THE B.A.S. SPEAKER

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In This Issue

Have you ever wondered whether the popular method of computing amplifier power on the basis of dollars per watt was really meaningful? It has been accepted practice to think this way for so long that few of us challenge it. But with the advent of the super-power amplifiers, the time may have come to reconsider. What the super-amp buyer purchases, after all, is a number of extra decibels of headroom before clipping—the exact number of watts necessary being perhaps more a matter of the efficiency of his associated speaker system than of any other system characteristic. Thus it becomes appropriate to think, maybe, in terms of dollars per dB of headroom. Connecticut member Tom Mashey does some ground breaking for us along these lines in this month's issue, and at the same time evaluates many of the most popular amplifiers in terms of their $ /dB rating. Some of the results may surprise you; you may even consider a slightly lower powered amplifier if your speaker system has the necessary efficiency.

Within the issue are notes on a variety of topics of interest to members: A modification to the Dynaco ST-400 (developed by Dyna) that is said to improve its high-frequency performance—one of the few areas, according to many, where the Dynaco unit might be lacking; a word of timely advice for Sound Advice subscribers—don't miss this one if you hope to see another copy of the magazine; use reports on various products including the Fulton J Modular speaker system, the Dual 1249 "professional" changer, the Sonus cartridge—which, appropriate to the season, appears like a second coming of the XLM; the ADC-XLM Mk. II—the real second coming (ADC owns the trademark) of a price-performance champ, this time in a more usable form.

Of special interest is a short note on what may be the first of the PCM-master-taped records to become available. We have been waiting impatiently for records derived from pulse-code modulated tape masters, and now they are appearing. A first hearing seems to bear out our hope for higher quality software. Also, in the same department, there is word of another small record firm entering the field with a vow toward quality; those who want discs as interesting to listen to as they are effective for demonstration should pay attention to Insight Records. And, of course, to forthcoming PCM-mastered discs.

There are other random notes including one you should read if you own a color TV set. The x-ray danger from these devices has long been known, and now there are agencies in state government that can evaluate your set for potential danger.

Next Month. Epistemology will break into full flower in the January issue of the BAS Speaker as Dan Shanefield and John Sprague further explore the territory opened in October on the way we learn/perceive/judge sound. The impact of this article on purely subjective equipment reviewers should be great; tune in. Also featured in January will be an article on high-frequency add-on (more properly, substitution) speakers for your system. Bob Graham has lengthy experience in custom speaker design, and intimate familiarity with electrostatic and ionic mid- and high-frequency drivers. He will review the Janszen electrostatics and the Ionovac next month—the latter being perhaps the best speaker ever produced, and one with the least acceptance. But audiophiles never made claim to rationality.

Erratum

In my article on Rectilinear HI quality control problems (BAS Speaker, Sept. 1975), I mentioned the lack of a chamber to seal the backs of the tweeters. Upon removing the tweeters from my Rectilinear III I find that the stock tweeters used are sealed units and do not require an additional chamber behind them. Rectilinear isn't the only one who makes mistakes.

— Jim Nichol (Massachusetts)

For Sale

- Burwen DNF-1201 noise filter, $200. Sumner Bennett, 491-0256 evenings.
- AR receiver and turntable, excellent condition, price negotiable. Victor Anderson, P.O. Box 139, Cambridge 02138, or 492-7049 evenings.
- AR FM tuner, superb condition, unit has been little used, $160. Two KLH-6 speakers (scratched), collector's items, over ten years old, made when the woofer basket was epoxied into front panel; one ebony, one lacquered walnut, $50 each. Two KLH-5 speakers, a matched pair with outboard crossover networks (can be biamped or triamped), $200 for pair. The following items were purchased by Advent for evaluation purposes; each has been used less than ten hours and is in perfect condition: Tandberg TCD-300 cassette deck, $200; Teac 450 cassette deck, $200. Andy Petite, 661-9500, ext. 238 days; 492-1997 evenings.
- BASF CrO_2 C-90 cassettes, case of 20, $45. Bob Borden, 276-3417 days.
- AR Tuner, immaculate condition, $125. Ace Zero-Distortion Preamp, excellent condition, $50. Ken LaFleur, 749-2219.

Wanted

- Would someone be interested in doing a phase-locked loop modification to my receiver? Price negotiable. Bernard Shavelson, 535-4242 days.

More Holmania

Last month's extended discussion of the Holman tests still left some points more implicit than explicit. To wit:

- The samples of the preamplifiers tested were statistically not significant; just as one swallow doesn't make a spring, one data point doesn't make a trend line. However, we feel that the rankings will generally stand up. Closely spaced preamps might exchange places in the rankings, but based on what we know of these tests, rankings are apt to be more a matter of basic design than of unit-to-unit variation. If this sounds like the Consumer's Union copout of saying that "differences of ten or so accuracy points are not judged significant," it isn't meant to. We will admit to some variations, but generally we'll stand behind our rankings.

- There may have been too much stress placed on rms voltage levels in the meeting summary and feature article. One BAS member, Abbott W. Lahti, obviously knowledgeable in such matters, wrote to ask whether the voltmeter used was in fact capable of making true rms measurements;

to the best of our knowledge, it was, but this measurement was of much less import (and perhaps without much meaning) than the spike voltage. That's why we drew a picture of what the scope showed, both because the rms measurement is hard to make with such waveforms, and because of the importance we attached to the spike.

• A low-pass filter was used to duplicate the Holman square-wave tests. Although Holman had designed such a filter into his test setup, we found that because of cable capacitance, etc., we had achieved the same effect without the use of discrete components. Sorry for confusion on this point. Note, too, that we repeated these tests on several preamplifiers with Holman's electronics and found no disagreement with our own results.

• Finally, the effect of this new information on comparison tests of phono cartridges should be apparent to everyone. It is no longer enough to say that one cartridge sounds better than another unless you can characterize the preamplifier with which the test was made. Even this might not be enough. It may well be necessary to standardize on a phono preamp without complex impedance interaction, with a correct RIAA curve, flat frequency response, and excellent even-harmonic distortion performance. Only with such a preamp, it seems, might comparisons of phono cartridges approach validity. And because these are still subjective tests, the word "approach" is used advisedly. As for prior cartridge tests mentioned in the BAS Speaker, we were fortunate in that almost all were made using good preamps (i.e., Marantz 7C). Thus, our downrating of the MicroAcoustics cartridge must stand unless the product is improved; our high ratings of the original XLM and Shure V-15 Type III cartridges similarly stand. But cartridge testing in the future will be more certain, at least where the preamp is concerned. — Jim Brinton

BEEPer's Workshop

Boston Experimental Electronic Music Projects, known as BEEP (the M is silent), is holding an advanced workshop which BEEP President Robert Ceely calls to the attention of the school's alumni, electronic music composers in general, and "others versed in the ways of electronic music, but with a hunger for more." It will cover basics, a review of the present state of the art, and some projections of future trends. The fee is $75, and it might be enough just to get the chance to work with the equipment available—a list much too long for this space.

The workshop runs weekdays January 12 to 23 and covers: sound generation, sonic control, event notation, sound storage, studio configurations, and individual time spent working in the BEEP studio. For information (quickly) contact Bob Ceely, BEEP, 33 Elm Street, Brookline, Mass. 02146. Phone (617) '731-3785.

Audio Equalizer from ACE

Kit and assembled versions of a new audio equalizer from Ace Audio will appear in stores soon. Those who have liked the no-frills features of the Ace Z-D preamp may like the firm's AE 2002. It has five equalizer bands centered at "bass," 250, 1000, 3500 Hz, and "treble"; there are separate controls for each channel. Ace specifies less than 0.05% distortion (harmonic and/or IM), hum and noise at -80 dB, and 2 volts output into 10,000-ohm loads. Price is $84.25 list for the kit; $133.75 for the wired version. We have no hands-on data on this unit, it having just been unveiled.

Sound Advice for *Sound Advice* Subscribers

Not everyone is an avid reader of the want ads in the back of Audio. but one plaintive ad appeared that many BAS members might be interested in:

Sound Advice Subscribers: The entire technical staff of the magazine remains together and continues to create the quality work you expect from us. We are changing publishers. If you wish to receive our magazine, send a Xerox of your cancelled check with your name and address to me personally: Peter Moncrieff, 2449 Dwight Way, Berkeley, California 94704.

Several BAS members brought this to our attention, but the award for distance goes to O. H. Stewart, Lincoln, Nebraska. Thank you all.

Dynaco Stereo 400 Modification

Owners of ST-400's disconcerted by the hint in the latest issue of The Stereophile that whereas the ST-400 was excellent in the low end, its high end was lacking (compared with that of the Ampzilla), can take heart from Dynaco itself. The company is publishing a modification note with high-end improvement in mind, which we reprint here in toto.

"The value of R305 in the Stereo 400 power amplifier has recently been changed by our Engineering Department from 10 ohms to 1.8 ohms to provide improved high-frequency square-wave response into reactive loads. With the most critically revealing loudspeakers, a subtle improvement in high-frequency sound quality will result.

"ST-400 kits and factory-assembled units will incorporate this change on or about July 15, 1975. The new choke coil assemblies will be black colored for easy identification, while the existing coils are copper colored. Resistor R305 is the form about which the coils are wound.

"If you wish to replace the choke coil assembly in your Stereo 400, the new coils may be ordered from Dynaco after July 15, 1975, at a cost of $6.00 the pair, postpaid. When ordering, specify (2) part #453001 and attach your check to this message in prepayment. No COD's, please.

"Owners of existing ST-400s may find it easier to perform a simple modification to their amplifiers to exactly duplicate this change. Purchase a pair of 2.2-ohm, 2-watt, ±5% resistors. Dynaco does not stock these resistors. Each resistor should be positioned along the upper edge of the existing copper colored choke coil assembly, on the Relay and Fuse Mounting Plate, near the front of the amplifier. The resistors should be soldered in parallel with the choke coils: solder one resistor between terminal strip lugs 3 and 11, and the other resistor between lugs 6 and 12. This completes the modification."

Other than the cues noted by Dynaco, there is one other way to determine whether your ST-400 may already have this modification. Check the parts list; if a 10-ohm resistor appears instead of a 1.8-ohm resistor, you require the modification. This is unambiguous as there is only one 10-ohm resistor (per channel) on the list in non-modified units, and it is the one replaced by the latter, lower value unit. — Dennis Boyer (Massachusetts)

Going on (About) Record(s)

The first of the pulse-code modulation (PCM) encoded discs are beginning to show up. We have known that they were coming for about two years, ever since two Japanese companies, Oki and Nippon Columbia, ran articles about their PCM tape recorders in the Journal of the AES (Sept. 1973, pp. 535 and 542). The advantages claimed (reasonably) for PCM recording include: almost complete freedom from crosstalk, phase shift, print through, and distortion; complete freedom from wow, flutter, and modulation noise; and ultra-wide frequency response and dynamic range. The disadvantages lay, and lie, mostly in cost—the technique demands 12- to 14-bit digital words or the equivalent and thus several megahertz of channel bandwidth. Thus, both the mechanics and the electronics are costly enough so that PCM recorders shouldn't appear on the

home market for a few years at least. On the other hand, price means less to commercial recording concerns, and the results can be dramatic, as noted below. One could wish, however, that PCM masters could be used to cut dbx-encoded discs. Use of any other cutting scheme seems a pity. — Jim Brinton

PCM Discs: First Encounter. Having just read George Tillett's article in Audio ("Update: Musings on the Four-Channel Scene," Nov. 1975) in which he referred to Denon of Japan using PCM techniques for recording their QMX matrix discs, I called on a friend who not only is a fellow hi-fi enthusiast but also buyer of classical discs for a large retail chain here in California. When I mentioned the Tillett article to him, he pulled out Odyssey 33200, Jean-Pierre Rampal playing Telemann ("Twelve Fantasies for Flute"). On the back of the album was this footnote:

> "This . . . record has been produced by a new PCM recording system developed by Nippon Columbia Co., Ltd., with the cooperation of the NHK Technical Research Laboratories. The PCM method enables . . . attainment of a dynamic range of more than 75 dB with flat frequency response from dc to 20 kHz, while wow, flutter, and modulation distortion are .. . unmeasurable. This PCM recording is further enhanced [Well, maybe less degraded.— Ed.] by Nippon Columbia's unique Non-Distortion Cutting method, resulting in the ultimate in high-fidelity recordings"

Our first impression upon playing the disc was of silent run-in grooves. We could barely detect the onset of modulation. Noise was lower than that of any prior disc or tape heard. The flute had such "air" and "depth" that we agreed that we had never heard anything sound so close to "live." The system used for this audition was an AR turntable with Ortofon SL 15E Mk. II cartridge, Levinson JC-1 preamp, Dynaco PAS-3X, C/M 911 amp feeding two Magnaplanar 1B's. A Bottom End infrawoofer also was used.

