switched over to the succeeding voltage amplifier and power amplifier circuits in the usual manner. Very clever! With no CD-4 module connected, of course, no sound will be heard if the selector is set to the CD-4 position.

As can be seen from Fig. 2, Kenwood engineers must have really worked hard to get all that circuitry into the confines of this chassis. Yet, the amount of point-to-point interwiring is kept to a minimum, with all critical parts on sturdily supported p.c. boards. Identical power output modules are used for front and rear amplifier pairs. Each employs a semi-complementary direct-coupled output circuit. The outputs are monitored by a speaker protection circuit which includes a positive-acting multi-pole relay. This relay introduces a time-delay on turn-on, preventing popping transients from being heard, too.

The tuner circuitry includes a 3-gang FM variable capacitor, an FET r.f. stage, solid-state i.f. filters and an IC limiter detector, as well as Kenwood's highly reputed "double-stereo-demodulator" multiplex decoder circuit. The matrix decoder section uses common circuitry for both RM (Regular Matrix) and SQ decoding, with necessary changes from one to the other accomplished by switching of matrix decode parameters. The matrix decoder is not equipped with logic circuitry of any kind.

Though not a part of the basic receiver, it is interesting to note that the optional CD-4 demodulator module contains 23 bipolar transistors, 3 FET's and 2 phase-lock-loop integrated circuits, not to mention a vast assortment of resistors and capacitors, plus four precision calibration controls. In all, $79.95 doesn't seem like an unfair price to pay for this neatly assembled option.

Laboratory Measurements

The FM performance of Kenwood's KR-6340 was measured in somewhat greater detail than is our usual practice, so as to include some of the suggested additions in the proposed new Measurement Standards of the Institute of High Fidelity. These additional measurements will be included in all future reports on stereo FM products reviewed by AUDIO. Figure 3 shows some of the monophonic FM measurements made, with separate stereo measurements graphed in Fig. 4. IHF sensitivity was 1.8 µV, a bit better than the 2.0 µV claimed. Ultimate mono S/N was a remarkable 72 dB compared with the conservative 63 dB claimed by Kenwood. Mono THD was a mere 0.16% as aganst 0.5% in the published specs. The 50 dB quieting sensitivity was 3.0 µV, with THD already down to 1.0% at that signal input.

With automatic stereo switching set to occur at 7.0 µV, that signal strength becomes, in effect, the stereo FM sensitivity, as shown in Fig. 4. The 50 dB quieting signal for stereo reception measured 30 dB, and distortion at that input signal strength was just over 0.3%. Ultimate THD in stereo measured 0.24% compared with 0.8% claimed in the published specs. By filtering out residual sub-carrier products (which are not audible as "noise"), ultimate S/N attained in stereo was 65 dB. These stereo readings have not been published by AUDIO

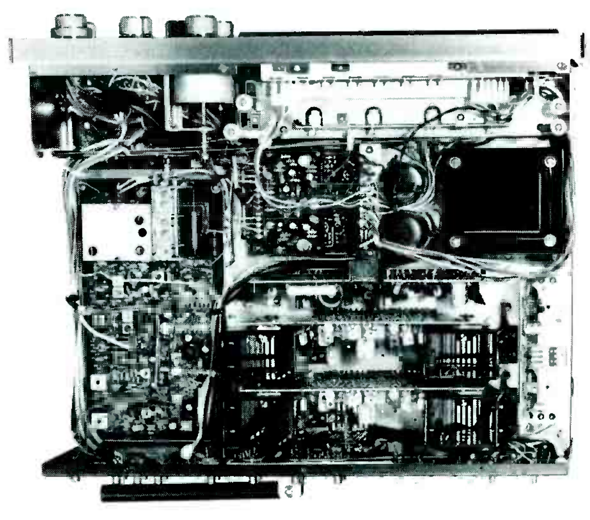

Fig. 2—Internal view of chassis.

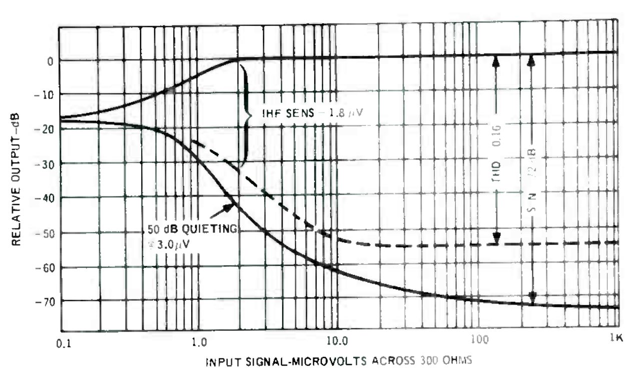

Fig. 3—Mono FM characteristics.

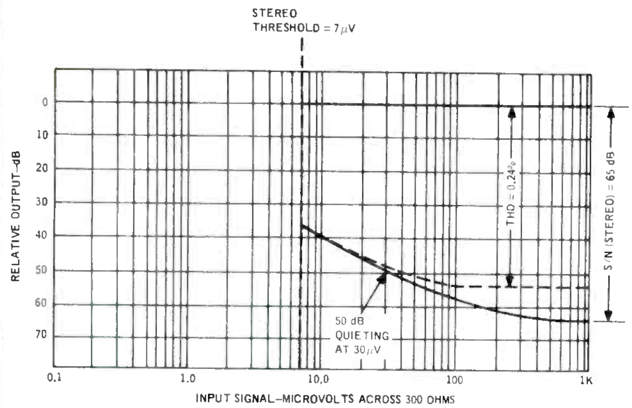

Fig. 4—Stereo FM characteristics.

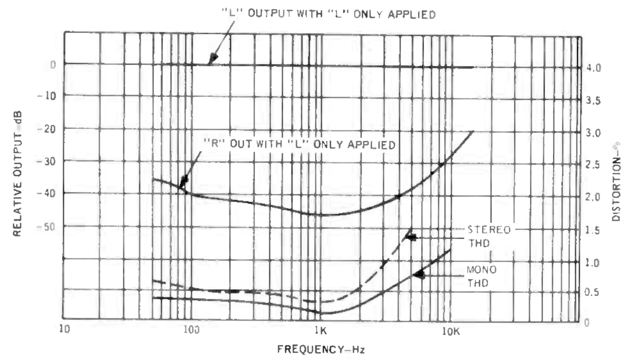

Fig. 5—Stereo separation and distortion characteristics.

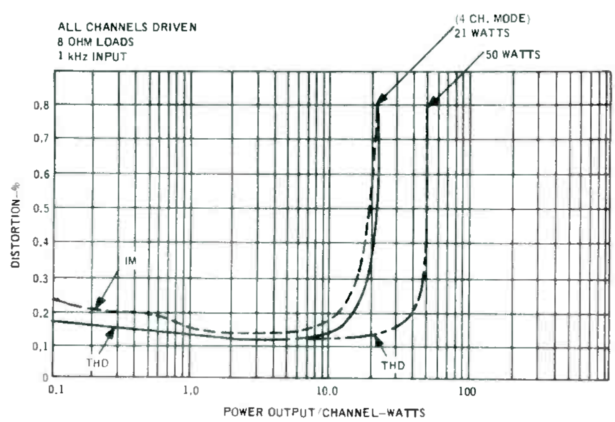

Fig. 6—THD and IM characteristics.

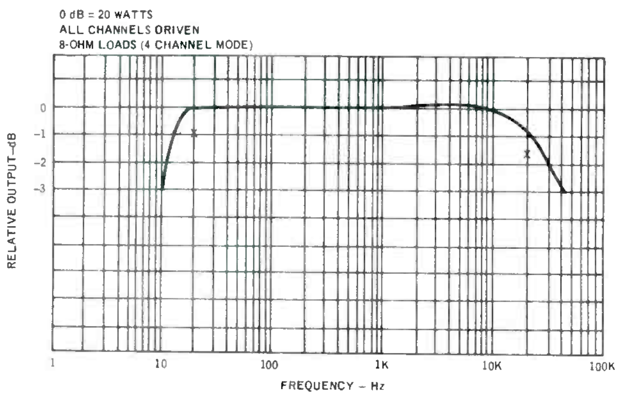

Fig. 7—Power bandwidth.

in previous reviews and readers may therefore be wondering just how "good" they are, since there is no basis for comparison. Well, they are very good *indeed*, as you will learn in future months as we continue to publish these more complete and meaningful FM readings.

Measured capture ratio was 2.5 dB while selectivity measured a bit better than the 50 dB claimed—about what one would expect from a three-tuned circuit front end and a three-stage i.f. system. Mono and stereo distortion at various audio frequencies, as well as stereo separation are plotted in Fig. 5. Mid-band separation measured about 46 dB, with a gradual reduction to 28 dB at 10 kHz. Stereo distortion readings were taken only to 5 kHz, at which frequency stereo THD measured 1.5% for full modulation.

Amplifier Measurements

Because of the fact that in the "strapped" mode there is no "common ground" connection at any of the speaker terminals, it becomes a bit difficult to measure performance using conventional test equipment hook-ups (generators, scopes and meters all share a common ground in most lab set-ups). We were able to plot "strapped" power output versus distortion, however, as shown in Fig. 6, and the rated THD of 0.8% was reached at a power output of 50 watts per channel. In quadraphonic mode, power output per channel was 21 watts for rated THD. At 15 watts and below, THD measured 0.2% or better, and IM also hovered around the 0.2% mark for all power levels below 10 watts per channel, reaching its rated value of 0.8% at exactly 21 watts per channel, all channels driven, using 8 ohm loads in all cases. Power bandwidth extended from 10 Hz to 40 kHz, a full octave better at the low end than claimed by Kenwood. Distortion versus frequency is plotted for outputs of 15 watts and 7.5 watts in Fig. 8 and reached 0.4% at 20 Hz in the case of the higher power output. At half power, distortion did not exceed 0.2% at any audible frequency. Tone control range and loudness characteristics are plotted in Fig. 9 and are seen to conform nicely with published information supplied by the manufacturer.

Listening Tests

Most of our listening tests concerned themselves with four-channel program sources. Our primary interest was with the CD-4 performance, and using a limited number of CD-4 discs available we can report that Kenwood's demodulator performs well. We particularly appreciated the availability of *two separate* 30 kHz carrier adjust controls—one for the left side and one for the right. Most previous demodulators we had used contained only one common adjustment of this critical parameter. With two carrier adjustment controls available, it becomes possible to compensate for unequal outputs from the left and right terminals of a given cartridge—a situation which occurs all too frequently.

Reproduction of CD-4 discs was clean and as distortion-free as we have heard them to date. It's always a delight to see the "Radar" light on the front panel go on when such a disc is played, even though the circuitry needed to perform this trick is no more complicated than that used to trigger the "stereo indicator" in the case of stereo FM reception. We're probably still intrigued by the novelty of it! In an overall sense, sound was clean, crisp and solid, and more than adequate power was available for our medium efficiency speaker systems. The benefits of strapping were apparent when we connected less efficient speakers for stereo testing. Fifty watts per channel is a lot of receiver power—even compared to "stereo only" receivers selling in this price range.