I next took the disc to a dealer friend. We played it on a Linn Sondek turntable with a Keith Monks damped arm and a Fidelity Research moving coil cartridge, Levinson JC-2, two custom built 100-watt/channel tube amplifiers, and Dahlquist DQ-10's. We both agreed that at last we were getting some state-of-the-art discs to match state-of-the-art equipment. Unfortunately, I couldn't leave the store without giving the record to my friend to use as demo material.

I got another copy, took it home, and played it on my system. (Thorens TD-125, SME 3009 with non-detachable shell, Grace F9E cartridge, Quad 33 preamp and 303 amplifier feeding two Quad ESL's. The system crosses over at 65 Hz to another 303 feeding two transmission line infrawoofers.) I am just as pleased with the PCM disc at home as elsewhere.

If this is a forerunner of discs to come, then we are surely in for some exciting listening. Please try this disc, and if you are pleased, for God's sake write Columbia and tell them how good it is. I did. — Nate Garfinkle (California)

Boosting the MHS. My last batch of records from the Musical Heritage Society brought with it the most desperate letter to date from Michael Naida, the Society's president. The recession has hit them hard, it seems. I understand the company almost folded this summer, and it may very well do so yet—a sad end for a record company that stands almost alone in the U.S. in its devotion to quality and its concern for its customers. At $2.95 each (less 10% for cash payment), you can't go too far wrong, so I encourage everyone to do us all a favor by plunking down for a few discs. To help you out, I've appended a comment or two on a couple of recent releases that I've enjoyed. If you don't already have their catalog, the Society will be happy to send you a copy. Just drop them a note at: 1991 Broadway, New York, New York 10023.

• Bach's Magnificat in D, BWV 243, and Cantata 187: Michel Corboz conducting the Chamber Orchestra and Vocal Ensemble of Lausanne on an Erato recording—MHS 1683. A lovely performance—one of the best choral recordings I've heard. It's very clean, with excellent dynamics and a good, deep bass range. The imprint on the disc indicates it was mastered at Sterling

Sound; certainly it sounds like their work. Side one of my copy has some surface noise, but side two is almost perfect. On the strength of this record, I've ordered Corboz's recording of the B Minor Mass, MHS 1708-10.

. Tchaikowsky's Serenade for Strings in C Major, Op. 48, and Dvorak's Serenade for Strings in E Major, Op. 22: Enrique Asensio conducting the English Chamber Orchestra on an Ensayo recording—MHS 1623. Another fine performance with very good recorded sound. (Ensayo, you may recall, produced the excellent AR demonstration record.) Surfaces on my copy are almost perfect. The only flaw I've noticed is that the strings sound a little hot at the top.

— Mike Riggs (Massachusetts)

New Insights. There is a new source of wide dynamic range, smooth sounding, realistic discs for those who have tired of the program material on some of the super-demo records most of us own.

Insight Records (7726 Morgan Avenue South, Minneapolis, Minnesota 55423) has promised three or four releases a year of classical and jazz material selling for $10 to $15. Their first effort is entitled "Fidelity First: An Unrehearsed Experiment." It is light, big band jazz recorded by a twelve-piece band.

The record not only has impact and wide dynamic range, but is very smooth and lifelike. It has none of the harshness, funky super-ambience, or overly forward closeup sound found on some of the other available "super records."

Doug Erickson, who seems to be the man behind Insight, says that during recording and mastering, every piece of equipment and every circuit that could be eliminated was done away with. There is no multi-miking, limiting, compression, or equalization. This leads to the interesting point that the records don't sound particularly good on ordinary phonographs, but are superb on wide-range systems. [Compression, limiting, and equalization can make poor phono's sound unrealistically good, but the resulting discs sound unnatural on good systems. — Ed.]

I could see no sign of limiting using an oscilloscope, even on two cuts which include solo voice. I measured peaks about 14 dB above standard 0 VU, but this gives an inaccurate reflection of the disc's dynamic impact, since it is cut several dB below normal industry levels. At the same time, there was little particularly bothersome surface noise either, though one side was less quiet than the other.

There are flaws, but compared to the technical achievement, and to the realistic, live-sounding playing—the band was jamming—they are minor. The record is called ". . . An Unrehearsed Experiment" because many aspects of its production were not refined before takes; the players weren't paid to rehearse before recording (that's not necessarily bad if you like life-like playing), mike placement and balance are better on some cuts than on others, and some takes are cut off without natural decay. This last comes as even more of a surprise since one is so easily caught up in the swing and naturalness of the music and sound.

This record is meant to serve as an introduction to the sort of quality Insight is capable of providing and is selling for $6.50, about half the intended eventual price. It also is meant to measure the market, and as part of this, Insight is looking for feedback from listeners as to their opinion of the technical approach used and also as to the sort of music wanted.

As for me, I'm looking forward to their future releases. — Ira Leonard (Massachusetts)

After sending in the above, Ira forwarded a letter from Erickson, from which we excerpt the following:

"The abrupt starts and endings of some cuts were made necessary by some of the musicians' comments, many of which occurred right at the beginning or end of a piece . . . If you're interested in the history of the disc, it's simple. All but one of the musicians are current or former

professionals . . . with famous big bands. One of their number owns a night club, and during the summer the group got together to play on Saturday nights. As friends from other bands came through town, they would sit in and jam. That's what happened the night of the recording, and that's also why there were no credits given them on the record jacket—many are under contract that would otherwise have prevented any recording. They agreed to let me record them if I didn't interfere and didn't care if they were drinking . . . but if you listen to the individual efforts you can tell that each plays well."

— Doug Erickson

[Ira also added a few notes: So far, just about everyone who has heard this disc wants his own copy (Ira is getting some). He feels, on reflection, that there is more deep bass on this disc than on the latest Sheffield; and finally, he suggests that the program material is good enough to listen to, not just to use as something to show off your system. And that's nice for a change.— Ed.]

The Dual 1249: A Brief User's Report

Having suffered through the inconvenience of owning a manual turntable for the past four years, I decided to look around for an automatic. The choice boiled down to Dual versus Technics, and I finally chose the Dual 1249 because I felt its (reputedly) lower tonearm mass and bearing friction were more useful advantages than the Technics' theoretically superior drive system (direct versus belt).

The 36-page instruction manual is in six languages; some quick division leaves only about 6 pages in English, so it's not so thorough as one might expect at first sight. I was flying by the seat of my pants during much of the unpacking and setup—too many aspects of the unit's installation and operation were only touched upon.

The turntable performs quite well, however. It has a very smooth feel to it, and although the cueing lever is just a bit "floppy" for my taste, cueing action is excellent—no side drift and nicely damped in both directions. The tonearm executes its automatic functions without a trace of any jittery motion. Rumble, wow, and flutter remain undetectable at all times.

But using the Dual 1249, I found myself affected by that dread disease, audiophiliosis. The 1249 has low-capacitance CD-4 wiring and my Shure V-15 Type III likes to work into considerably more capacitance. As I listened to the first few records, I was positive I heard the peaked upper midrange and rolled-off high end characteristic of a V-15 working into too low a capacitance. So I went back to Tweeter, Etc., where I bought the unit, and they gave me a new set of higher capacitance cables, which I thought was very nice of them. Now it sounds much better . . . I think. Or does it sound any different at all? Or was there really anything the matter in the first place? To be quite honest, I don't know. What I do know is that the Dual 1249 is a fine turntable, one that I recommend without reservation to anyone looking for that type of record player.

— Steve Feinstein (Massachusetts)

More on Phono Cable Capacitance

Chapter XI in the BAS's continuing search for accurate data on the capacitance of your turntable's phono cables: Massachusetts member Andrew Kobziar sends word on Sony units. This is believed to apply to all Sony turntables; says Sony: "Each cable lead is approximately 210 picofarads up to the cartridge. There is little variation between models." Thank you, AK; those of you with similar information of known accuracy, please forward same to Box Seven.

Cartridge Capsules

Herewith, notes on Peter Pritchard's best.

Sonus Blue Label

I would like to alert you, if you don't know about it already, to a new contender for the state-of-the-art cartridge award, the Sonus Blue Label. This is Peter Pritchard's new baby, and one of the first products of his new company (Sonic Research Inc., 27 Sugar Hollow Road, Danbury, Conn. 06810). [If you write, mention the BAS. — Ed.]

My previous standard was an ADC-XLM Mk. II in a paddle-damped SME 3009 with non-detachable shell. The Sonus blows away the XLM. The improvements noted were: 1) more focus, especially on the human voice, than the already very good XLM, 2) more detail than I have ever heard from any cartridge, 3) deeper and tighter bass than the XLM, 4) better tracing and tracking than the XLM, and 5) very good overall balance.

The detail and focus are beautiful. Strings have that resinous quality that I have never before been able to elicit from my system. The reproduction of the human voice gives the uncanny impression that the soloist is right there in front of you. The cartridge also gives a good feeling of depth—it does a good job of placing some instruments near you and some farther back. Transients are great without giving the feeling that the music is all transients—an effect I have sometimes noted with the Shure V-15 Type III, The Sonus Blue Label now is my reference cartridge.

The system used in this evaluation consists of an SME 3009 non-detachable, Sony TTS-2251, Dynaco PAT-5, Phase Linear 400, and Dahlquist DQ-10's. The Sonus was compared with the Shure V-15 Type III, ADC XLM Mk. II (two), Ortofon M15E Super, Grace F8C, and Grado F1+.

— Jeff Stake (Illinois)

[Editor's Note: The Blue Label is priced at $115 list, although it is occasionally found discounted to $80 to $85. Go shopping. The Blue Label is a Shibata stylus unit; elliptical (Red Label) and conical (Green Label) versions are available at $95 and $80 list, respectively.

The Sonus Blue Label also is getting raves from the Atlanta hi-fi club, Audio Forum. To wit (culled from their publication Mixdown): "The Sonus cartridges, particularly the Blue Label, continue to represent the finest available . . . A second-generation (of these cartridges) now is available with an improved and strengthened cantilever; thus it appears that the production problems of the initial run have been solved. (Early Sonus tended to collapse in all but the lightest arms, and appear to work best only in damped unipivot designs. — Ed.) Some success has been had using the Sonus in properly damped SME 3009 arms with lightened head shells, but the SME does not allow the Sonus to function properly." The note goes on to suggest use with, first, the Vestigal tonearm, and beyond this, the Keith Monks, Formula 4, and Decca.