We've seen just about every combination of volume/balance controls on quadraphonic equipment and, in the absence of a

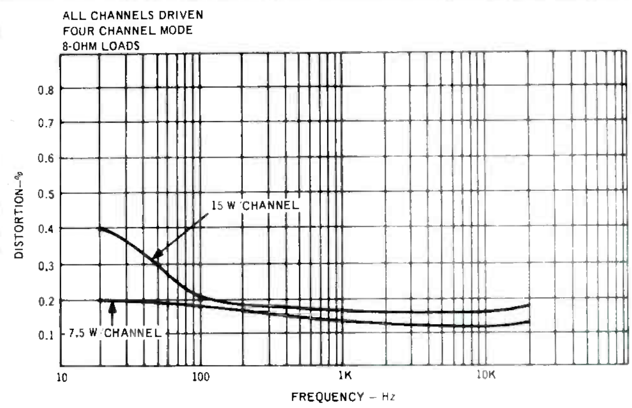

Fig. 8—Distortion vs. frequency.

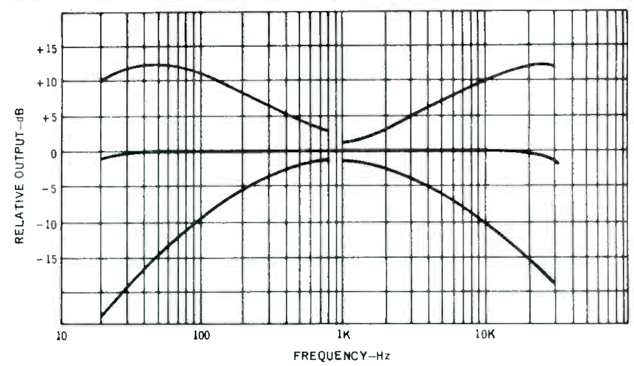

Fig. 9—Frequency response, tone control range and loudness control range.

"joystick" control, the arrangement chosen by Kenwood—tandem balance controls and tandem volume controls—makes balance adjustment in quadraphonic listening quite simple.

The absence of any logic circuitry in this receiver makes listening to matrix discs a bit of a let-down after the wide-separation of CD-4, but this, of course, is not the fault of the receiver. No four-channel receiver that we know of offers logic *plus* CD-4 capability even at the combined price of $560.00. Using this simple matrix format, there was little qualitative difference between the RM and SQ decode positions—just a slight shift of instrument location, as would be expected.

Tuner section performance was quite good, with muting effective for all signals of less than 7 microvolts. FM calibration was just about perfect and the transition from mono to stereo reception was positive with no switching back and forth—even at weak signal conditions. With the aid of our outdoor directional Yagi we were able to receive some 52 usable signals, 24 of them in stereo. Signal strength meter indications were not too helpful, however, since the first few microvolts of signal cause the meter to deflect nearly all the way. If Kenwood could not afford dual meters on this unit, we would have preferred a center-of-channel type instead of the peak reading one supplied.

Just to convince ourselves of the significance of "strapping" (and because the control flexibility of this receiver let us experiment) we tried listening to stereo two ways: first simply selecting the "2-channel" position on the selector (without setting the rear panel switch to the "strapped 2-ch" position) and then by paralleling the pairs of amplifiers, as recommended. We can honestly say that, in the case of our low-efficiency air-suspension speakers, the strapping feature (and the resultant increase in power output of more than two to one) made all the difference. While quadraphonic operation at about 20 watts per channel "fills the room" nicely because of the multiplicity of speakers in use, trying to make do with "half the receiver" in stereo left us with a feeling that we needed more power. Fortunately, the strapping circuit used by Kenwood (and others) affords the hesitant and undecided purchaser with the best of both the stereophonic and quadraphonic worlds.

Leonard Feldman

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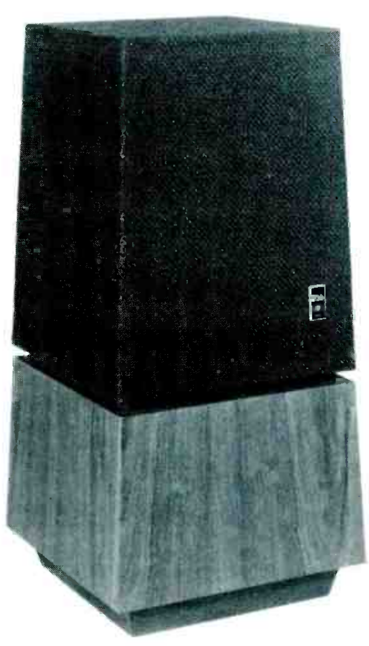


ESS amt-1 Speaker System

MANUFACTURER'S SPECIFICATIONS

System Type: Two way, floor standing, ported enclosure. **Drivers**: Heil air-motion transformer tweeter; 10-in. woofer. **Crossover**: 600 Hz. **Frequency Response**: 45 to 24,000 Hz ± 2 dB in a controlled field environment. **Power Requirements**: 30 watts rms minimum per channel. **Power Handling**: Greater than 350 watt musical peaks without distortion. **Nominal Input Impedance**: 4 ohms (minimum). **Finish**: Hand-rubbed oiled walnut. **Dimensions**: 31 in. H. x 14½ in. D x 14½ in. W. **Price**: $300.00 each.

Very few recent loudspeaker designs have created the interest that has surrounded the recent introduction by ESS, Inc. of the amt-1. The singular factor which sets this apart from more conventional loudspeaker systems is its high frequency driver. Sitting on top of a reasonably conventional ducted-port enclosure is a small rectangular unit which ESS calls the Heil air-motion transformer. While this unconventional tweeter is designed to radiate through an acoustically transparent grille, ESS has wisely made the grille itself readily removable—not certainly for maintenance or hookup reasons but for the natural curiosity of the dedicated audiophile who might otherwise claw it open in order to see what is inside.

All speakers must set air in motion to reproduce sound. In the air-motion transformer, developed by Dr. Oskar Heil, of Heil Scientific Labs. Inc., this is accomplished by changing the volume between adjacent folds of a convoluted diaphragm, which resembles a small version of a pleated drape. The diaphragm is made of a rectangular section of 0.5-mil thick polyethylene onto which is bonded a continuous conductive striping laid down in a tall, thin "square wave" pattern. The diaphragm is then pleated parallel to the vertical sides of the square wave so they lie adjacent and face each other on the inner sides of the pleats. The short top and bottom sections of the square wave serve as electrical interconnections between the much longer parallel vertical conductive strips.

A magnetic field is impressed across the diaphragm so that when electrical current is passed through the conductive strip, all of the leading edges of the square wave tend to move in one direction in the plane of the diaphragm, and all the trailing edges tend to move in the opposite direction. In this manner alternate pairs of pleats are forced to move synchronously, reducing the volume of air enclosed between outward facing pleats on one side of the diaphragm while almost precisely increasing the corresponding volume on the opposite side of the diaphragm. This action causes the Heil unit to be a broadside radiator in which a small motion of folds in the plane of the diaphragm is transformed to a larger motion of air directly into and out of the diaphragm.

The magnetic field must be relatively uniform and perpendicular to the plane of the diaphragm, which tends to cause any normal magnetic structure to obstruct acoustic radiation. ESS has made a virtue of this possible defect by shaping the pole pieces in such a way as to provide more uniform acoustic dispersion. The magnet structure is symmetrically shaped so that sound radiates equally well in front and back, providing an effective dipole radiation for the frequencies above 600 Hz which are handled by the Heil unit. Frequencies below 600 Hz are reproduced by a more conventional front-mounted, 10-in. high-compliance cone speaker, bass loaded by a ducted port enclosure.

Because the electrical current in the conductive strips in the Heil unit simply provides a proportional force acting to change pleat volume against atmospheric pressure, the shape of the pleats and their uniformity of spacing is not of primary concern to the production of sound. We point this out to prevent some readers from assuming that obvious physical differences in diaphragms infer acoustic problems. The elegant simplicity of the Heil radiator has allowed ESS to use production techniques less complicated than those which would be required for a conventional transducer, though diaphragm tolerences must be held at least as tight. After you have satisfied yourself with what the air-motion transformer looks like, we suggest that you replace the grille cover to restore peace of mind and gain back an attractive-looking speaker system.

The enclosure is meant to stand alone on the floor and is relatively small, measuring only 31 inches high by 14½ inches on a side. The lower half is finished in hand-rubbed walnut and the upper half is the flat black removable grille. The grille is meant for acoustic transparency and is not capable of safely supporting any object such as an ash tray, drinking glass, or lamp, even though the top of the speaker is at a level which invites such action. Connections and controls are accessible at the bottom, necessitating tipping the enclosure on one of its sides. Since the natural tendency will be to tip the speaker forward and grasp the removable grille when the heavy, top-mounted Heil magnet begins to pull it over, care must be exercised to prevent damage to the woofer cone. Connection is made by insulated terminal posts which require no tools for hookup. The fused, three-position tweeter control, and hookup terminals are physically close but well labelled. One small gripe this receiver has is the unconventional clockwise rotation of the tweeter control to decrease the tweeter from BRIGHT to NORMAL to SOFT. This, coupled with a circular knob which has few tactile clues to identify its position, meant a lot of speaker tipping and upside down reading by aid of flashlight when experimenting to find best room and equalizer position.

ESS supplies an excellent set of hookup instructions with the speaker and is to be congratulated in this regard. The amt-1 is covered by an original-owner lifetime warranty against material and workmanship defects in the Heil unit and a five-year warranty on the remainder of the system.

Technical Measurements

The impedance of the amt-1 is shown in Fig. 1. The lowest impedance in the audio range is 5 ohms at 100 Hz. One surprise is that there is a woofer resonance peak of 18 ohms at 11 Hz, well below the normal audio range. The 58 Hz impedance peak is due to vented-enclosure resonance.

Resonance effects associated with these low frequency peaks can give rise to some coloration which fortunately can be minimized by simple precautions which do not otherwise affect the sound. A moderately high level pure tone near 58 Hz can produce enough vent air velocity that vent-tube noise with its characteristic overtone structure is audible. However, the vent acoustic emission is downward and out of the back, so this is not significant in the large majority of listening locations. We recommend that the amt-1 be placed on an acoustically absorbing surface, such as a rug, in preference to a hard floor surface in order to minimize any possibility of such sound. In all fairness, while this vent noise was audible with test tones, we could not hear its effect with the program material used for listening test.

There was a problem associated with the 11 Hz resonance, however, when playing warped discs at high levels. The listening test, performed prior to any technical measurement, had disclosed a tremolo problem due to unusually large woofer cone displacement when playing warped records. Since no definitive test apparently exists for speaker susceptibility to the subsonic frequencies of record warp, it was necessary to originate one. The data of Kogen et. al. (AUDIO, August, 1973, Fig. 5) was used to establish a worse-case warp velocity. Using this data, a test signal was generated which is the equivalent of a 5 Hz sine wave warp component at 0.5 cm per second and a 440 Hz sine wave musical tone at 10 cm per second. Because record warp is liable to be a slightly greater problem with the lower signal-modulation levels of CD-4 records, the Audio-technica AT15s cartridge (which was in fact the

(Continued on page 72)

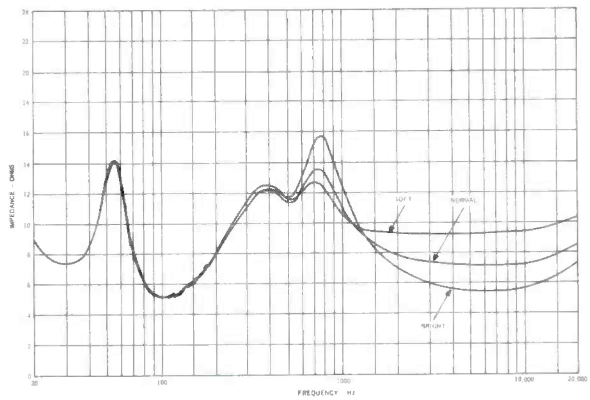
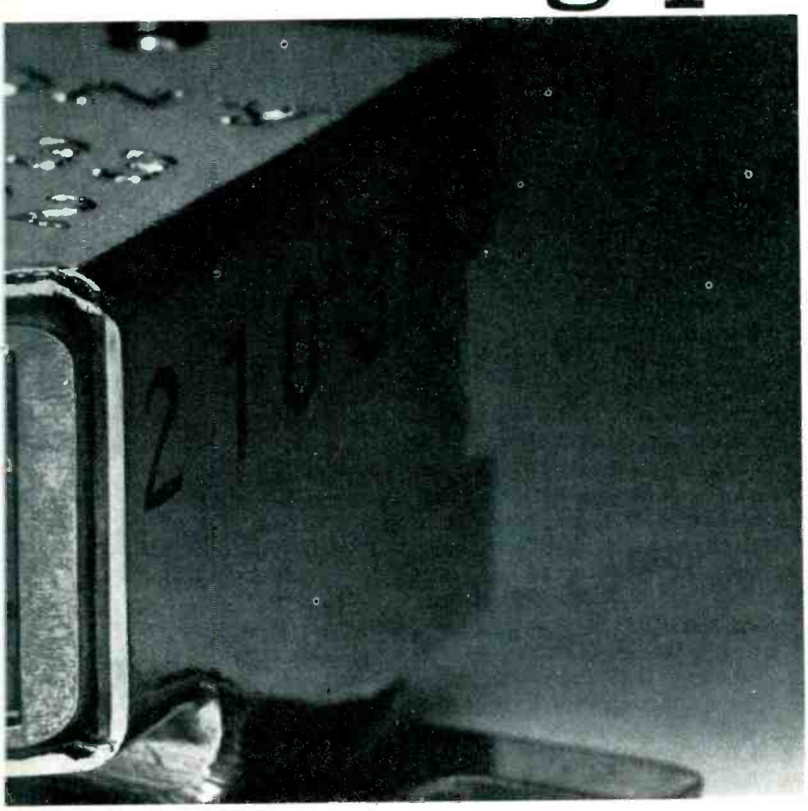


Fig. 1—Impedance for three positions of the BRIGHTNESS control.



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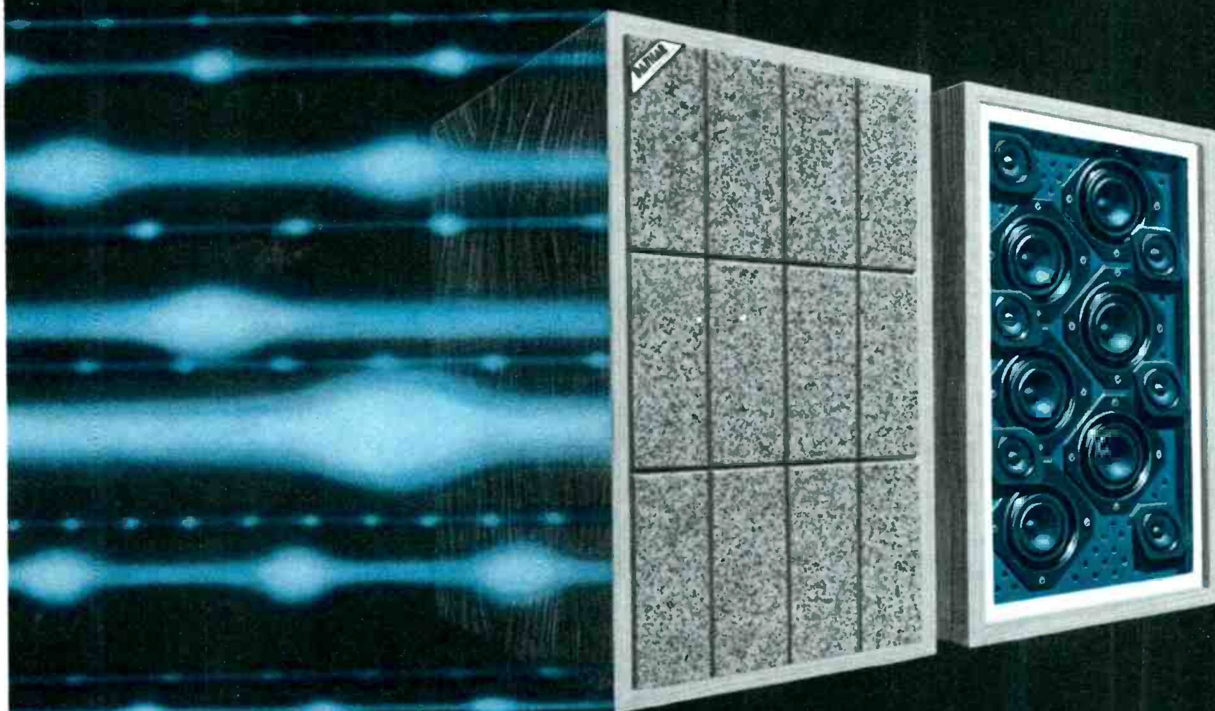

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(Continued from page 63)
cartridge used for listening tests) was used as a basis for relative reproduced output at these velocities. The electrical output voltage of a Marantz model 33 preamp (with the tone controls set flat) was measured as a reference for the electrical signals which could be expected when tracing this simulated warped record. The 440 Hz signal was thus determined to be 20 dB higher than the 5 Hz signal. This was the combination fed to the amt-1 for test of warp susceptibility.

At an electrical drive of eight volts peak-to-peak for this combination of signals, corresponding to nearly one watt into 8 ohms, a distinct tremolo effect could be heard on the A_4 tone of 440 Hz. The acoustic output of 440 Hz has both an amplitude and phase modulation which was measurable and increased with drive power. Both the audible and measured modulation disappeared when the pre-amp rumble filter was switched in. The 11-Hz woofer resonance is also very close to the resonance frequency of many phonograph arms, which could cause additional difficulties in some installations. For this reason, we strongly recommend the use of a rumble filter when playing records through the amt-1, even if the turntable rumble is otherwise inaudible. We must stress that we are testing here for an unusual subsonic program situation due mostly to warped records.

The anechoic frequency response is shown in Fig. 2. The mic position for this test was directly on axis and one meter in front of the tweeter. The pressure amplitude response is unusually uniform from around 100 Hz to beyond 20 kHz. A slight acoustic rise is noted at 90 Hz with a smooth roll-off below 50 Hz. Response, corrected for the path length of earliest sound, is of non-minimum phase from 1 kHz to 2 kHz but is of a type indicating a smooth acoustic transition from the tweeter to the midrange acoustic position. A non-minimum phase roll-off is noted above 10 kHz relative to the 2-10 kHz region. Phase response is not plotted below 250 Hz because of the difference in acoustic position of Heil unit and woofer.

The three tweeter positions of SOFT, NORMAL, and BRIGHT only produce a few dB high frequency level variations and for clarity only the NORMAL position was chosen for Fig. 2. The audible effect of this brightness control is extremely small.

The removable grille cover which constitutes the top portion of the amt-1 was found to contribute narrow absorption notches above 10 kHz which would not be discernible either in third-octave bands or listening test, but for fairness to the performance of the Heil unit we measured the response with the grille removed.

Two types of diaphragms were tested for the Heil tweeter. The amt-1 units, which had been shipped to AUDIO some months before the testing began, had an earlier diaphragm design. During the listening test, ESS shipped us a set of replacement diaphragms which differ primarily in the fact that the second design has a damping compound on the surface. ESS tells us that the damping brings diaphragms that are marginal in response within spec and that both designs are considered standard. The two undamped diaphragms on the same Heil driver did not show as much as one decibel variation in SPL from one unit to the other. The same consistency was evident in direct comparison of the two damped diaphragms with each other. This shows excellent uniformity of design. The second or damped diaphragm response is shown plotted in Fig. 2. The damped diaphragms elimi-

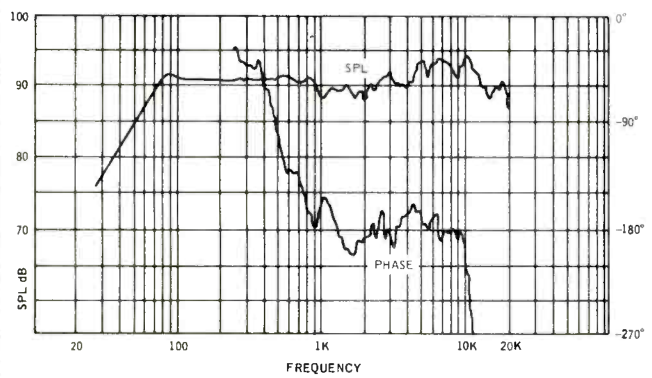

Fig. 2—Anechoic frequency response including amplitude and phase measured one meter on-axis with one-watt input.

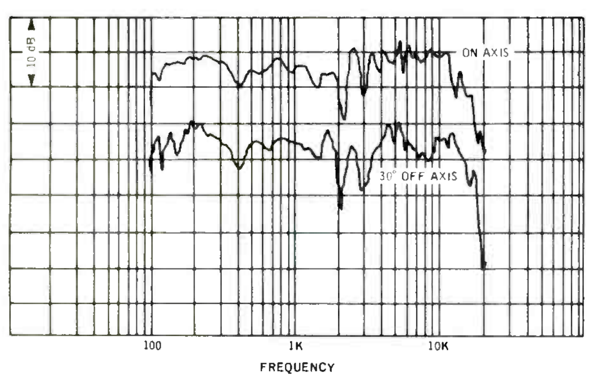

Fig. 3—Frequency response of the first 10 milliseconds of sound in a conventional listening situation three meters from the amt-1. On-axis and stereo response are shifted 10 dB for clarity.

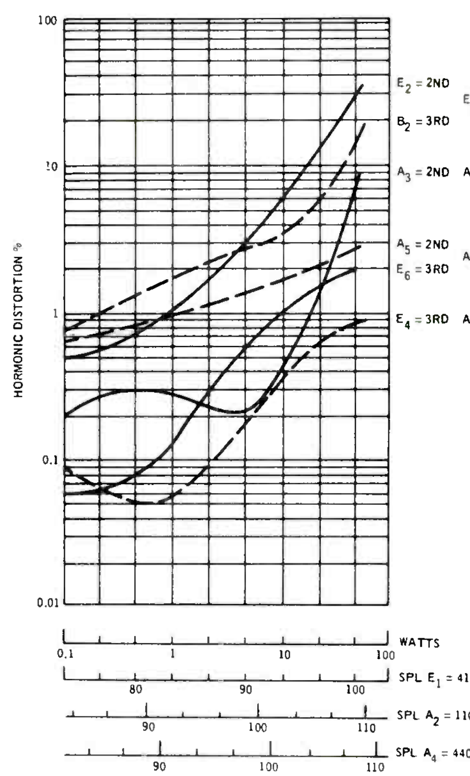

Fig. 4—Harmonic distortion for musical tones of E_1, A_2, and A_4.

nated small 5 kHz and 10 kHz peaks found in the undamped diaphragms and replaced them with a broad but small brightness peak in the 4 to 11 kHz range.