If you would like to subscribe to Mixdown, send $12 for a year's worth to Damon Hill, 3261 Circle Oaks Drive, NW, Atlanta, Georgia 30339. — Jim Brinton]

ADC-XLM Mk. II

When stylus replacement time for my XLM last came around, I went out and instead bought an XLM Mk. II (serial number 243281). It turns out to be a genuine improvement, with better definition, resolution, and separation and without the slightly withdrawn quality of the old XLM. Best of all, it is substantially less compliant than its predecessor (less compliant even than the V-15 Type Ill according to High Fidelity's test report). I'd been getting very good results

using the older XLM in a Keith Monks arm. It tracked most warps without visible or audible trouble. Still, if I peeled away the grill cloth from one of my speakers, I could see some woofer bounce. The Mk. II has ended that. It does require greater stylus pressure than the original but seems to track just as well. If you like the XLM, I think you'll like the Mk. II better.

— Mike Riggs (Massachusetts)

[Editor's Note: This new XLM may be the current price-performance champ despite its list price of $100. It is currently being discounted to $38 at K&L, $35 at Dixie Hi-Fi, and even less at other mail-order emporia. Its combination of high output and its inductance makes it a very quiet cartridge—audibly more so than the Shure V-15 Type III, for example. — Jim Brinton]

X-Rays and Your Color TV

When Ron Dunlap, a physician and co-founder of Dunlap-Clarke Electronics, was a guest on "Shop Talk," the hi-fi talk show on WBUR, Boston, he suggested that it was a good idea to have your color TV checked for excessive x-radiation. I arranged for such a check with the Massachusetts Department of Public Health (727-6214 in the Boston area), and three months later an inspector came to my home and performed the 15-minute test. The testing device is called a Storm's Meter, which contains about twelve individual Geiger-Mueller tubes and costs $1200. My TV was found safe, with radiation below that allowed by the federal standard. The inspector stated that if any TV is ever found to be emitting excessive x-rays, the manufacturer is obliged to repair or replace it.

The inspector also stated that only a trained technician should service color TV's to ensure that radiation be kept acceptably low. He suggested that the primary cause of excessive emission is improper adjustment of operating voltages to levels higher than those recommended by the manufacturer, and a re-test after each service call should thus be requested. Large-screen color sets (greater than 14 inches) are more likely to be radiation offenders than black and white or small-screen color TV's. (Sets manufactured after January 15, 1970 will carry a tag certifying that they are safe according to federal standards.)

The testing service is free for the asking, and they will also check microwave ovens for dangerous radiation. It is reassuring to know that these devices are operating within safe limits.

— Alvin Foster

Noted at the AES Show

Master tape drives: Twenty-four tracks getting increasingly popular. Perhaps the most interesting drive was on the Stephens machine. (John Stephens is a California designer who started out modifying 3M drives with his own electronics. He now builds everything. His present machine has no capstan or pinch roller; tape motion and tension are wholly controlled by the feed and takeup reel motors. An idler in the tape path provides speed sensing.

A couple of time delay units were present: the Delta-T from Logicon and the Time Line from Pandora (really, Pandora). The Time Line's price started at $2500 per channel.

3M introduced Scotch 250 mastering tapes to give a 4 dB signal-to-noise ratio improvement over 206 series tapes. Ampex claimed similar improvements with their 406 series.

Pioneer had their top loudspeaker system with carbon fiber woofers and high polymer film tweeter and ultra-tweeter.

White Instruments had a real-time spectrum analyzer for $3200.

Electro-Voice Professional Products has a set of construction plans for a series of low-frequency speaker systems in tuned enclosures. The results are slightly astounding. Their 30-inch woofer in an enclosure 8 feet by 4 feet by 32 inches (80 cubic feet) has a 3-db-down point of 17.5 Hz and will put out 1/2 acoustic watt (about 109 dB) at that frequency. A 12.8-cubic-foot enclosure with four 12-inch woofers will put out 72 watts (123 dB at 10 feet) from 100 to 800 Hz; 3 dB down frequency is 38 Hz. — Mark Saklad

The Fulton J Modular—Background and Review

This article is primarily about a speaker system and incidently about a very interesting dealer partly responsible for its development. The speaker is the Fulton J Modular and the dealer is Eugene Coggins of Paoli High Fidelity Consultants, Inc., of Paoli, Pennsylvania.

About a year and a half ago, Bob Fulton of Fulton Electronics introduced a small line of bookshelf loudspeakers. The lowest priced Model 80 caught the attention of Gordon Holt, editor of the Stereophile and Coggins, president of Paoli Hi Fi. Here was an $89 speaker which, they felt, was astonishing in its musicality and naturalness when driven with good tubed equipment. Wouldn't it be great if it had an extended high and low end of equal quality, they thought. Coggins, particularly, stressed a modular concept toward this end that would allow an audiophile to purchase units piecemeal, as his budget permitted, to avoid "obsoleting himself" with presently affordable complete speaker systems.

The J Modular began to take shape as Fulton added a slightly modified RTR ESR-6 electrostatic array for the extreme high frequencies and started designing an infrawoofer system for the lows. Over the next year, countless design modifications were made.

I had purchased the 80's and later added the electrostatic screens and then waited patiently over the next 14 months as the woofer and crossover designs were worked out. In communications with Fulton during this time, he impressed me as being dedicated to obtaining the best possible sound from the system prior to marketing it. A talented recording engineer (listen to the Fulton discs on Ark Records), he was concerned with sonic subtleties that many manufacturers (sadly) are not bothered by.

Finally, after solving a major speaker efficiency problem, the J Modular was complete. I received my infrawoofers late in July and have lived with them since then.

Physically, the system is very large. Picture a medium size black refrigerator with 1-inch-thick walnut slabs on both sides of its lower half. The driver complement includes a downward facing, planar-slot-loaded infrawoofer, a forward radiating 10-inch woofer, an 8-inch midrange, two 2¼-inch upper midrange speakers, and six-element electrostatic array. The J's are set up as mirror image pairs. The 80's are set on top of the woofer cabinets, with the ESR 6's placed on top of them. An acoustically transparent shroud covers these last two for aesthetic reasons. Construction quality is absolutely top-notch, as is attention to detail. Placement of the boxes on top of each other is critical for precise imaging, and detailed instructions and measurements are included for proper setup. Versatility is great, with separate tweeter and woofer level controls and provisions for single, bi-, tri-, and tetra-amping with and without an external crossover. The FMI Model 100 also can be used instead of the 80. Each speaker system weighs 225 pounds and costs $750.

Before beginning comment on the J's sonic qualities, a list of associated equipment is in order. I use the Decca Mk. V Export cartridge in the Decca arm mounted on a Linn Sondek turntable. My Audio Research SP3A-1 includes a recently developed Paoli Hi Fi modification that has dramatically improved its sound. This feeds two Paoli Model 60M amps and an Epicure Model lamp, with the Epicure handling everything below 375 Hz. All of this equipment was carefully picked out after a great many unhurried listening/consultation sessions with Coggins in his home.

The J's remain fairly inefficient. I don't think they will do well in very large rooms, no matter how much power they are fed, as very high levels cannot be obtained without the sound tending to "block up" and become confused. Up to and including the 95-dB point, however, they are capable of reproducing some of the most transparent, natural sound I have yet heard. Their frequency response is subjectively very flat over the entire audible range. Bass is clean, defined, and goes all the way down; highs are very smooth and unrestricted, and midrange definition is excellent. Imaging is one of the J's strongest points. One drawback is that precise imaging is available in only a small area of possible listening positions. Reproduction of the acoustic space of the recording, size of various instruments, height and size of voices, and front to back as well as lateral and vertical focus are amazingly accurate. This imaging and the lifelike quality (euphonic coloration?) of the midrange occasionally combine to produce a shockingly real sound image. This is particularly true on (what else?) some of the Fulton discs. The J is a most satisfying product which I will continue to evaluate and enjoy for many years to come.

— Desmond Fretz (Maryland)

[Editor's Note: In Boston, there are few J Modulars, seemingly, but BAS member Gary Rancourt, who knows both Fretz and Coggins, has a pair of FMI 80's. These were auditioned by Mike Riggs, and A-B compared with (large) Advents. According to Riggs, the FMI 80's "do indeed have excellent definition, focus, and depth resolution—better than that of the Advents and remarkable for speakers in their price class. The deep bass is missing and the upper treble is a bit rough. Overall, I would characterize the sound as being less neutral than that of the Advents, perhaps a trifle boxy, but not as dry. The Advents seem to strain less at higher levels. It's a tough choice between the two, and very much a matter of taste." — Jim Brinton]

Room Placement of Folded Horns

After constructing a Speakerlab SK, a speaker kit patterned after the Klipschorn, I attached two sheets of plywood to the rear of the woofer section to simulate the effect of the walls. This allowed me to move the woofer around the room while still maintaining the horn characteristics more or less intact. I first placed the woofer in the corner and took sound-level readings using 1/3rd-octave bands of pink noise at two listening positions, 24 inches and 40 inches away from the rear wall. In both listening positions, I noted resonance peaks around the 100- and 160-Hz bands (see Fig. 1).

I next moved the speaker away from the corner and along the wall (see Fig. 2). Again taking sound level readings at the two listening positions, I found the 24-inch position to be still pretty bumpy, but the 40-inch position worked out reasonably well. The response still drops off pretty badly below 100 Hz, but this could be boosted with a single equalizing section. I admit this boosting would be at the expense of increased modulation distortion in the woofer, but life is a compromise.

In my attempts to minimize room resonances I found it useful first to place the speaker in a convenient position and then run through the sound pressure measurements at a convenient listener position. Pick the worst resonant peaks, play a sine wave of that frequency through the system, and walk around the room listening to the tone to detect a dip in the sound. Reposition the sound level meter here and run through the sound level measurement with 1/3 octave noise again. Don't be surprised if the resulting curve is different, but not better. Or you may find a speaker-listener combination that is acoustically good, but impossible to live with. At this point you may become philosophic, take up drink, or place the speaker in a different position and try again.

If you can come up with a reasonable speaker-listener position, you may be able to save money by simplifying the equalization requirement to the point that remaining problems could be solved by adjusting the bass tone controls or by building a small equalizer with two or three sections tuned to your particular resonance peaks and dips. — Jim Nichol (Massachusetts)

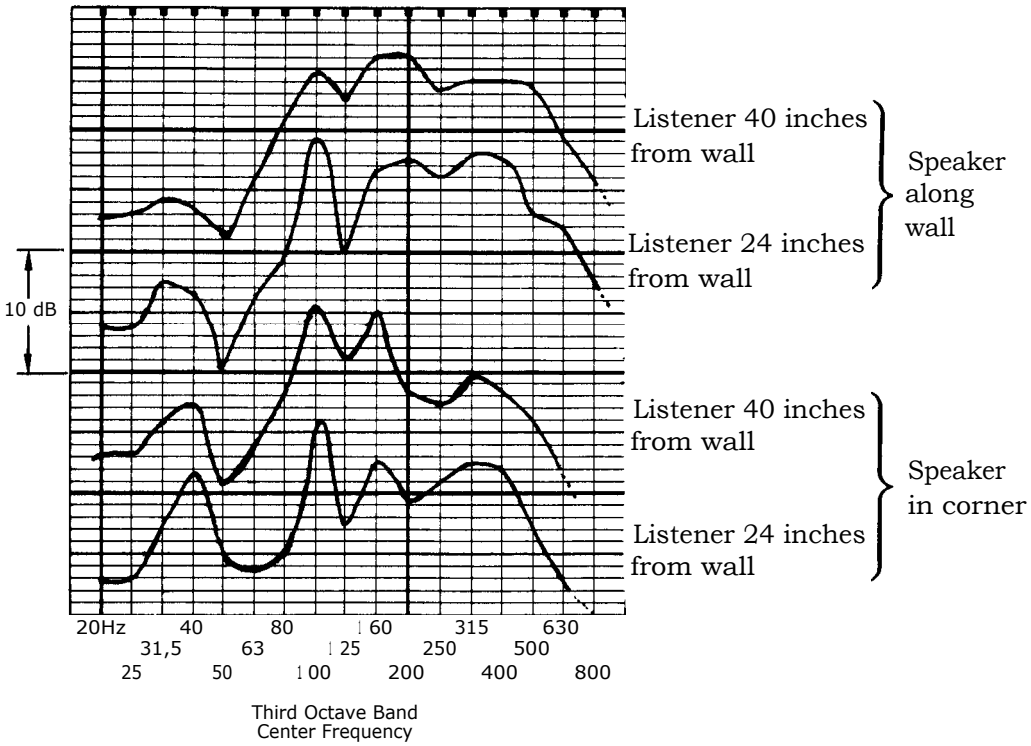

Fig. 1. Speakerlab SK folded horn woofer response versus speaker and listener position in room