The three-meter room response is shown in Fig. 3 for on-axis and a typical stereo listening position of 30 degrees off-axis. The plots are displaced 10 decibels on the chart for clarity of presentation. Since the amt-1 is a floor standing unit, the test was made with the speaker on a carpeted floor at least two meters away from any wall surface. The frequency spectrum of sound arriving at a listening position one meter above the floor and three meters from the speaker is shown for the composite sound image due to direct path, floor reflection, and ceiling reflection. No subsequent reverberant sound due to walls or furniture is included in this spectrum. This is thus a measurement of what is known as the "early" sound when the speaker is used as a source in a conventional environment. Tweeter response was set to NORMAL. This measurement substantiates the listening impression that the sound of the amt-1 is that of clean, extended frequency response with no peaking or presence-robbing midrange dip.

Harmonic distortion was measured for the musical tones E_1, A_2, and A_4, and this data is shown in Fig. 4. These tones are primarily tests of the woofer since by measurement, the woofer handles the acoustic energy below 800 Hz.

Because of the unusual tweeter design, harmonic distortion was also measured at 3 kHz. This data for the damped diaphragm is shown in Fig. 5. These are burst tests of less than five seconds duration. The measurements show that for momentary bursts of energy, the harmonic distortion is comparable to that of a quality tweeter. However, a sustained level of greater than 10 watts for periods greater than 20 seconds produces a distortion creep manifest as a gradual increase in distortion, which accelerates its rise toward a run-away condition if the tone is maintained. Dropping the power level to below 100 milliwatts causes a gradual restoring of the distortion to its former low value. The uncoated diaphragm went into this run-away condition at lower power-time products than did the coated diaphragms, so if the effect is thermal, it has been effectively combatted by the damped design. In any normal use, even hard rock reproduction, it is highly unlikely that you could tolerate the sustained SPL required to permanently damage a diaphragm.

Signal suppression tests for the capability of the amt-1 to handle crescendos substantiated the harmonic distortion measurements. A 1 kHz tone was not suppressed when high level noise was superimposed for short duration, even up to the ESS rated 350-watt peak. Desensitization sets in after 20 to 30 seconds when the noise is maintained at a 50-watt

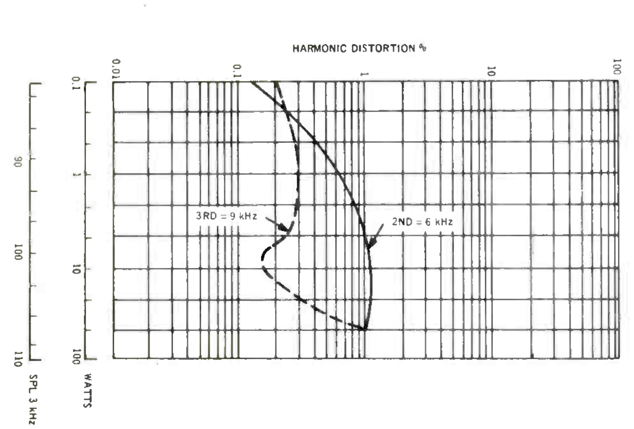

Fig. 5—Harmonic distortion at 3 kHz.

peak level. After removal of the burst, the diaphragm response gradually restores itself. The uncoated diaphragm shows noise peak handling difficulty for power levels greater than 200 watts peak, again showing the improvement represented by the damped design.

The reason for belaboring this point of power-time limitations is not to find fault with the Heil unit, which is an unusually fine tweeter, but to provide precautionary guidance to users of the amt-1 who might have super power amplifiers which can, if improperly used, cause permanent speaker damage to any system. ESS clearly outlines the hazards of excessive amplifier power in the instructions packed with each speaker.

Intermodulation distortion of 440 Hz by 41 Hz is shown in Fig. 6. This is primarily amplitude modulation. The two-tone intermodulation distortion of the Heil unit remained well below 1 per cent for any two tones in the range 1 kHz to 20 kHz mixed in equal ratio when the average power was below the harmonic distortion creep point.

The polar energy plot for the 20 Hz to 20 kHz range is shown in Fig. 7 for each of the three tweeter control positions. The polar response is very similar to a dipole radiator, with equal contributions from front and back and a sharp dip in response at 90 degrees off axis. This plot shows that the amt-1 need not be carefully positioned in a room to get good stereo imagery for direct sound so long as you are sitting within 45 degrees of the frontal axis position. The strong well-balanced radiation from the rear indicates that a substantial reflection component may exist if the amt-1 is placed in front of a reflecting surface.

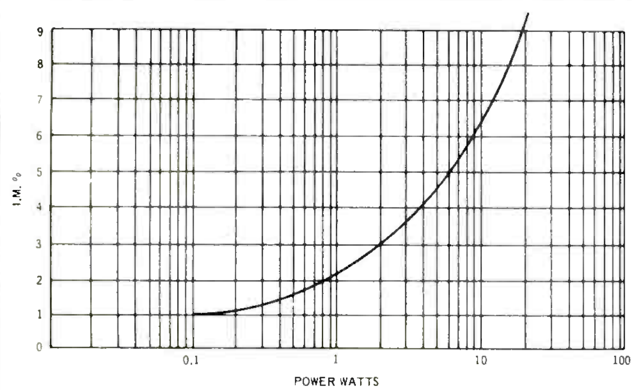

Fig. 6—Intermodulation distortion of 440 Hz by 41 Hz mixed 1:1.

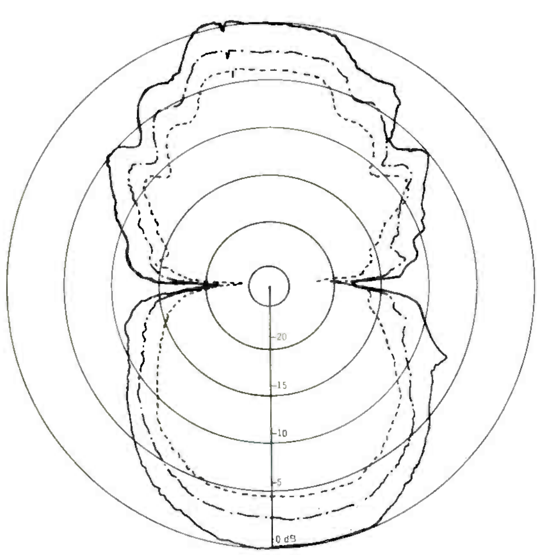

Fig. 7—Polar energy response.

The energy-time curve, which is a measure of the transient response for all pulse components from 20 Hz to 20 kHz, is shown in Fig. 8. The time spread after the principal peak is due to the frequency response amplitude and phase behavior above 10 kHz. The contribution at 3.8 milliseconds is due to the midrange response of the woofer.

An interesting technical specification given by ESS is that of a 20-microsecond rise time for a 5 kHz square wave. The rise time at one meter on axis was measured at 25 microseconds for the ten to ninety percent value. Correction for amplifier and microphone acoustic response brought that value close to the 20 microseconds of the ESS specification.

Listening Test

The first impression one has of the sound of the amt-1 is its unusually clear and extended high frequency response. Because there is as much high frequency energy coming out the rear as out of the front, the sound in a moderately live room may appear bright. Reducing the high frequency response by tone controls may not be the best solution in this case because the direct sound, with the conventional directional effects of the woofer handling sounds below 600 Hz, may then be unbalanced in timbre with the room reverberant field richer in high frequency energy than the direct sound. Positioning the amt-1's in front of a moderate amount of acoustic absorbing material usually gives a good balance of direct-to-reverberant spectral energy.

After no small amount of consternation with stereo image wander, we discovered that one of the amt-1's had been delivered with an out-of-phase Heil driver. It was immediately corrected and the stereo localization improved markedly. Later, during the technical measurements, this phasing condition was verified. Stereo localization, both side and center, is extremely good with the amt-1.

One side benefit of the broad horizontal dispersion of sound is that a wide stereo image can be achieved in those rooms in which it is impractical to provide wide speaker separation. This can be effectively achieved by rotating the speakers so as to increase the ratio of early reverberant sound to direct sound.

While well satisfied with the performance of the Heil unit for clarity of response at shattering rock levels as well as

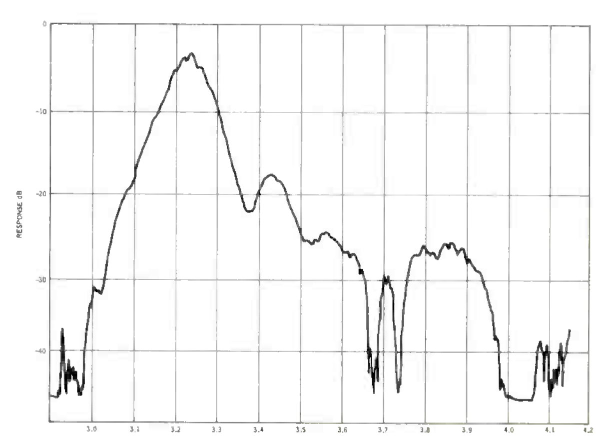

Fig. 8—Energy-time plot for a 20 to 20,000-Hz impulsive at one meter from the speaker.

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soft symphonic passages, it is this reviewer's opinion that the bass unit doesn't fully match the tweeter's performance. Perhaps with a conventional cone tweeter, the balance of low bass and high treble cutoff would give a more conventional sonic balance, but the Heil unit's extended response simply outshines the woofer's low frequency performance. Higher pitched percussive sounds are accurately reproduced and sharply defined in stereo imagery while percussive mid bass, in this reviewer's opinion, is not as accurate when judged by the Heil unit's standard. In fairness, the bass unit has no trace of the boominess sometimes associated with vented box designs, is clean at moderate to loud levels, and did not reveal any vent sound with program material.

This opinion is, of course, related to overall performance without consideration of cost or ease of installation. It is also this reviewer's opinion that the amt-1 gives an extremely accurate sound reproduction for the investment of $300. This, coupled with the wide horizontal dispersion of sound, which gives good stereo for almost any room, makes the amt-1 well worth its price. *Richard C. Heyser*

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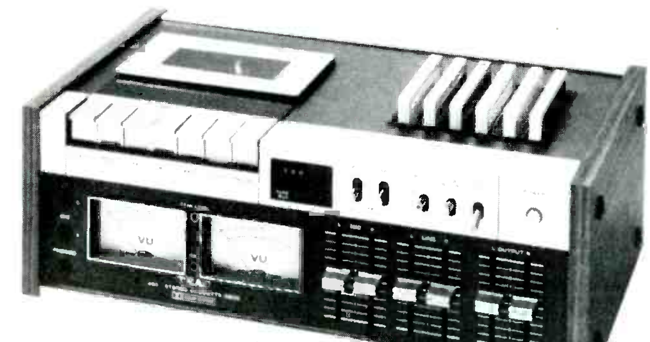

TEAC 450 Cassette Recorder

MANUFACTURER'S SPECIFICATIONS

Heads: Two, erase and record-playback. **Motor**: Hysteresis synchronous outer-rotor. **Wow and Flutter**: Less than 0.07%. **Frequency Response**: CrO_2, 30 to 15,000 Hz, +2, −3; Hi energy, 30 to 13,500 Hz, +2, −3; Regular tape, 30 to 11,000 Hz, +2, −3. **Signal/noise**: 52 dB, 60 dB with Dolby. **Line output**: 0.3 V. **Headphones**: 8 ohms. **Dimensions**: 7 in. H x 17½ in. W x 10½ in. D. **Price**: $429.50.