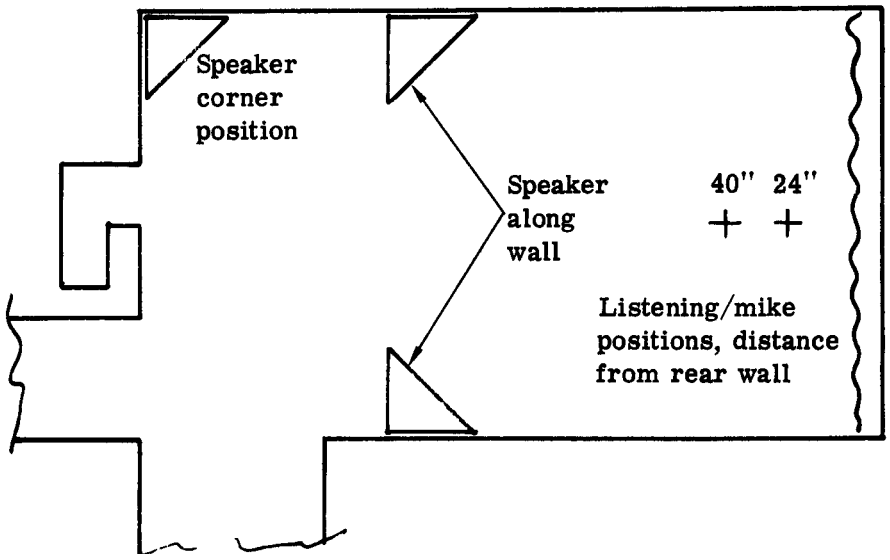

Fig. 2. Speaker and listener positions

The Idea File

In the last two issues of the BAS Speaker we have offered a few ideas as food for thought, substance for a few experiments, and hopefully for articles. Now I wish to solicit some data from those of you who work for audio equipment manufacturers.

I am very curious about what goes into the pricing of a piece of audio gear. I have checked parts costs for a 60-watt amplifier, and found that the electronics cost about $45, and this at single quantity prices; the amplifier retailed for about $200. I would be interested in seeing a breakdown of what it cost to manufacture that amplifier; what percentages were parts, labor, overhead, R&D, quality control, and warranty costs.

It would be interesting to discuss the tradeoffs that go into design. Obviously there are several tradeoffs that can be made: Complexity may mean more performance but less reliability. Small size may mean improved saleability but increased cost and, therefore, reduced saleability. Quick product development will gain a jump on the competition but may mean increased early warranty costs. I think it might be interesting to know how different companies make these tradeoffs.

Some similar questions can apply also to the music we buy. We know that making a classical record is enormously expensive, with orchestra costs going to $7000 an hour and total costs occasionally reaching $100,000 even before the record is pressed. Where is the breakeven point on such records? How many must be sold before the company makes a profit? Does a record company let the pop records support the classical in part or must everything carry its own weight?

What does it cost to introduce a new technique into record processing? An example might be quad or dbx processing. Years ago audiophiles paid a premium for stereo. Would a dollar a record charge for dbx processing pay the costs of multiple inventory and extra shipping for a limited market?

Certainly these examples could go further. I hope someone knowledgeable will enlighten us.

— Mark Saklad (Massachusetts)

Book Reviews

Audio Alternative: The Definitive Guide to High Fidelity, by Mark Tobak. $8.40 postpaid from Tobey Publishing, Box 428, New Canaan, Connecticut 06840.

This book would be much better had its author elected to explore systematically the technical and practical problems of buying, installing, and maintaining a high-quality stereo system. If Tobak had really done his homework, he could have written a solid, genuinely valuable consumerist book about high fidelity. Instead, he's given us a large (10½ - by 14½ -inch) paperbound tome filled with photos, superficial information, misinformation, and folklore.

In the first half, he discusses the various components of a system and reviews some individual products in each component category. The reviews are always subjective (apparently digests of reviews that have appeared in The Stereophile and in The Absolute Sound), frequently skimpy, and sometimes misinformed or out of date. We read praise of the Citation 11a's "sub-sonic" filter and damnation of Crown's failure to include one in their IC-150. It doesn't take much effort to look up the High Fidelity test reports that show the action of Crown's more accurately labeled low-cut filter to be virtually identical to that of H/K's "subsonic" filter. The author says nothing about the Ortofon cartridges but gives us three paragraphs on the BSR 310AXE changer. And he seems to recommend Sherwood receivers, despite their low phono overload margins, notch distortion, and poor reliability records. His general discussions leave the impression that he is less knowledgeable than the typical BAS member, who doubtless does not consider

himself qualified to write a "definitive guide to high fidelity." Tobak thinks the FCC puts a 50 Hz lower limit on FM broadcast frequency response, that a tonearm's effective mass is its most important characteristic (the lower the better) and that it has something to do with the arm's weight (true enough, but misleading if not explained), that one can safely rely on manufacturers' speaker impedance specifications, that the average audiophile can do a good job of aligning his kit-built tuner, and on and on and on.

The second half of Audio Alternative talks about buying equipment, about building equipment, about installing what one has bought or built, and about getting it repaired when it fails. It's a better effort than the first half, but not much. The author provides few hard facts, little useful advice on how to cull the real gems from the rhinestones, and virtually no insight into the critical interfacing problems that are such important determinants of a system's total performance. At the end, he reviews some books and the audio press, praising the "underground" and rapping the American slicks, which is all well and good as far as it goes. Gordon Holt and Harry Pearson deserve praise for much of what they do, and Stereo Review merits censure for what it conveniently neglects. But the indepdenents have deficiencies that should be pointed out to beginners, and the commercials, however much they may limit themselves, do contain information that the consumer can use, if he's told how to find and interpret it. Again, Tobak's consumerism, well-intentioned though it be, comes up lame. There are many worse books on high fidelity, but that doesn't make this one good. It contains too many simple-minded mistakes and foggy generalizations to be taken seriously. — Michael Riggs (Massachusetts)

And on the same book: I just got the most impressive looking hi-fi book I have ever seen .. . called Audio Alternative. It seems not quite up to date. The technical editor is one George Ritschner, a recording engineer; technical consultant, one J. Gordon Holt. It seems to be a compilation of material from the underground pubs plus others from here and abroad. Tobak, the editor, advises one to approach his views cynically: is there any other way? It can be interesting reading, though; either basic or slightly advanced depending on where you are . . . I am tempted to forget the whole business, learn to play the electronic organ, and attend some live performances. — Nate Garfinkle (California)

Modern Recording—A Review of a New Magazine

The second issue of Modern Recording (Dec./Jan. 1976) is now on the street and some early reactions are in order. Conceived and published by one Vincent Testa, who has successfully been conducting recording seminars around the country (dba Recording. Institute of America), the new publication purports "to serve today's music/recording-conscious society" with articles of interest on the process of recording. Also promised are profiles of major engineers, producers, and artists, with concentration on actual studio techniques, mike placement, mixing, etc. In equipment reviews, they promise to keep to hardware not usually treated by hi-fi magazines and to avoid restraint if they come across a "less-than-topflight" piece of equipment.

How do the first two issues shape up? First, the negatives. The equipment reviews, with Len Feldman doing the measuring and Norman Eisenberg the listening, are a cut (albeit a thin one) above what one expects from hi-fi mags generally, and of the eight test reports in the first two issues, only two of the products reviewed (the Teac A-6100 recorder and the Sound Workshop 882M mixer) can make any serious claim to being high-end items of interest to the recordist. The people stories ("A Session with Loggins and Messina") offer the neophyte an interesting look inside a real recording session, including value judgments on equipment and techniques, but offer little helpful information to the experienced recordist. And, finally, one is chagrined to note that advertiser support, although it includes some professional equipment manufacturers, also includes a number of "hi-fi" lines. One wonders what effect that will have on editorial content.

Now, for the good stuff. A reader feedback section, titled "Talk Back," runs 12 to 14 columns per issue, and the readers' questions are answered, not by the editorial staff, but by working professionals in the field. The new products section features items of interest to the recordist, as opposed to the general audiophile, and the How To (Build Your Own Recording Studio for Under $500) articles furnish practical cook-book ideas you can use today. And while it won't improve your recording practice, Bob Angus' book-length series on the history of recording makes interesting reading.

Capsule summary. Probably not for those who have already experienced hundreds of hours of actual live recording, and have reduced their equipment and techniques to formula, rather this magazine is designed for those who want to record but are still getting their act together. For the latter group, Modern Recording is worth the annual subscription price of $7.50 for six issues. Subscription information is available from Modern Recording, 15 Columbus Circle, New York, New York 10023. — Dick Lewis (Massachusetts)

In the Literature

Audio, Dec. 1975

- Miking With the 3-Point System: Illustrated description of the use of this simple system, of interest to new recordists.
- Equipment reviews include the Yamaha CT-7000 tuner, the Crown crossover, the Nakamichi Reference Monitor loudspeaker (which seems a strange beast at best), and the BGW 500D amplifier.

High Fidelity, Dec. 1975

- Records of the Year include many obscure releases, some of which can possibly be purchased through the newly revived BAS European buying service (see meeting summary). The BAS versus RFI is mentioned on p. 38 and BAS President Jim Brinton gives his maxi-review of the supertuners. In the letters section, a reader thanks the magazine for publishing Jim Brinton's damping article in the July issue and says his Bob Graham-style modification to his tonearm cost "less than ten cents." Also a vice president of the STP Corp. writes that the fluid also is used for other damping applications such as automobile shock absorbers, and that it is a polymer that is unlikely to exude "fumes."

Popular Electronics, Dec. 1975

- Build a Direct-Drive Turntable: PE has almost pulled a major coup with this construction article, which offers a full kit including electronics, motor, mounting board, and base (but not tonearm) for $100. But the rumble as measured by J. Hirsch is -31 dB before weighting, -58 dB with RRLL weighting. Other specs are very good, including lack of sensitivity to acoustic feedback. (p. 41)
- How Good Are Ferrichrome & Other New Cassette Tapes?: Eleven new top-of-the-line tapes compared on an Advent 201 and a Nakamichi 500. The tabulated results cannot be summarized here, except to note that in general the Advent outperformed the Nakamichi and TDK SA (Super Avilyn) and Capitol Music Tape are among the winners. Must reading for the cassette user. (p. 46)
- New Trends in HiFi Electronics: A short bit about nine topics, mostly well-worn by now. (p. 49)
- Chosing a Phono Cartridge: Basics. (p. 59)
- A New Industry Standard for FM Tuner Measurement, Part 2: The conclusion of the battle of the microvolt versus the femtowatt. (p. 61)

Radio-Electronics, Dec. 19'75

- For those of you who want a space-shuttle control panel in your den, the Marantz 4400 is reviewed. (p. 44)
- Bookshelf Speakers, Part III: A bit more useful than the previous installments in this series; speaker placement and control settings are discussed. (p. 51)
- Power FET's for Audio: This is the longest and most complete description of the FET amplifier system to appear to date in newsstand publications. (p. 58)

Stereo Review, Dec. 1975

- Tuners: Ho-hum.
- Music on the Air: Perhaps the rapid loss of classical music FM stations has begun to taper to a stable plateau. Includes a box about Richard L. Kaye, Executive Vice President of WCRB, Boston, describing his career and some of his pioneering broadcasting techniques. One other-than-obvious fact is that he adds "a very small amount of reverberation" to broadcasts from Avery Fisher Hall (in New York's Lincoln Center). He admits, "I know some people will disagree with me on that. I'm trying to produce a sound the listener can relate to in terms of being in a concert hall—not what he is likely to hear on record." (p. 62)

The Stereophile, Summer 1975

- Full reports on the Dyna PAT-5 and the dbx noise reduction gear; "quickies" covering the Polk Model 9 speaker, the Yamaha CT-7000, the FMI J-Modular, the EPI 100, the IAD expander, the Yamaha NS-1000 speaker, the ESS AMT-1, the Denon 103 and 103S cartridges, the Audio-analyst A-100X, the Infinity SS-1A, the Otari MX-5050 tape recorder. the Russound QT-1 patch bay, the Sony TC-161SD, the Infinity Monitor II, and the Zerostat, and a comparative report on the Dyna 400 and Ampzilla. Eight very nice pages of record reviews and two pages of mediocre (at best) rock reviews (Holt should consign Karagianis to the cutout bin). He drops hints that there will be a new magazine soon, and a record, and brings up a hitherto unsuspected compatibility problem between tape recorders.

StereOpus, Vol. 1, No. 2

- Full reviews of the Audio Research SP-3a-1, Ampzilla, the Crown DC-300A, the B&O MMC 6000, the ADC-XLM Mk. II, the All-Test phono preamp, the RTR ESR-6, the Infinity Monitor II, the Rectilinear 5, and the Braun L810. Short reports on the Dyna PAT-5, the Koss Model One full-range electrostatic, and the Shure V-15 Type III. The Constructor's Corner reports on building Ampzilla and on sources of raw speakers. A little better issue this time out, though still not quite up to its brethren. A second reviewer has joined the staff.

Wireless World, Oct. 1975

- In the letters section, the first item may inspire some members to contribute their ideas (e.g., as in The Idea File column) even if they are not sure they are absolutely correct. (p. 465)
- Television Tuner Design: This sounds like a good article, but one look at the diagrams will scare off all but the professional designer.
- Electronic Circuit Calculations Simplified, Part V: Discusses the rolloff frequency of RC networks and gives some simple rules for their design and for their combination to give complex response curves (e.g., in RIAA networks). Of great use to the audiophile.

November BAS Meeting

Business Meeting

Over 70 BAS members and guests crowded into Boston University's Sherman Union for the November meeting. Due to time constraints, discussion of changes in the bylaws and quorum requirements presented in the October Speaker were postponed.

An overseas record-buying service is being organized by Dr. Brian W. A. Leeming to purchase discs from a British firm on a prepaid order basis. Purchases will be made only after total orders reach $100 or more, since a 5% discount is available above this figure. Orders will be placed and records shipped by air in the interest of expediency, although this will add about $0.50 per record in shipping cost. A subscriber to the Gramophone, Dr. Lemming is willing to act as an advisor on recommended recordings. For more information, contact Dr. Leeming through Box Seven.

After a year of work by BAS members on packaging and circuitry for the Thermo Electron 814 and 814C electret microphone capsules, Thermo Electron has made the decision to drop this line of business and has sold the patent rights and tooling for their complete line of mike capsules to Knowles Electronics in Chicago (their largest competitor in hearing aid mikes). As far as could be determined Knowles has no plans to produce the 814 or 814C, although a smaller capsule, used by Group 128 for their mike, will be produced by Knowles. Not much is known in BAS circles about how the smaller capsule compares acoustically with the 814's. However, the electrical connections are via solder terminals rather than pins (a la 814). Initial attempts to solder to 814's resulted in several damaged units and does not appear to be a recommended procedure. Peter Mitchell has managed to obtain about ten 814's and a few experimental 814C's which had been modified by Thermo Electron but still meet specifications. They will be available at the December meeting on a first-come, first-served basis.

A short note on the BAS oscillator for those who have built kits. The value of the 39-ohm feedback resistor may need to be changed, due to variability in the amplitude-stabilizing lamp. This may be done by substituting values or using a 500-ohm trimpot in parallel with a 47-ohm resistor. (See also "BAS Oscillator Feedback," BAS Speaker, Oct. 1975.)

Some questions were raised on the validity of judging preamp quality based on Holman tests of single samples, as reported in last month's Speaker. Jim Brinton noted that the samples are statistically small but felt the rankings were indicative of a trend and could be used as a general indication of quality. As a matter of record, Jim also revealed that listening tests with the Micro-Acoustics QDC-1 cartridge, reviewed a few months ago, were made with Marantz 7C and Audio Research SP-3A preamps, both good performers in the Holman tests. Thus the conclusions reached remain valid. (See "More Holmania," in this issue.)

Meeting Feature—Reducing Distortion in Tape Recorders

David Griesinger has had a long-standing interest in acoustics, electronics, and the relationship of what can be heard to what can be measured. He heads his own recording company and has recorded for Nonesuch and other labels. Besides describing the principle and operation of a predistortion system that cuts distortion in tape recorders by a factor of 10, he talked about microphone and speaker placement to achieve more realistic musical reproduction.

The section of his lecture on predistortion covered so many topics so interestingly and thoroughly that rather than risk making errors in transposition of his material to text, we are reprinting (with his permission and that of the Journal of the Audio Engineering Society) the full text of Griesinger's JAES paper of March 1975 in which much of the same territory was covered in detail.

Reducing Distortion in Analog Tape Recorders

DAVID GRIESINGER

David Griesinger Recordings, Cambridge, Mass. 02140

A predistortion system is described which reduces the harmonic and intermodulation distortion of an analog tape recorder by a factor of 10. The system consists of an inexpensive analog computer coupled to a recording head which uses cross-field bias. The system is both accurate and easy to adjust. The cross-field bias, by narrowing the width of the critical region, ensures that low distortion is maintained through the entire audio band. Since the correction is applied to the recorded flux, tapes can be played with low distortion on any machine.

The system has been tested extensively by recording live classical music, and no audible artifacts have been found. Tapes made with the system are clearer and easier to listen to than tapes made on conventional machines.

INTRODUCTION: All analog magnetic recordings suffer from harmonic and intermodulation distortion, especially when material is recorded at high level. This distortion is primarily the result of saturation in the magnetic tape. It is well known that under some conditions the harmonic distortion can be reduced by properly predistorting the recording current, and several commercially made tape recorders have some nonlinear circuit in the recording amplifier for this purpose. Not all recording engineers find these circuits desirable, since simple predistortion systems (linearizers) have several drawbacks when they are used to record music. Unless the recording amplifier produces the exact inverse of the saturation nonlinearity of the tape, increased amounts of high-order distortion will result. Furthermore, the amplitude and phase of the distortion produced by a conventionally biased recording head is a strong function of frequency. Unless some method is used to compensate for this frequency dependence, predistortion will seriously degrade the distortion of the machine above 2 kHz at 15 in/s (380 mm/s).

The work described in this paper was guided by a simple principle: predistortion is not desirable unless its use with any input results in both lower amplitude and a lower order of distortion than the use of a conventional system. As a result of this work a predistortion system which is capable of reducing tape distortion by a factor of 10 was built.

The major problems with simple linearizers are the following.:

1) It is difficult to make an inexpensive recording amplifier which has the exact inverse of the nonlinearity of the tape.

2) Phase shifts in the ac biased recording process cause the predistortion to increase the distortion of the machine if the recording signal is above 2 kHz at 15 in/s (380 mm/s) or 1 kHz at 7.5 in/s (190 mm/s).

3) The overload properties of the recorder are degraded. Accidental overloads cause hard clipping and a very harsh sound.

4) The most inexpensive circuits are difficult to temperature compensate, which makes frequent adjustments necessary.

5) The most effective circuits are difficult to adjust for different types of tapes.

6) Unless the output of the nonlinear circuit is dc coupled to the head, the predistortion is not very effective on any asymmetric signal.

DISTORTION MEASUREMENTS

The exact nonlinearity of the tape was determined by measuring harmonic distortion as a function of tape flux level. These measurements were made on a studio tape recorder with variable bias current. The recorder electronics had very low harmonic distortion. The tape flux level was measured with an averaging voltme-

ter connected to the output of the playback preamplifier. All levels in this paper are thus total nonfiltered tape flux levels, relative to a fluxivity of 185 nWb/m (the "Ampex operating level"), in decibels. This fluxivity usually corresponds to a deflection of 0 dB on the volume indicator.

Harmonic distortion in a tape recorder is tricky to measure. There is enough wow and noise to make a notch-type fundamental canceling distortion meter unusable below about 1 % distortion at 500 Hz. When predistortion is used, there is also a rise in the modulation noise at the frequency of the third harmonic. A wave analyzer with a filter width of 12 Hz was used in these measurements. The filter width of 12 Hz was found to be wide enough to be independent of wow at most frequencies, and yet was narrow enough to exclude the modulation noise. Measurements of harmonic distortion with third-octave filters tend to be higher.

The results of third-harmonic measurements without predistortion for several different brands of tape are shown in Fig. 1. The major inaccuracy in these measurements occurs in determining the flux level of the recorded tone (± 0.3 dB). Cross-field bias was used [1]. (Cross-field bias will be explained in detail later in the paper.) Each tape was biased for minimum distortion at a flux level of 0 dB at 500 Hz. This criterion for biasing was chosen to simplify comparisons between these tapes. However, with cross-field bias the bias current which produces minimum distortion at 500 Hz severely alters the shape of the recording zone. The result is lower harmonic content when the tape is played, but very poor high-frequency response. For best operation of the predistorter the bias should be 1—2 dB less.

Harmonic distortion depends greatly on the design of the recording head. The first measurements used a metal two-channel Ampex recording head with a 25-μm gap length. The bias frequency was 200 kHz. This head produced about 0.6 % harmonic distortion at a flux level of 0 dB with Ampex 406 tape. A Philips ferrite head with a 12-μm gap length produced 0.3 % distortion under the same conditions. Adding cross-field bias reduced the distortion with both heads. The data shown in Fig. 1 were taken with the Philips head using cross-field bias, and they show 0.2 % distortion at a flux level of 0 dB. When biased for best operation of the predistorter, this head produced 0.3 % third harmonic distortion. The Ampex metal head also produced 0.3 % third harmonic distortion when biased for best performance of the predistorter, and the distortion did not improve when the bias was increased. This head is currently being used in this machine. (After only a hundred hours use the ferrite head shows ablation of the ferrite material at the edges of the gap. Further, at high frequencies the metal head produces a higher level without saturation.)

These measurements support other reports that ferrite recording heads produce lower distortion than metal heads, at least at low frequencies [2]. It is not obvious why this is so. The heads used in these experiments were different in permeability, gap length, gap spacer material, and high-frequency loss. The fact that both the metal head and the ferrite head produce similar distortion when used with cross-field bias might be an important clue. Further research should be done in this area, preferably by an organization with access to a great variety of heads. An improvement in the distortion properties of conventional tape machines might result.

The results of the distortion measurements are consistent with the results reported by Langevin [3]. They can be summarized as follows:

First, if the bias waveform is very good and the recording head is completely demagnetized, there is very little even-harmonic distortion. This is equivalent to saying that the tape transfer characteristic is completely symmetric.