The 450 is TEAC's top-of-the-line cassette recorder and so we expected a high standard of performance. We can say right away that we were not disappointed. This model is not cheap at $429.50, but we are sure many people will find that the extra facilities are well worth the extra cost. In appearance, it is rather different from most recorders being slightly higher with all the controls on the vertical front panel. Depth is less than 11 inches so the recorder can be placed on a shelf at eye level if so desired. The two VU meters are on the left, and to the right are three pairs of slider controls for microphone inputs, line inputs and outputs. Above the meters are seven piano-key switches for EJECT, RECORD, REVERSE, FAST FORWARD, FORWARD, STOP, and PAUSE. To the right of these is a tape run indicator, tape counter, equalization and bias selector switches, Dolby FM/copy switch, timer selector, and then the POWER/OFF switch. At the extreme left are sockets for headphones and microphones, and there are two small indicator lamps located between the VU meters. One is the record indicator and the other is a peak level monitor. At the top, behind the piano keys, is the cassette-loading position and a large recess next to it will hold up to six tapes.

Now for a few words of explanation concerning some of the more unfamiliar controls. First, that Dolby FM/copy switch—the primary purpose of this control is to enable Dolby broadcasts to be recorded, and operation of the other Dolby switch will let you monitor either the Dolby decoded signal or the encoded signal. At the rear of the recorder is a calibration level control and all you have to do is to wait for the standard Dolby signal level signal which precedes the broadcast and then adjust the control until the VU pointers are at the Dolby calibration marks. Another use for the FM/copy switch is for copying Dolby encoded cassettes without re-encoding. Now for the equalizer and bias switches—they are entirely separate although they are both labelled NORMAL, HIGH and CrO_2. They should, in fact, be used in tandem. (In theory, it might be possible to vary the equalization with normal tape or vice-versa, but we did not find it worthwhile with any of the tapes on hand; neither was this procedure recommended in the list of switch selector recommendations for various tapes printed in the owner's manual.) I found the timer selector switch easy enough to use, although it is an unusual facility for a cassette recorder! It is used in conjunction with an ordinary automatic timer—a clock unit with a switched a.c. outlet socket. The procedure is to set the volume level, wind the tape to the required position, and depress the play and pause buttons. When the timer switches the recorder on, the pause button is automatically released to start playback, or record if the record switch is on. At the end of the tape, the machine is switched off, together with a tuner or other equipment plugged into the a.c. outlet socket at the rear of the 450.

Here, it might be appropriate to say a few words in praise of the owner's manual. Like all those we have seen from TEAC, it is comprehensive and written in such a way that even a complete novice can understand. Standard accessories supplied with the machine include a plastic cover, silicone cleaning cloth, cleaning stick, spare fuse and input-output connection cord.

Measurements

Figure 3 shows the frequency response at 0 VU and −20 VU, measured with Maxell UD tape. The −3 dB point is 13 kHz with overall response within 2 dB from 40 Hz to 12 kHz.

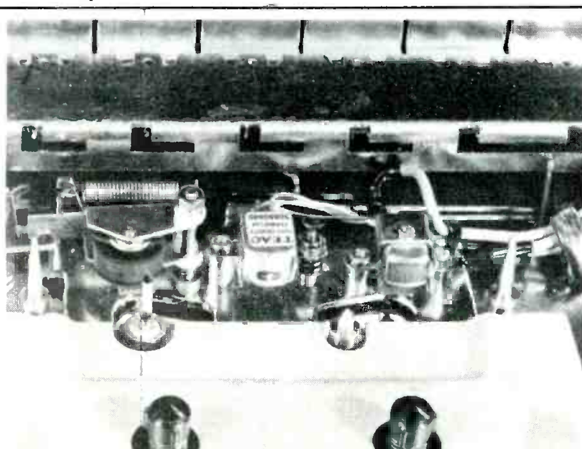

Fig. 2—Head assembly of the 450, viewed from the rear.

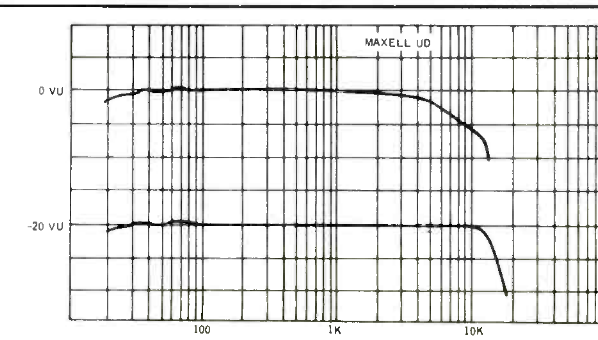

Fig. 3—Frequency response at 0 VU and −20 VU, measured with Maxell UD tape.

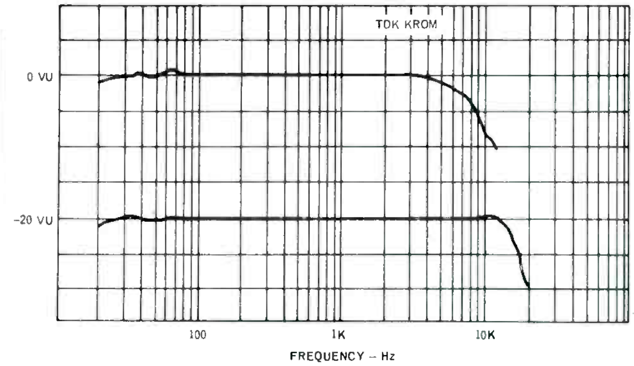

Fig. 4—Frequency response with TDK KROM-O_2 tape.

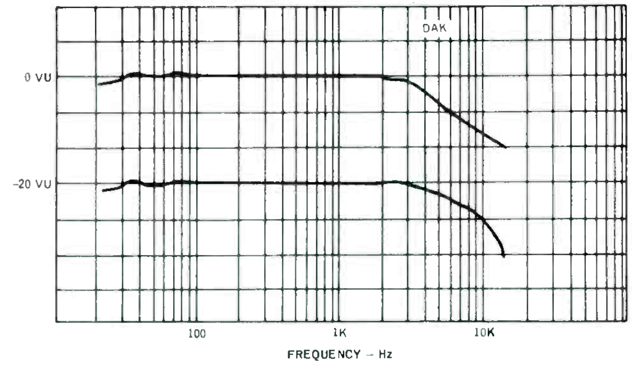

Fig. 5—Frequency response with DAK cobalt tape.

The next graph, Fig. 4, shows the results from TDK KROM-O_2 tape and it will be seen that the −3 dB point is a little higher at 15 kHz. The third graph (Fig. 5) shows the response from an inexpensive tape—DAK cobalt-energized UHF. Bias and equalizing switches were set to NORMAL positions. High frequency response was obviously not as extended as with the special low-noise tapes but the signal/noise ratio was almost as good. It would seem that the bias is a little too high for this kind of tape—at least for optimum results. Figure 6 shows the results with another kind of tape—Certron Gamma 60 iron oxide which is claimed to give a high performance without bias changes. Again, the signal/noise ratio was excellent—as good as the Maxell, in fact, but the response did not go out so high. Figure 7 shows the response from a standard test tape, and the distortion at −1 to +4 VU can be seen in Fig. 8. In order to reduce the possibility of overload, the VU meters are purposely calibrated 3 dB higher than DIN standard. In other words, +3 dB on the 450 corresponds to 0 VU on most other machines. The peak level indicator flashes at about +4 VU—another safeguard against overloading. Distortion was unusually low, being less than 0.5% at 0 VU and less than 1 percent at +3 VU over most of the band (see Fig. 9). Signal/noise came out at −52 dB, increasing to −62 dB with Dolby using CrO_2 or low-noise tapes. Output for 0 VU input signal was 420 mV and the input required was 85 mV. Wow and flutter measured 0.08% (DIN), the lowest we have measured in a cassette recorder, and speed was very accurate—right on the nose. Rewind time was 92 seconds for a C-60 cassette.

Most of our recordings were made with the Dolby system switched in. Incidentally, if you are wondering why no Dolby frequency measurements are shown, the reason is simple—the divergencies were negligible, which is as it should be, assuming the calibration is adjusted correctly. Unfortunately, there are no FM stations in our reception area using a Dolby system, but some Dolby cassettes were copied with complete satisfaction. Because of the excellent signal-to-noise ratio, it was possible to keep the VU meters well below the +3 VU mark and record quite high transient peaks without distortion. The low frequency end was well defined with a solid bass comparable to tapes made with an open-reel recorder. We found the large VU meters easy to read, and all the controls worked smoothly without fuss. All-in-all, a nice machine to use. In terms of distortion, frequency response, and wow and flutter, there is no doubt that the 450 is the best—certainly one of the best cassette recorders available today. And, of course, there are the extra facilities like the provision for a timer and the Dolby copy switch—not forgetting the headphone outputs. Many cassette units do have this last facility but the 450 is one of the few that contrive to give really good power output!

Check No. 62 on Reader Service Card *G.W.T.*

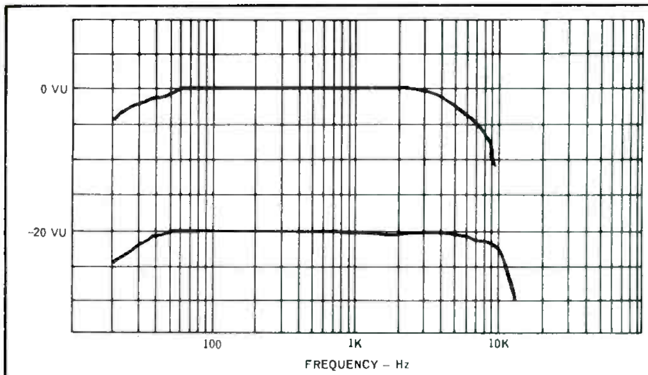

Fig. 6—Frequency response with Certron Gamma 60.

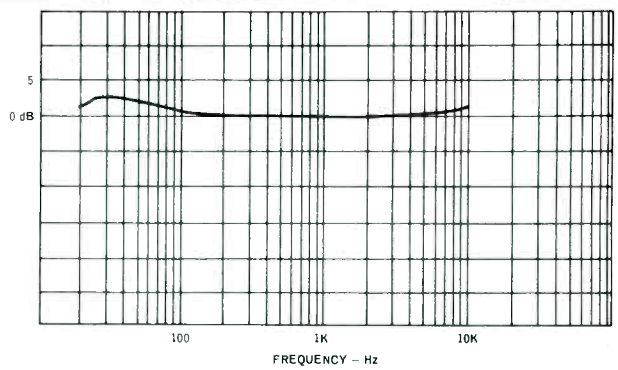

Fig. 7—Frequency response from standard test tape.

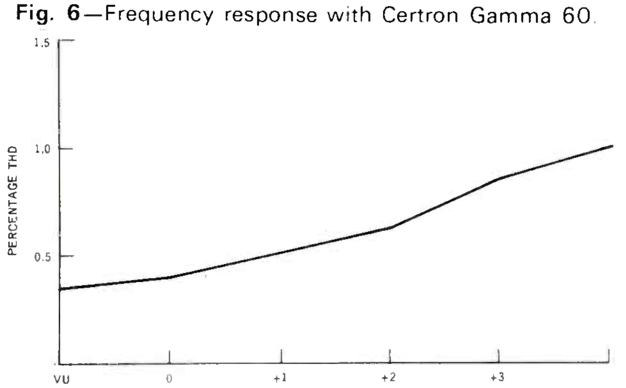

Fig. 8—THD from −1 to +4 VU.