Second, the amplitudes of harmonics higher than the third are very small.

Third, when plotted on a log—log scale such as Fig. 1, the third-harmonic distortion data can be fit by a straight line, at least over the most important part of its range. This is the fact which makes a good predistorter practical.

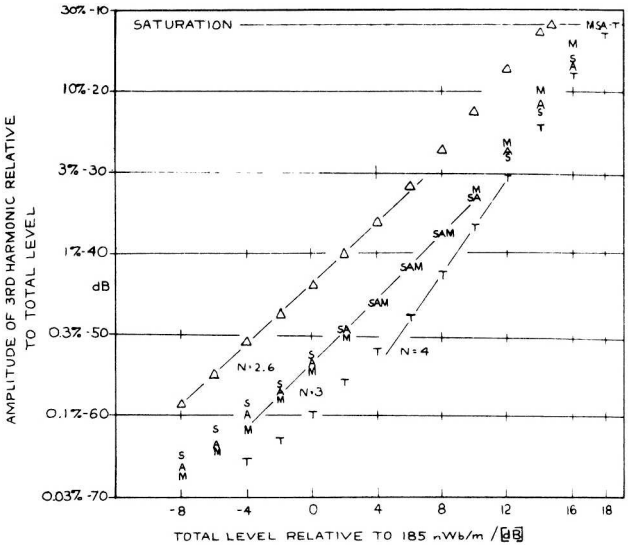

Fig. 1. Harmonic distortion as a function of tape flux level. No predistortion. A—Scotch 203 tape; S—Scotch 206 tape; A—Ampex 406 tape; M—Maxell UD 50 tape; T—TDK SD 150 tape. Philips ferrite recording head, cross-field bias, 15 in/s (380 mm/s), 500 Hz.

DEVELOPMENT OF THE PREDISTORTER

The shape of the curves in Fig. 1 suggest that the tape nonlinearity may be closely approximated by a power law.[1] Specifically, if ϕ is the flux recorded on the tape and i is the recording current,

$$\phi \propto \chi(i \pm C|i|^N)$$

− when i > 0

+ when i < O.

The constant x relates the recording field produced by the recording current to the recorded flux at low levels. N -1 is given by the slope of the distortion data in Fig. 1, and N varies from 2.5 to 4 in the tapes tested. The constant C is best found by trial and error on a given recorder. However, it can be computed from the data in Figure 1. The value comes out to be about 0.05 for Scotch 202 if i is normalized to 1 at a flux level of 0 dB.

Guided by the above measurements, several circuits were constructed using analog computer techniques to produce the exact inverse of Eq. (1). After a long and sometimes frustrating development, the type of circuit shown in Fig. 2 was chosen. The majority of the circuit is designed to compute a power of the signal at its input. This part of the circuit is then placed inside the feedback loop of the recording amplifier to generate the exact inverse of Eq. (1). The first step in finding the power is to find the absolute value of the signal using an active rectifier. The next step takes the logarithm of this absolute value. An amplifier then multiplies the logarithm by the value selected for N. The antilog is then taken, giving the absolute value of the input signal raised to

[1] Eq. (1) is only valid for low values of i. As tape approaches saturation, the recorded flux approaches a constant value, whereas Eq. (1) predicts a continuous decrease. In the predistorter design a soft clipper, along with some feedback around the power circuit, partially correct for this error. There is not enough bandwidth in the recording process, and tape is not uniform enough from reel to reel to correct the distortion at high levels perfectly. It is better to design the predistorter to produce as few high-order harmonics as possible, and record at slightly lower level. For a very interesting discussion of the interaction between bandwidth, disc predistortion, and level, see [4].

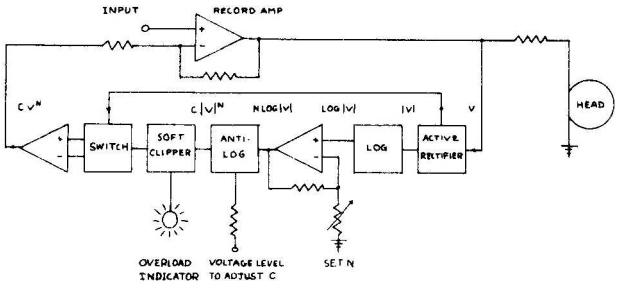

Fig. 2. Block diagram of predistorter.

the Nth power. This signal is soft clipped if necessary, and the sign is reinserted with an electronic switch. Timing errors in the switch do not produce crossover distortion, since the switching takes place only when the correction signal and its first two derivatives are zero (Fig. 3).

This circuit has many advantages. The constant C can be adjusted by means of a dc voltage, which means that several of these circuits may be ganged to one control. Thus a multichannel recorder may be easily adjusted for different tapes or bias levels. The exponent N is set by a single resistor, the value of which can be computed from the data in Fig. 1. The value of N need not be changed for most of the tapes in common professional use ($N = 3$). The circuit is inherently symmetric; both the positive and the negative parts of the signal are affected identically. The circuit is completely temperature independent, stable, and dc coupled. Parts for the circuit cost about $8.00 in small quantities.

Fig. 4 shows the performance of this circuit using Maxell UD-50. At flux levels below +8 dB the distortion is almost completely removed. These measurements were made by setting the predistorter for minimum distortion at a flux level of +8 dB at 500 Hz. The distortion does not remain quite as low at other frequencies, but at low frequencies it stays below 0.1% for any flux level below +4 dB. Notice that at the higher levels the error bars on the distortion-reduced data are rather large. This unevenness in the distortion is due to the lack of uniformity in the coating of the tape. About once a revolution of the supply reel there is a quick jump in the distortion. The size of the jump shown in Fig. 4 is about average for many brands of tape, although some individual reels may be perfectly uniform. Such a jump in distortion is usually accompanied by a slight drop in the tape output, and this drop can sometimes be heard if a noise reduction system is in use.

Even with these faults the improvement in harmonic distortion is dramatic and immediately noticeable by ear when pure tones are played. The decrease in intermodulation distortion when two randomly selected tones are recorded at the same time is even more dramatic.

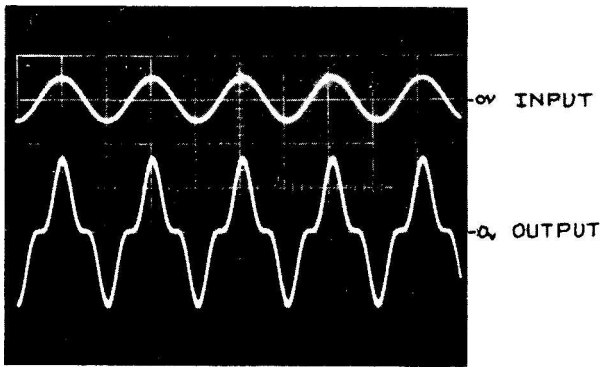

Fig. 3. Performance of circuit that raises input voltage to Nth power ($N = 3$).

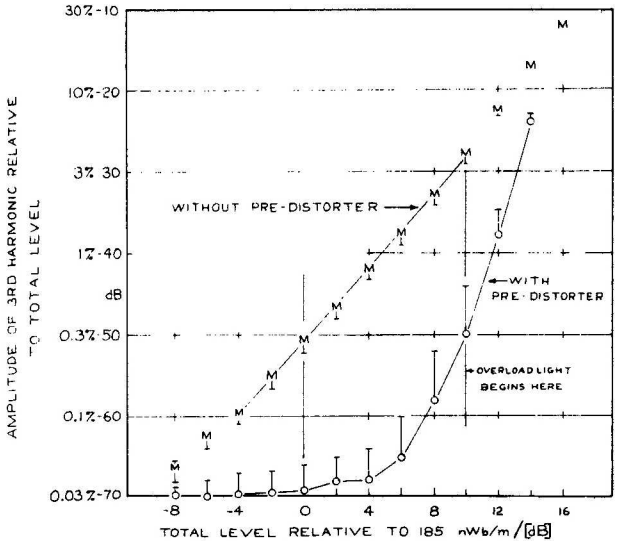

Fig. 4. Harmonic distortion as a function of tape *flux* level with and without predistortion. Ampex metal recording head, cross-field bias. 15 in/s (380 mm/s), 500 Hz, Maxell UD 50 tape.

The soft clipper in Fig. 2 limits the action of the predistorter whenever the instantaneous level exceeds +10 dB with Scotch 206.. Above this level the distortion gradually rises to that of uncompensated tape. A red light is illuminated whenever a transient exceeds this level, and this light is a very valuable indication to the recording engineer. This limiting system was chosen after many listening tests and works well. Although the predistorter causes the higher order harmonic content of a grossly overrecorded tape to be somewhat greater than a normal tape at the same level, accidental overloads do not result in disaster.

We are accustomed to thinking that we can always pass an audio signal through a large capacitor without changing the signal in any audible way. However, the predistorter and the recording head are part of a very nonlinear system, and they cannot be decoupled in the usual way. If an asymmetric signal is being recorded (a series of short positive pulses would be a good example), a net current must flow through the head, or the predistortion will be less effective. Experiments indicate that most solo instruments (especially the human voice) produce asymmetric signals [3]. An ac coupled predistortion system is a good example of an audio device that can produce good results when tested with a single pure tone, but fails to work with music. The best test signal for this effect is a mixture of two oscillators with equal amplitudes tuned almost exactly in octaves. The odd harmonics of these two frequencies will not be completely canceled if ac coupling is used, and some even harmonics will be generated (Fig. 5).

The fact that the head is dc coupled causes no problems. Since the power-law circuit has no output at very low level, the dc offset voltage which appears at the recording head is determined only by the input offset voltage of the recording amplifier. Even without adjustment this offset is only a few millivolts, and the flux produced is less than that caused by the typical head magnetization.

For best results with the predistorter, the bias current should be very stable. Since the bias is set near the point of minimum distortion, drifts in the bias current do not affect the predistorter strongly, but the current should be held to within 3%. There are enough variations from batch to batch in most tapes to make it necessary to readjust the predistorter whenever a new batch is started. Changing the tape speed also requires a small adjustment of the predistortion. Fortunately, only the constant C need be changed. This can be done by ear using a very simple test set. The set consists of a 400-Hz low-distortion oscillator and an *RC* notch filter tuned to 400 Hz. By simply varying the constant C while

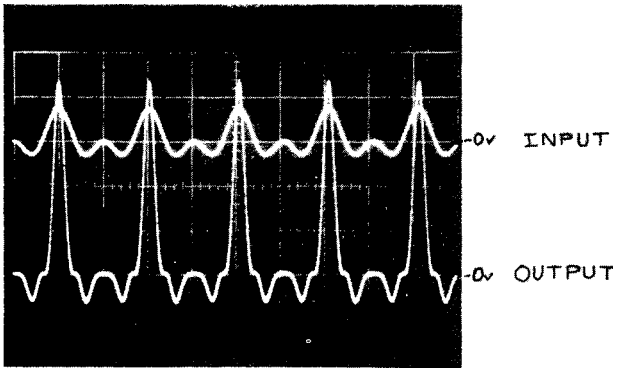

Fig. 5. Response of predistorter to asymmetric signal. The input consists of 1000 Hz and 500 Hz mixed equally. Notice that although the input has no dc component, the output appears to have a strong dc component. The measured dc component is + 0.5 major division.

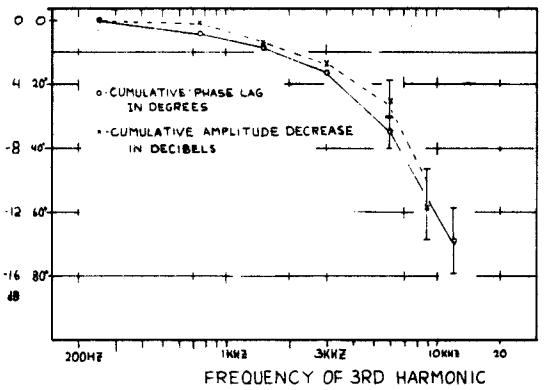

Fig. 6. Phase and amplitude of correction signal as a function of frequency if low distortion is to maintained at high frequencies and conventional bias is used. Scotch 202 tape, 7.5 in/s (380 mm/s), Philips ferrite recording head, conventional bias.

listening to the playback of the oscillator through the filter, the third harmonic can be easily nulled to less than 0.1%. Changing the control for C has no effect on the output level of the machine except at very high levels.

FREQUENCY-DEPENDENT EFFECTS

As was previously mentioned, the behavior of the predistorter with frequency is complicated. At low frequencies there are small shifts in the amplitudes of the distortion products which limit the effectiveness of the correction. However, once the predistortion has been set for the type of tape used and the tape speed, overall distortions of less than 0.1 % can be achieved at a flux level of 0 dB.

Unfortunately, at high frequencies the situation is not so simple. The major difficulty is with phase and amplitude shifts in the recording process as the wavelength becomes short. The linearizer assumes that the amount of harmonic distortion in the tape is independent of frequency, and that the fundamental, the harmonics generated by tape saturation, and the inverse of these harmonics generated by the linearizer are recorded in the same physical location on the tape. Most of these assumptions are incorrect.

These phase and amplitude shifts are serious. Unless some method of correcting them is found, a linearizer adjusted to work well at low frequencies will cease helping the distortion at all around 2 kHz at 15 in/s (380 mm/s), and 1 kHz at 7.5 in/s (190 mm/s). Above these frequencies the distortion with a linearizer becomes rapidly worse than the distortion in an uncompensated recording.

In an effort to understand this problem better, a network was placed in the output of the linearizer which could vary the phase and the amplitude of the third harmonics generated. The phase and amplitude shift necessary to eliminate the third-harmonic distortion generated by the tape at high frequencies was then measured. Throughout these tests the predistorter remained adjusted for best results at low frequencies. The results of these tests are shown in Fig. 6.

What is the meaning of these measurements? Consider the model for the recording process developed by Camras [1]. In this model the magnitude of the bias field determines the location on the tape where recording takes place. It can he shown that recording takes place in a "critical zone" on the trailing edge of the recording head, where the bias field falls from a value that is sufficient to saturate the coating to a value which has little effect (Fig. 7). The length of this region depends on the thickness of the coating and the sharpness of the hysteresis curve for the oxide. For a full discussion of this model, see [1].

When both the wavelength of the tone being recorded and the wavelength of its third harmonic are large compared to the length of this critical region, the predistorter can be expected to work well. However, as the wavelength of the third harmonic becomes comparable in size to the critical region, the situation becomes very complicated. Keep in mind that we are trying to cancel harmonics generated in the tape by recording over them with their exact inverses generated by the predistorter. If we assume that the harmonics generated by the tape nonlinearity are distributed uniformly through the critical region (i.e., that they accompany the fundamental), the phase data of Fig. 6 imply that the harmonics generated by the predistorter are recorded toward the trailing edge of the critical region. Thus they must be slightly delayed by a network if they are to still cancel the harmonics generated by the tape.

However, Fig. 6 also shows an amplitude effect. Apparently the harmonics generated by the tape must partially cancel each other when their wavelengths become short compared with the critical region. Unless the amplitude of the harmonics created by the predistorter are reduced, more distortion will be recorded on the tape than was there originally. This is the major reason that the performance of a simple linearizer is so poor at high frequencies.

Designing a network which would compensate for both the amplitude and phase shifts at the same time turned out to be very difficult. We had some success at 15 in/s (380 mm/s), through use of a delay line. However, two serious problems became apparent immediately. First, such a network is very dependent on the tape characteristics. A small change in the tape orientation or oxide thickness renders the network useless. Second, a network which successfully cancels harmonic distortion may cause an increase in intermodulation distortion when two high-frequency tones are recorded at high level. The low-frequency intermodulation products from two such tones may be increased by the action of the linearizer.

It is remotely possible that these problems could be reduced by very careful design of a conventional record head. However, experiments with different heads were not encouraging. Many give shifts similar to the Philips head, and the Ampex alloy head has shifts about 1.5 times worse. The best solution is to use cross-field bias.

[2] An exact analysis of these phase and amplitude effects should include the fact that at high frequencies the playback head can only sense the flux near the surface of the tape coating. We have chosen not to consider the playback process in this paper because tests showed that a tape which played with low distortion on one machine played with equally low distortion on all machines. Tape predistortion is very different from disc predistortion in this respect. In disc predistortion the playback stylus radius, dynamic mass, and tracking angle are all very important to the success of the predistortion, and yet are not under the control of the recording engineer [4].

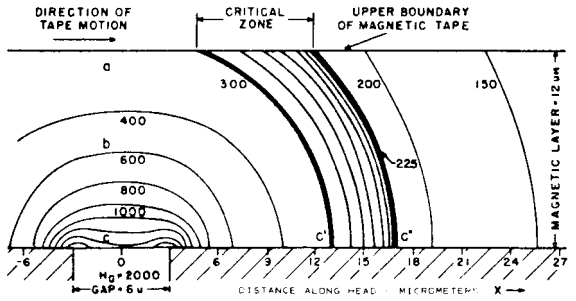

Fig. 7. Critical zone in tape at recording gap (from Camras [1]).

CROSS-FIELD BIAS

Cross-field bias can be explained using the model by Camras [1]. In the cross-field process a separate bias field is generated perpendicular to the recording head. This extra field adds to the bias field generated by the recording head in such a way as to cause a very sharp field gradient at the trailing edge of the recording gap. As a result, the critical zone is much narrower with cross-field bias than with conventional bias, and much better recording resolution results (Fig. 8).

Camras has developed a recording head which can produce cross-field bias in a single-sided head. Since such heads are not available, we used a bias head on the other side of the tape to produce the perpendicular bias field. The bias head (obtained from Tandberg of America) consists of an erase head with a relatively long (approximately 0.25 mm) single gap. It is mounted so that the gap of the bias head is about 0.5 mm upstream and 0.25 mm above the recording head gap. The actual spacings are not critical. It is only important that the bias head be located upstream of the recording head, and that there be enough room between them for the tape to pass freely. However, once set, these distances must be accurately maintained. Only the bias head is driven with bias current. The recording head is connected directly to the recording amplifier. The bias field in the recording head is supplied by induction. The bias current is set by adjusting the bias and the predistorter simultaneously for the best null of the third harmonic of a convenient frequency, such as the 400-Hz signal supplied by the test set, used at a tape speed of 7.5 in/s (190 mm/s). This value of bias current is also optimum for the high-frequency response of the machine, and produces a minimum of modulation noise [6]. Bias seldom needs adjustment.

The results of using cross-field bias were very gratifying. At 7.5 in/s (190 mm/s) the recorder would record up to 4 kHz without increasing the distortion above the values for uncompensated tape. This represents a fourfold improvement. At 15 in/s (380 mm/s) the performance was even better (Fig. 9).

Cross-field bias has several other advantages. It is possible to record a much higher level at high frequencies without saturation.

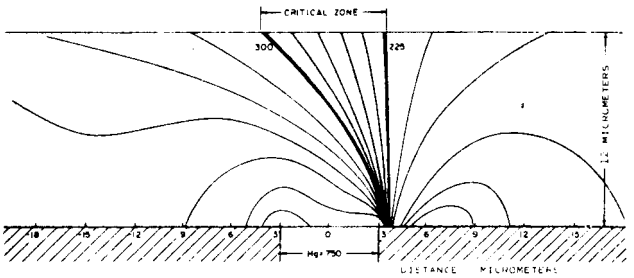

Fig. 8. X-field head and tape showing critical zone (from Camras [1]).

At 7.5 in/s (190 mm/s) and 15 kHz the level at which the tape begins to saturate is only 0.8 dB less than the maximum level that can be obtained without any bias. This corresponds to a recorded level of about -1dB at 7.5 in/s (190 mm/s), with NAB equalization, the Ampex metal alloy head, and Ampex 406 tape. This is at least a 6-dB improvement over conventional bias. Perhaps the biggest added advantage of cross-field bias in a mastering recorder is that you can change tape types with little or no change in the recording equalization. Frequency response variations at 15 in/s (380 mm/s) are less than 0.5 dB even on tapes as different as Ampex 406 and Maxell UD 50. Thus tapes may be chosen with respect to modulation noise or dropout without needing to reequalize the machine.

LISTENING TESTS

Experimental use of the predistortion system for recording classical music has been rewarding. The sound is very pleasant and easy to listen to for long periods of time. The most obvious subjective impression is the clarity of the sound. Organ music is dramatically improved by the reduction in intermodulation distortion, but even on very complex material some improvement is noticeable. On music with massed strings or voices the predistortion gives improved smoothness, less scratch, and, surprisingly, less apparent modulation noise.

As usual, there is a price to pay for such improved sound. All predistortion systems, either for tape or disc, must be both correctly adjusted and very carefully used. This predistortion system obeys the principle stated at the beginning of the paper, only at moderate levels. If users of predistortion increase their average level, it is very likely that the quality of their tapes (or discs) will be lower than if no predistortion were used. If the level is raised above normal levels the high-frequency distortion (which is only partly reduced by the predistorter) may become noticeable [4]. More importantly, an increase in average level causes overload to occur much more frequently [5], and the action of the predistorter will make these overloads more serious. Higher order harmonics will begin to be apparent in some types of music, and many listeners will object to the sound. If reducing distortion is your object, you must give up the notion that a very high level is synonymous with quality.

When the predistorter is installed in a recorder which has a standard volume indicator (vu meter), the overload light can be used to indicate the proper level. On continuous material, such as organ or a capella chorus, an infrequent flicker indicates the perfect level. The level must be kept low enough to keep the light from flashing brightly. The sudden onset of distortion is very

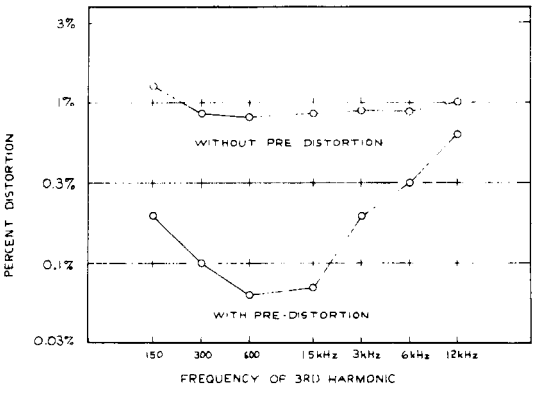

Fig. 9. Distortion as a function of frequency. Ampex 406 tape, 4-dB level, 15 in/s (380 mm/s), Ampex metal head, cross-field bias, NAB equalization.

disturbing in such music, especially when one has become accustomed to its absence. With material which contains many transients, such as any music with drums, the light may flash rather merrily without any easily audible effect. Saturation of the tape should be avoided with all material. It is seldom possible to record a high-quality tape with the volume indicators indicating more than +2 dB (Ampex 406 or Scotch 206 tape). If the recorder is equipped with peak program meters, the maximum level should be a fluxivity of 700 nWb/m.

These recording levels are based on experience and personal preference. The author believes that recorded music is much more pleasant to hear when it contains no audible distortion. To our ears, normal recording levels (in conjunction with Dolby A noise reduction) provide an ample signal-to-noise ratio. Other people have used the predistortion system to record very high levels without evident discomfort.