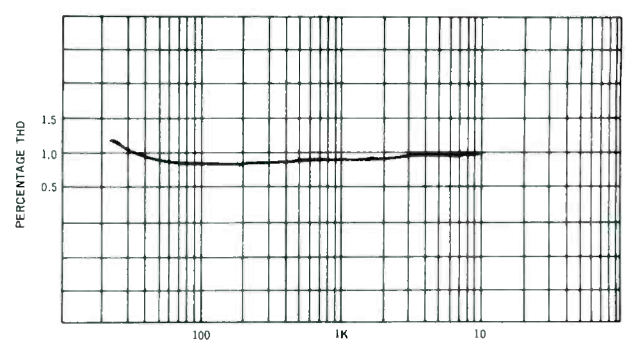

Fig. 9—Distortion versus frequency at +3 VU.

Sherwood's Forest

Sherwood L. Weingarten

I'M DREAMING—with apologies to Irving Berlin—*of a black Christmas.* A while ago, after a short lull in a lawn conversation, one of my suburban neighbors said, "You really *are* color-blind, man." A smile divided his chocolate face. I grinned back, obviously basking in the compliment and the sheen of my white liberalism.

Clank! Too late did I hear the trap close. "No, man, dig!" he continued after just the right pause. His smile was gone now, with mine in hot pursuit. "I've been thinkin' about what you said the other day, about the *Shaft* flicks being nothin' but exploitation of Blacks by other Blacks. That's crap. Black pride's where it's at. Don't matter that the story stinks, or the characters come off as cartoons. Don't even matter that whitey's always the heavy. Only real thing is that we can begin to *identify* with somebody bigger than life who isn't shufflin' his feet every time the man says boo. And that goes for *all* of us, even dudes like me who got out of the ghetto and made it to an *in-te-gra-ted* middle-class scene where they only call you nigger behind closed doors with big brass knockers."

I started to protest. "No, man," he cut in, "don't shoot from the hip. All you'll do is give me an answer you've been programmed to give. Think about it."

"But," I started again. Too late. He'd already turned toward his own home. I stood there, looking idiotic and feeling hostile; I watched the sun bounce off the big brass knocker on his door, imagining that my college-educated engineer neighbor was muttering something like "stupid honkie muthah . . ."

Inside my ticky-tacky refuge, it didn't take long for me to relate to *his* truth, *his* reality. Flash! Picture your own childhood, Weingarten; relive the cringing each time you were called a dirty Jew bastard; remember the crying when you felt like an outsider; recall the shame of just being you, wanting to trade your life with someone else, anyone else. All that pain, and *your* people were pretty well accepted. Too easy to block, to disregard the scars. And too easy to forget what soothed them, the pride you subsequently learned.

Pride, that's *really* black power. So *you* dream of a black Christmas with me, neighbor. It'll be easier now, now that I truly understand a little better. And there's a lot of music around to keep reminding me, just in case.

In particular, there's **THE LIVING WORD** (WATTSTAX 2), a double-disc album of live music from the original movie soundtrack. It's a package swollen with pride, even though the overall product isn't quite as good as the first two-vinyl set from the film based on the Los Angeles Coliseum concert.

It's a Stax production (STS-2-3018) that includes a moving statement by the Rev. Jesse Jackson, who while chanting *I Am Somebody* talks of the beauty of blackness regardless of one's status. It's an outpouring of identity, linking the performers and audience through gospel and soul and rhythm 'n' blues. It's a humorous, R-rated look at black experience through the eyes of comic Richard Pryor, who zeros in on bar life, crapshooting, police-rousting, Saturday night flings and other elements of ghetto living. It's real, it's honest, it's touching; it's vital, it's exciting, it's entertaining.

Most of the showstoppers come on the second record, things like Jonnie Taylor's renditions of *Stop Diggin' Me*, a slow, mournful blues entry, and *Steal Away*, a rocker. Or Little Milton's *Walking the Back Streets & Crying*. Or Isaac Hayes' *Rolling Down a Mountainside*.

But to get the entire texture, a listener must skip nothing. Or risk missing The Emotions (who could pass, if you're not paying that close attention, for The Supremes), Jimmy Jones, the Rance Allen Group, The Golden 13 (which consists of everyone and his brother, almost, whipping out that *Old Time Religion*), David Porter (who generates excitement-plus on *Reach Out & Touch*), Mel & Tim, and the Dramatics (who offer a rocking soul version of *Whatcha See Is Whatcha Get*).

Hear it and you must feel something. Maybe even enough to dig this quote from the liner notes: "Today's nigger is the child of sweat and blood and death and bitterness. Today's Black man is the child of freedom rides and marches and Niagara movements and Atlanta addresses and hope and rhetoric and moonlight marshes with bloodhounds baying."

And if that whets your appetite, you might pick up a copy of **THE SOUL YEARS** (Atlantic, SD2-504), another double-disc winner. Marking the anniversary of Atlantic Records' start, the album is a super history of black music for the past 25 years.

The first two sides are mono, the latter two stereo; all the sound quality is good, however, given the criterion that some of the material came from antique masters.

It all begins with "Stick" McGhee & His Buddies doing *Drinkin' Wine Spo-Dee-O-Dee*, straight rhythm 'n' blues aimed then at a Black-only audience. The final song is *I'll Be Around*, a recent chartbuster by the Spinners. Sandwiched between are too many hits to list, but some of the highlights are Chuck Willis' *C.C. Rider*, one of the first black singles to use white background singers; *What'd I Say*, a Ray Charles swinger that ranks among my all-time favorites; the Drifters' *There Goes My Baby*, which introduced strings to the R&B market; an instrumental success by Booker T. & The MG's, *Green Onions*; *Mama, He Treats Your Daughter Mean*, by a rock artist long before the term had real meaning, Ruth Brown; and The Clovers' *One Mint Julep*, an R&B hit that years later was covered for the white market and turned into a global smash by Charles.

If you want to pre-date the now kind of rock, this is the place to look. And if you desire to pre-date even R&B, find **LEADBELLY** (Playboy, PB-119), a live album with 18 mono recordings taken from a concert at the University of Texas in Austin.

The disc, of material performed June 15, 1949, half a year before the folk-singer died, was created from a wire recorder original, so the sound quality isn't the best. But it is the only "live" Leadbelly album around.

It's all him, Huddie Ledbetter, his 12-string guitar, his fading voice, his sense of humor and sense of self, except for the last two cuts, when his wife, Martha, joins him on *Old Ship of Zion* and *I Will Be Glad When I Get Home*.

Irene Goodnight is offered twice, perhaps to make up for an abbreviated version of *John Henry*. *Skip to My Lou* is sprightly and *Rock Island Line* as good as any, but *Old Hannah* shows the range narrowed, the energy sapped. All but two of the tunes are Leadbelly's, or traditional, the others being Bessie Smith's *Backwater Blues* and Irving Berlin's *I Don't Want No More of Army Life*.

It's sometimes too talky, with virtually every number being introduced at length by the singer, and it's sometimes almost embarrassing, especially if you're a collector of his earlier Folkways records. But if we're talking about pride, baby, it's a milestone.

Still, perhaps the pride you want to deal with is more modern. In that case, we can shift to **SOUL MAKOSSA** (Paramount, PAS 6061), pure Afro jazz that could give a listener whiplash through shaking his head so hard to the driving, driving, driving rhythms.

Babatunde Olatunji comes out of hiding for the first time in four years to sing and play African drums on five tracks. According to Olatunji's liner notes for the Famous Music-distributed disc, the past and present merge "in all the selections, the impact of Africa is felt throughout, polyrhythmically and in the catchy melodies." Odd thing. He's right.

But what he doesn't say is that the music is totally infectious; even if your forebears didn't suffer as slaves, even if your skin is so light the merest hint of sun burns it, you are compelled to move and feel and think black, if only for the time the turntable spins.

Modern in a different way is **THE WORLD OF IKE & TINA** (United Artists, UA LA064-G2), another two-record package, this one covering a live European tour by the Turners. Hysteria and perspiration and exhaustion are the order of the day when sexpot Tina deals out her soul goodies with hubby and background outfit, the Ikettes.

Witness the onset, the everpresent *Theme from "Shaft,"* or the finale, *1-2-3*, rock 'n' soul to please any audience. Or a golden newie, *River Deep, Mountain High*. Or *Let Me Touch Your Mind*, undoubtedly the song with the rawest emotion shown in the last decade.

Possibly you want to hear them doing other performers' works; listen then to Joe Tex' *I Gotcha*, the Beatles' *She Came In Through the Bathroom Window*, *With a Little Help From My Friends* and *Get Back*, Joe South's *Games People Play*, Mick Jagger's *Honky Tonk Women*, and Otis Redding's *I Can't Turn You Loose*.

You're defied to remain still; you're challenged to be uninvolved. Impossible on either count.

Blackness, of course, can transcend many musical arenas, and is absolutely comfortable in the pop field. Witness **PLAY ME** (RCA, APL-1-0094), a slick, slick, slick outing by Harry Belafonte, and **KILLING ME SOFTLY** (Atlantic, SD 7271), a glossy, professional presentation by Roberta Flack.

Belafonte slows everything to a moody pace, inviting a switch of the light-dimmers; romance and melancholia come to the fore. Best of the 10 cuts are *So Close* and *Long, Long Time*, a pair of duets with Eloise Laws, whose voice blends neatly with the ex-calypso king's.

Top solos include a couple penned by Neil Diamond, the title tune and *Morningside (for the Children)*, the latter featuring the Meri Mini Players, a kiddie chorus, and Don McLean's *And I Love You So*, a pretty piece with marvelous guitar work by David Spinozza.

The Flack album, on which the moods vary radically from number to number, proves again that the songstress is superb in her ability to communicate. On many levels. She changes, for instance, from funky (*River*) to brassy, honky-tonk (*When You Smile*) to pathos-filled (Janis Ian's *Jesse*), with no loss of impact. She can be ebullient (*Killing Me Softly With His Song*, a top-of-the-charts scorcher) or bluesy, still opting for the perfect touches of soft rock and gospel, as on *No Tears (In the End)*.

Without question, though, she's better than any thrush around when she tackles a piece with depth, as in her nine-minute, forty-five-second rendition of Leonard Cohen's haunting *Suzanne*, a thing of beauty originally that now bursts with poignancy and pure Roberta Flack soul.

DELIVER THE WORD (United Artists, UA LA 128 F) is still another instance of Black togetherness, though the artists, War, allow a tinge of white to creep in. Maybe that's because the seven-man group is only six-sevenths dark-skinned.

At any rate, the perpetrators of *Cisco Kid*, a song I learned to hate because of Top 40 repetition, come up with a magnificent rock-pop entry, *Gypsy Man*, which drives and builds, drives and builds, drives and builds until you almost can't stand the peak excitement. And the 11:35 version presented here far outshines their abridged hit that's currently burning up the airwaves.

H_2 Overture, in contrast, is a multi-mood jazz instrumental, simple yet beautiful. *In Your Eyes*, with lots of synthesizer sounds, spotlights vocals that combine soul and rough pop. The title tune, a change-of-pace sleeper, is slow and gospel-inspired, though it's toned down and cleansed. *Southern Part of Texas* is a raucous offering, reminiscent of *Cisco* in spots (mainly through its use of redundancy of phrasing, its blending of voices and occasional vocal gimmickry). The big happy surprise, however, is *Me and Baby Brother*, a heavy rocker of the first order whose title disarms you into thinking in lullabye terms.

Variety, expertise with instruments, success, and just think, they're doing it all without Eric Burdon.

Speaking of doing without, **MUSIC FOR SOULFUL LOVERS** (Buddah, BDS 5139) manages to completely eliminate soul. The misnamed Cecil Holmes Soulful Sounds performs a whitewash on Black tunes, turning soul hits into something not far removed from results obtained by the Mystic Moods Orchestra. There's really nothing wrong with it, if you don't mind blandness instead of Blackness, a Muzak sound sure not to intrude on your activities or thoughts.

An idea of what's offered can be found in the titles: *Break Up to Make Up*, *You Are the Sunshine of My Life*, *Pillow Talk*. If the orchestra is soul-searching, somebody else better show them the way.

As for me, I'll just keep dreaming of a black Christmas.

Classical Reviews

Edward Tatnall Canby

Messiaen: Quartet for the End of Time. Le Merle Noir. N.Y. Philomusica Ensemble, A. Robert Johnson; Paige Brook, fl. **Vox Candide CE 31050,** stereo, $3.98.

Here is Vox's excellent intermediate line, continued (together with Vanguard's Cardinal series) with great musical success where the original from Elektra failed. The idea is to offer lower-priced recordings that are all new, not reissues, and it is a good one.

Messiaen's music is a problem for many of us; it is largely charged with religious symbolism, out of his passionately Catholic faith. Needless to say, this kinship with the more astrological mysticisms now popular has produced a lot of Messiaen in concert and on records lately, to catch the wave of the moment. This work, the *Quartet for the End of Time,* is an early piece and some say the composer's greatest, even if for small ensemble. The symbolism is there—just read the accompanying notes (or don't, if you'd rather just listen), but the music stands very easily on its own expression. Out of the early and distressing WW II years, performed first in a German prison camp, it has a refreshingly dry, spare quality of great clarity and color, which is excellent for the recording mics. And only occasionally do we feel that fanatical need to go on and on which creeps into so much mystic-based music. The little *Merle Noir* (Blackbird) piece is a competition bit for flute and piano. Flute players naturally love it and maybe you will too.

Performances: A Sound: A-

Handel: Royal Fireworks Music (Original scoring); The Water Music (Suite). English Chamber Orch., augmented wind ensemble, Johannes Somary. **Vanguard VSD 71176,** stereo, $5.98.

What a splendid noise! There have been dozens of versions of the Fireworks Music, from Sir Thomas Beecham onwards, but this is the first to my knowledge with a sound I have always wanted to hear—*twenty-four oboes* all going at once. Plus 12 bassoons and 2 contrabassoons, not to mention two serpents, 9 trumpets, 9 horns and all manner of drums. It must have been quite a show in the original outdoor performance before King George, a victory celebration that ended up in a glorious fire when the fireworks went off and burnt the place down. It *is* a splendid show, for the ears, just as I knew it must be, and young Johannes Somary, at last, has got the right ornaments, trills, what-not, into the bare bones of the music, and a rightly lively, peppy set of tempi, all according to the latest (and best) musical thinking for this type of performance. Sir Thomas Beecham would turn green in his grave, though not with envy.

In accord with current English practice, the instruments are modern ones, as far as I can see, except for the two serpents, gargantuan coiled affairs like pythons, invented in Handel's day. In Germany, they would use "Baroque oboes," with a fruitier, more raucous sound, and I would have liked that even more. But this is plenty good and what counts, remember, is the musicality of it all. *Very* musical.

The Water Music numbers, it was long ago recognized, fall into two main keys and were very possibly originally composed according to those keys, at different times. The Suite here recorded (with an "ordinary" Baroque orchestra) follows this thought, with two parts, one in F, the other in D, as have other modern recordings.

Performances: A Sound: A-

Wagner: Die Walküre. Bayreuth Festspiele, Karl Böhm. **Philips 6747 047,** 4 discs, stereo, $27.92.

This monster album was ingeniously recorded "live" at the actual Bayreuth Wagner festival, one album in a series that, presumably, aims at the entire Wagner catalogue of operas. This is part of the entire "Ring," all conducted by Karl Böhm. I have discussed the implications of this daring and risky "live" recording technique in "Audio, E.T.C." (February, 1973)—I note here merely that the project is astonishingly successful in view of the risks inherent in any "live" recording, and that the musical aspect, while not really as forceful as the powerhouse Von Karajan Wagner, at least in recorded form, is far ahead of much weak-voiced Wagner we were hearing on discs a decade or so ago.

The lead singers, including several distinguished pairs, male and female, are once again (on records at least) both powerful and long-breathed, equal to the heroic expression; the orchestra, beautifully recorded in the unusual dry Bayreuth acoustic, is also very much alive. For awhile, many of us had thought that Wagner was effectively dead for contemporary performance. Not so!

Siegmund and Sieglinde are sung here by James King and Leonie Rysanek, he an adequately strong sub-hero (though not vocally quite up to old Melchior, the vocal paragon of Wagnerian heldentenors), she a somewhat appealingly tremulous wife-sister, in the famed "incest" scenes. (Brother discovers long lost sister, carries her off in triumph to produce Siegfried.) Brünnhilde and Wotan are Nilssohn and Theo Adam, an excellent pair for these roles; Adam also has his vocal duals with wife Fricka, Annalies Burmeister, who upholds the sanctity of marriage and is anti-incest in very convincing terms. And so it goes. The pace isn't too even, the long continuity not as strong as it might be, but there is so much genuine singing/acting here, so much dedication, that the work is really very well served. The accompanying booklet and text is invaluable, for any serious listening.

Presumably the other operas are done in similar fashion—I haven't plunged into them yet. (On records, I don't see why I can't do one act an evening when it comes to Wagner. No point in torture, after all, unless you are in the actual opera house.) You can get the entire set of four, the whole of the "Ring" in one colossal album, if you wish. I haven't counted the sides but there should be maybe around 32, if not more. Now *here's* where we could use one of those four-hour LPs. . . .

Performance: A- Sound: B+

Glenn Gould's First Recordings of Grieg and Bizet. Columbia M 32040, stereo, $5.98.

Glenn Gould, the pianist who never plays "live" concerts, has always been a Romantic in his personal piano style and, indeed, was one of the founders of the current "neo-Romantic" style, now embraced by dozens, hundreds, of younger artists with longer hair. Yet Gould has mostly recorded the earlier keyboard classics, notably Bach, and—a big jump—the post-Romantic German school, notably Schoenberg. Here, he explores the high Romantic period.

I don't know the Grieg Sonata Opus 7 well enough to make comparisons with two other recordings, nor does it matter. One buys Gould for what Gould has to say. Even in a new pianiatic era, Gould is here very much himself and characteristic Gould—which means that the playing is technically expert (his fingers can cope with any problem) and at the same time, he is constantly probing, exploring in depth, note by note, chord by chord. He is always that way. Never a flashy moment, always that same blazingly serious direct concern with ultimate meanings—the confrontation of souls in musical terms. I don't mean to be facetious—far from it. That is the way Gould is.

If you are a Bach-Mozart-Scarlatti type, you may find this late Romantic music a bit weighty, if solid and brilliant; Gould doesn't try to make it fly when it doesn't want to. It was a heavy era. He dwells, as he always does, on many a detail, with much rubato, that emotional hesitation in tempo that is a part of the Romantic style. This makes things not quite as simple as, say, in a flying Rubinstein or Horowitz performance, all superb bravura! Again, no matter; Gould is Gould, and why not.

Gould writes a caustic note to critics of his playing, enough to curl the toes off some big-city music critics, who distrust his non-standard thinking (and particularly his lack of interest in the conventional piano concert circuit). As a record critic I agree with his thoughts but must observe (as a writer) that his playing is better than his satire, which gets thick. But the notes on the music itself, also by him, are excellent and meaningfully first-hand.

Performances: A   Sound: B+

Strauss: Sonatina in F (1943) "From an Invalid's Workshop"; Suite in B Flat, op. 4 (1883/84). Netherlands Wind Ensemble, Edo de Waart. **Philips 6500 297,** stereo, $6.98.

This is a companion disc to another absolutely first-class Strauss recording by the same group, the Symphony for Wind Instruments ("The Happy Workshop") and the Serenade Opus 7—the two together are not only the best Strauss wind playing I ever hope to hear but the best wind playing, period. Astonishingly fine, and beautifully recorded too. I'd rate these as milestone recordings and nothing less. Also as first rate entertainment in sonic terms.

Each of the two discs offers a very late Strauss work on one side and a very early one on the other, and one feels immediately the relationship—over a 60-year span, in which fit all the big Strauss pieces you ever heard and plenty more. It is an intimate and continuing one, the young, ambitious composer, not yet the overbearing, all-conquering success of his later youth, and the old, old man, now philosophically reminiscing, a superbly expert craftsman still and a man at last humble in the face of approaching death. He was in his eighties.

There are wind groups galore on records. Their all-too-common failing is professional narrowness. Everything they play is virtuoso in performance and it all sounds exactly the same. Look at us—we are WINDS, and *are* we professional! Gets to be extremely boring for those of us who know other music and resent, say, having our Mozart or our Strauss treated as so much fodder for professionalism at the conservatory. Not these young players! They have a miraculously musical way of playing, a perfect ensemble, a marvelous sense of style, a long, sensitive line, superbly intelligent balance among the parts, and an over-all humbleness of approach that is hard to believe in this day of brash professionalism. If you want to hear wind music, go no further. (They have also recorded a lot of Mozart.)

Performance: A Sound: A

Khachaturian: Piano Concerto. Liszt: Hungarian Fantasia. Entremont; New Philharmonia, Ozawa. **Columbia MQ 31075,** SQ quadraphonic, $6.98.

"Hatchet-urian!" It's been ages since I've heard this once-super-popular Concerto, the favorite vehicle of the late William Kapell before he went down in a plane accident. "Khachaturian Kapell," we used to call him. Now, the gentler but equally firm pianism of Philippe Entremont brings it back in an altogether new kind of sound, and I'm not meaning just the quadraphonic.

A number of interesting points. Khachaturian, after Shostakovitch and Prokofiev, was one of the big Russians whose music suddenly invaded the U.S. in the 30s and again continuing after the war—loud, clear, immensely difficult and hard as nails in the externals, this music suited the mood of the time. Kapell, too, was of the hard-fingered pianistic generation, those who streamlined Romantic music to make it dry, tough and really modern, and played this clattery kind of concerto with fierce joy and chrome-plated vigor. On records it was, if not chrome-plated, plenty tinny! The cutting styli (and the playing needles) of the day simply could not cope, and exaggerated the steely, chrome-dry sound. That's the way I remember Khachaturian.

But Entremont, French, is of a much gentler generation, a powerful pianist of course, but of a very different keyboard persuasion. He plays for music, almost neo-Romantically, for all his power. And the recording, natch, is as smooth as silk! No problems. So if you want to hear the New Khachaturian, this is it. Liszt too.

Performances: A– Sounds: B+

Hermann Goetz: The Complete Works for Solo Piano. Adrian Ruiz. **Genesis GS 1023,** stereo, $5.98.

Sometimes, I'm thinking, the present "Romantic revival" seems a conspiracy among pianists—practically everything is for piano. No matter! It's all very instructive and often interesting.

This little pipsqueak guy, who managed to survive until he was 36 before dying of TB, wrote a lot of quite progressive mid-century music, far stronger than most of the piano junk that survived in front parlors on into the early 20th century. He was a real musician and no copycat, either. The piano music, on a small scale, nevertheless flows and lives; it's real. Howcome nobody ever heard of him, until the recent revival? Well, all the usual reasons, mostly of the arbitrary sort that bury dozens of good musicians after their day, including Bach and Schubert. But there are good musical reasons too.

On the basis of these piano works, I sense a very definite wall that limits the fluent and often lovely expression. Two minutes of a Brahms, a Schumann, a Mahler work and you hear the difference.

And yet—there's so much that is *less* interesting! The celebrated *Songs Without Words* of Mendelssohn, for instance, which today seem nothing but sentimental claptrap. They were awesomely famous throughout the past century. Our grandparents still played them. For today, Goetz is far preferable in the listening. You might call him a mild earlier Grieg, though Grieg was both cornier (more "commercial") and stronger, whether for good or bad.

Adrian Ruiz plays these with cool-fingered competence, making of himself a good transducer from printed score to listening ear. A few of the pieces are unexpectedly virtuoso—he has a bit of occasional trouble here, if not without reason.

Performance: B Sound: B+

* * *

Classic Film Scores for Bette Davis, RCA ARL1-0183, $5.98.

Yes, I'm a Bette Davis fan, too. But the music here collected is, generally, of a banality unimaginable. Especially when you consider that Miss Davis herself has never been dull or flaccid, even when her roles were occasionally beneath her.

Charles Gerhardt recorded these film scores fresh this year. Eight of the twelve were written by Max Steiner, the others by Korngold, Waxman and Newman.

The famous theme from *Now, Voyager* works better when you can see what's happening up there on the silver screen. Without the visual aids, the score sounds polite, a little rarefied (like the story). The music for *Dark Victory* is melodramatic and a bit overstated, but the *Blindness* theme recalls those last poignant moments when everything went blurry. I had forgotten how richly orchestrated Steiner's *A Stolen Life* was, and what grand passion is suggested by Korngold's F-sharp theme for *The Private Lives of Elizabeth and Essex.* Franz Waxman's clairvoyance was evidenced by his use of dodecaphony in *Mr. Skeffington*, with its unresolved chords suggesting panic, frustration, ultimate silence. Alfred Newman's music for the classic *All About Eve* catches the glamorous excitement of backstage life, but it also has an integrity to it that points at larger human issues—issues that authentic theatre itself points to.

The other themes are mediocre at best. Liner notes see profundities in shallow music, and sound vaguely beefed up, lacking the candor of author Tony Thomas' book, *Music For the Movies.*

This album should be marked "Restricted to film addicts who are as undiscriminating as the album's producers." *Donald M. Spoto*

Classified

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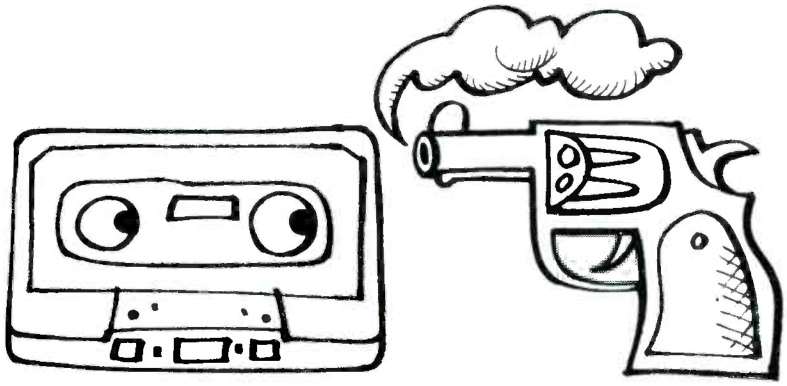

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THOUSANDS OF OLD RADIO COMEDIES, Dramas, Band Remotes, Mysteries, etc., $6.00 for 6 Hour Reels. Catalogue: $1.00 (Refundable). Cassettes also available. RADIOVOX 1756 Washtenaw, Ypsilanti, Michigan 48197.

REAL ESTATE

IDEAL 5-ACRE RANCH. Lake Conchas, New Mexico, $4,975. No Down. No Interest. $30/mo. Vacation Paradise. Good investment. Free Brochure. Ranchos, Box 2006 JF Alameda, California 94501.

SONGWRITERS

GET IN ON THE MONEY to be had in the booming song and music world as a lyric writer. Co-write with me on a 50-50 basis. Publishers contract guaranteed. Recording promotion. Send lyrics with stamp: Paul Jackson, Rt. 9, Box 292-cr, Athens, Ala. 35611.

INVENTIONS WANTED

PROSECUTE YOUR OWN Patent Application. All Material Necessary—Write: Inventors Service, Box 3574, Washington, D.C. 20007.

PLANS & KITS

WAVEFORM Generator Kit $10.00. Stereo Multiplex Kit $19.95. Free Kit Catalog. Photolume Corp., Box 139, N.Y., N.Y. 10016.

PYROTECHNICAL chemicals, casings, tools, supplies, fuse, literature. Giant, illustrated catalogue/handbook includes formulas, instructions—50¢, with samples—$1.00. Westech, Box 593, Logan, Utah 84321.

ELECTRONIC PARTS, semiconductors, kits. FREE FLYER. Large catalog $1.00 deposit. BIGELOW ELECTRONICS, Bluffton, Ohio 45817.

AUDIO DEALER PRODUCTS

AT LAST! DEPENDABLE, LOW COST Component Switching Devices for A-B comparison of speakers, amplifiers, and tape decks. Write for information and prices to—B.A. Kunz Electronic Equipment, 12111 La Padera, St. Louis, Mo. 63033.

REPAIRS & SERVICES

AMPEX AUDIO & VIDEO PARTS-SERVICE-TAPE. Jones Electronic Service Co. 947 Old York Road, Abington, Pa. 19001. (215) 887-1522 or 568-7711. Expert Service on all brands of Audio & Video Equipment.

FILMS

CAGNEY! BOGART! CHAPLIN! KEATON! DRESSIER! FAIRBANKS! Many more. The usual, the unusual; 16-8MM, sound & silent. 200 ft. sampler reel, $2. Catalog free. Thunderbird, Box 4081 AM, Los Angeles 90054.

SITUATIONS WANTED

NEED JOB AS CLERK, TYPIST, CASHIER. Pvt. J. Doyle, C-13-4, USAARMC, 266-39-1700, Fort Knox, Ky. 40121.

HOLOGRAPHY

HOLOGRAMS

You've been on a sound trip for a long time! Add a visual trip! Experience HOLOGRAPHY. True three-dimensional pictures for only $10.00. You will receive a 5"x5" hologram, filter, and easy instructions for viewing with your slide projector. Send check or money order to Holex—Box 65-G Eagleville, Pa. 19408.

1973 ANNUAL INDEX

LOUDSPEAKERS

MICROPHONES

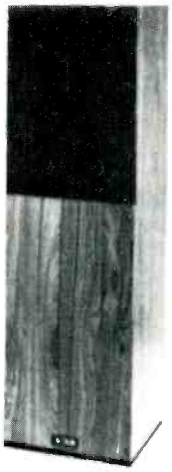
QUADRAPHONICS

SURVEYS AND DIRECTORIES

TAPE RECORDERS

TURNTABLES

WORKBENCH



Author Index

I bought a Marantz 4 channel receiver because I refuse to be stuck with an electronic antique.

Not one to tolerate obsolescence (planned or unplanned), I considered the stereo vs. 4-channel question carefully, then purchased a Marantz receiver for three compelling reasons.

One. Marantz has Dual Power. This means you get full power of four discrete amplifiers working all the time. When you're listening to regular 2-channel tapes and records you can combine the power of all four channels into the front speakers. This means even if you're not ready to commit yourself to a complete 4-channel system, you can buy Marantz now and when you get the other two speakers just flip a switch. You have 4-channel. Meanwhile, you're not compromising 2-channel because you're getting more than twice the power for super stereo.

Reason number two. Marantz receivers feature the exclusive snap-in snap-out adaptability to any 4-channel matrix decoder. This means that your Marantz stereo will never be made obsolete by any future 4-channel technology because the Marantz snap-in SQ* module is designed to keep up with the changing state of the art. What's more, Marantz receivers have Vari-Matrix — a built-in circuit that will synthesize 4-channel sound from any stereo source (including your stereo records and tapes) and will also decode any matrix encoded 4-channel disc or FM broadcast.

Reason number three. Marantz receivers, from the Model 4230 up, feature built-in Dolby** noise reduction to bring you the quietest FM reception ever. And you can switch the built-in Dolby into your tape deck for noise-free, no-hiss recording from any source. A real Marantz exclusive.

I chose the Marantz Model 4270 because it suits my needs perfectly. It delivers 140 watts continuous power with under 0.3% distortion. And it's literally loaded with features. However, your requirements may be more modest than mine. In which case you can own the Marantz Model 4220 which delivers 40 watts with Dual Power. Or you can go all the way and get the Marantz Model 4300 with 200 watts. It is the very best. Choose from five Marantz 4-channel receivers from $299 to $899.95.

The point to remember is this — whichever model Marantz 4-channel receiver you do buy, you can buy it today without worrying about its being obsolete tomorrow. Look over the Marantz line of superb quality receivers, components and speaker systems at your Marantz dealer. You'll find him listed in the Yellow Pages. Think forward. Think Marantz.

marantz.
We sound better.

*SQ is a trademark of Columbia Broadcasting System, Inc.
**TM Dolby Labs, Inc.

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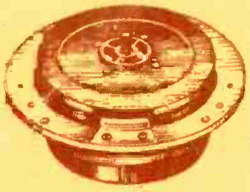
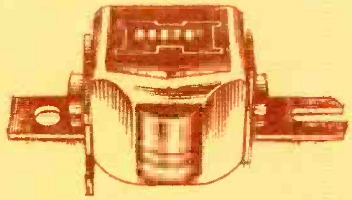


DIRECT DRIVE DC MOTOR

+  + Dolby

+ CrO_2 =

Frequency Response	20Hz – 17kHz
Wow & Flutter	Less than 0.10%
Signal to Noise Ratio	More than 60dB

We made up the formula. But we didn't have to make up the specs. Because they're from our RS-276US cassette deck and they really speak for themselves. But the features that make them possible are worth a closer look.

The direct drive DC motor puts the capstan right on the motor shaft. Does away with gears or belts. And substantially reduces wow and flutter.

And our patented HPF™ recording/playback head means reliable high frequency response. Because its super-hard composition resists wear for ten years.

There's Dolby* to deal with tape hiss. And it's adjustable for any kind of tape.

And the recording bias can be switched to take advantage of the superior frequency response of CrO_2 tapes.

Some of the other outstanding features are solenoid-operated function controls. Locking pause control. Photo-electronic Auto-Stop. Three-digit tape counter with Memory Rewind. And optional remote control.

The RS-276US. The concept is simple. The execution is precise. The performance is outstanding. The name is Technics.

*Dolby is a trademark of Dolby Laboratories Inc.

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