The predistorter has turned out to be very useful in the study of the audibility of different types of distortion. Not only does it supply high-quality tapes for use as source material, it can be wired to produce an electrical replica of the distortion which would be produced in a conventional tape recorder. Listening to this signal is most unpleasant and can serve as an excellent ear training for hearing tape distortion. This signal can also be used to determine at what level distortion from a conventional tape recorder becomes audible. Naturally, this threshold of audibility depends very much on the type of music used, but it can be below 1%.

CONCLUSIONS

With good music and good miking, tape recordings made with the predistorter can be stunning. The only defects which remain are the tape-related problems of modulation noise, coating irregularity, dropout, and skew.

Requests for further information on this predistortion system are welcomed by the author and may be addressed to him at 15 Bellevue Avenue, Cambridge, Mass. Manufacturing rights are available. If there is sufficient demand from individuals interested in experimenting with distortion reduction, it might be possible to produce a few of the nonlinear circuits as modules.

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Predistorters For Sale. You will see from the article reprint that the unit works best (or with least possible complication) with cross-field-biased tape recorders. With this in mind, and realizing that many BAS members are capable of installing the predistorter between the record amplifiers and heads of their tape machines, Griesinger is offering predistorter modules for $40 (per channel, assembled) and a kit of parts for those competent to assemble them at $25 per channel. The latter includes a printed circuit board and all parts; some adjustments are necessary.

A Note on Tape-Recorder Clipping. In the course of the meeting, Griesinger fielded a question from the floor as a member noted that he had measured the clipping of his Revox at approximately 13 to 14 dB above zero VU; this came after Griesinger had mentioned record-amplifier clipping points of +20 dB relative to zero VU. Both men were correct; the member had measured the overall response of his Revox from input to output (including the tape) at the point where sine wave inputs began to flatten slightly at their maxima and minima; a realistic measurement for the recordist.

But Griesinger's measurement also is realistic. After the meeting he noted that in order to fully realize the benefits of tape's "soft-clipping" characteristic, a record amplifier must have significantly more headroom than normal tape. While it easily is possible to record a signal of 1000 nanowebers/meter (approximately equivalent to +12 or +13 dB above zero VU) on high quality tape, it is possible to record signals with strengths approaching +16 dB or so without causing severely audible distortion because of tape's soft-clipping characteristics. Absolute saturation might not be reached until, perhaps, +18 dB above zero VU. Thus, it is important to have record electronics capable of at least 15 and preferably 20 dB of headroom. To use lower quality electronics invites the harsh distortion that a recording would otherwise not exhibit.

Miking. Griesinger also discussed the factors involved in microphone use, speaker placement, and room acoustics to obtain realistic sounding recordings. Usually it is desirable to record and reproduce not only the musical performance but also some of the acoustical ambience of the hall to make the livingroom listening experience as similar as possible to that of the hall.

He feels that the key to recreation of hall ambience is reproduction of its low-frequency characteristics, reverberation time, resonance modes, and the arrival time of discrete reflections. That each of these factors is important in aurally distinguishing the size of a room can be appreciated by noting that when only one characteristic, reverberation time, is made equal for a large and a small room, the two rooms still will not "sound" alike. To completely reproduce these large-hall effects in the home is difficult and in some instances impractical. However, proper microphone and speaker placement can yield a substantial improvement over what is experienced with most commercial recordings.

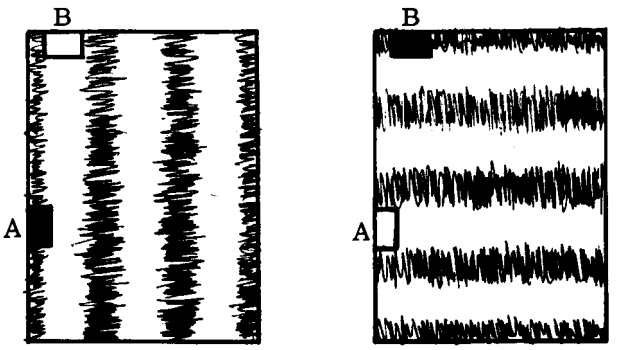
Beginning at the recording end, the best microphone techniques are those that preserve phase information and pick up at least half of the recorded sound from the reverberant field. Phase information in the direct sound aids in localization of the instruments. In the reverberant field, after steady-state conditions have been reached, phase information is ambiguous as it has been "homogenized" through multiple reflections within the room. However, during transients, when an instrument begins to play a note, the phase relationships at the mikes change as the reverberant field builds up. This rate-of-change-of-phase information depends upon the size of the room and its reverberation time, and its preservation aids the ear in recreating the acoustic "sense" of the hall.

A good microphone arrangement for sensing and recording these phase relationships is the spaced, omnidirectional pair. This arrangement can, however, lead to broad sonic images of soloists with the wide spacings needed for large ensembles. To recover localization in these instances coincidence mikes should be used for center fill and be mixed very carefully with the stereo pair to avoid washing out the phase information. The coincidence mikes also are necessary if the stereo signal is ever going to be converted to monaural, since spaced mikes often don't produce good monaural signals due to phase cancellation when the two signals are added. Recording with coincidence mikes alone, though, tends to give the feeling that the sound is coming to you in your livingroom through a large picture window beyond which is the concert hall.

Speaker Placement. It is well known that at frequencies below a few hundred hertz sounds tend to be non-directional, and therefore carry little stereo information. But, phase differences between channels can produce audible effects even at very low frequencies. This was demonstrated by playing separate low-frequency tones through each speaker with each tone having a frequency difference of 1 Hz. The effect created as the two sources went in and out of phase at a 1-Hz rate was that of sound washing around the room, but with no particular point of origin evident.

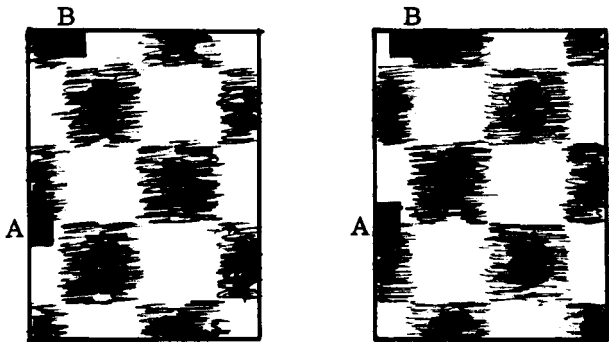
Speakers usually can be placed to optimize the effect of low-frequency phase differences recorded with a spaced-pair mike setup. Often, for aesthetic reasons, speakers are placed symmetrically in a room. When considered in terms of how the speakers couple to the standing-wave modes of the room, however, asymmetric placement may be a better choice. In Fig. 10, two speakers are shown placed on adjacent walls such that one optimally excites the standing-wave room resonance along the room's short dimension while the other most efficiently excites a resonance at the same frequency along the room's long dimension. When played simultaneously and in phase, the standing wave patterns of each speaker overlap to form the two-dimen-dimensional pattern in Fig. 11a. The 180° out-of-phase condition is shown in Fig. lib. Note that the shaded and open areas, representing regions of maximum and minimum sound intensity, respectively, reverse positions when the two speakers shift their relative phase by 180°. A listener standing at or near the center of one of the shaded areas would experience a feeling of movement of bass energy in the room with phase differences in the signals fed to the two speakers.

This simplified analysis has been idealized to a single frequency and carefully chosen room dimensions. However, this phenomenon will operate in varying degree for other frequencies and rooms, and can, to some extent, enhance the realism of the reproduction by simulating the fluctuations in bass energy characteristic of a large hall. This is possible, though, only if the necessary phase information has been preserved during the recording. — John Schlafer



(a) (b)

Fig. 10. (a) Speaker A exciting a standing wave along the short dimension. (b) Speaker B exciting a standing wave along the long dimension.



(a) (b)

Fig. 11. (a) Speakers A and B in phase. (b) Speakers A and B out of phase.

A Publication of the BAS

Amplifier Pricing: Dollars per Watt or Dollars per dB?

Tom Mashey

While pondering amplifier power ratings I began to consider cost versus power. Power, of course, does not tell the whole story about the audible quality of an amplifier, but power is at least a definite amplifier specification, compared with the more indefinite distortion specs, which don't really describe how an amplifier sounds. We are all looking for solid-state amps that sound as good as tube-types but that have higher power, don't wear out, have better slew rates, etc., but we usually begin our search by defining the general power rating in which we are interested. Beyond this, and except for a few only slightly meaningful distortion or noise specifications, selection is usually a matter of taste (though in general the better sounding amplifiers do cost more). The most common way of comparing amplifiers within any group or of spotting bargains in power amplifiers is to examine one versus another in terms of its costing so many dollars per watt. In this article I consider just how meaningful this "specification" is.

The amplifier spectrum is highly varied, running from the tube-type Futterman 60-watt/channel H-3A at $350 to the solid state STAX DA300 costing $3600. Of course all watts are not created equal. Factors such as compatibility with other system equipment and environment as well as hearing ability and personal preference to tolerable types of distortion come into play, but let's ignore these realities for the moment and merely examine raw power. Specifically, let's consider numerically both power ratings and the headroom for peaks that high power is intended to provide [further simplifying the initial analysis by considering FTC power and not peak unregulated power supply ratings.—Ed.]

I emphasize in this exercise that all "dollar" figures come from the list prices, ignoring, for example, the fact that most people buying the Dynaco wired Stereo 400 would pay more like $460 than the $600 list price. (If this discount price were used, however, the 400 would jump from position 14-15 to position 7 in Table 2 presented below, so the differences can be substantial. Bear this in mind for other discounted amplifiers.)

As regards sound quality, durability, etc., if you can hear a difference, then that should take precedence over pure cost, at least within the limits of your budget. Even with these qualifications, I think the tabulation that follows will be of some help in un-jumbling the amplifier scene.

In Table 1 I have arranged some common (and not-so-common) amplifiers alphabetically, and have listed the cost and power data used in the calculations. Included here are the list prices, the rated (FTC) "rms" watts, and this power translated into the number of decibels of headroom above a nominal reference of 1 watt. (See notes 1 and 2 at the bottom of this table.)

From the dollars and the watts, a ratio "dollars per watt" is computed and listed in another column. Finally, from the cost and the headroom figures for each amplifier, a "dollars-per-dB" ratio is computed and listed in the final column.

Now let's rank these amplifiers in order of increasing cost-versus-power, first on a dollars-per-watt basis and then on a dollars-per-dB basis. The results are given in Table 2. (The 1 watt basis for headroom could have been any other convenient level, e.g., 100 mW. Although the dollars-per-dB figures would change, the rankings in the table would not.)

Obviously, there are some drastic differences in rankings in the two sections of this table. As might be expected, the Phase Linear, Dynaco, and Ampzilla all do well on a cost-per-watt basis, as do the Quatre and even the Bose. But on the basis of dollars per additional decibel of loudness, the super-power jobs fall well down the list and the more moderate-powered amplifiers rise to the top. Note the SAE 31B, the Quatre (again), and the Citation. The result is one consistent pattern: it costs more, not less, per every additional unit of power on a dB basis. Each extra 3 dB costs more and more as one climbs the power ladder. It is now apparent what I am demonstrating: In reality, dollars per watt is about as useful a quantity as dollars per pound for comparing amplifiers. This is because we hear in "decibel" units, and what we are trying to achieve with a high-power amplifier (assuming decent speaker efficiency) is peak handling capability, i.e., headroom. When we buy raw power (ignoring other attributes such as transparency, three-dimensionality, smoothness, etc.), we are buying headroom in dB. And it costs.

I question the worth, other things being equal, of spending a lot of extra money for an extra 2 to 3 dB of amplifier power. Consider, if you will, that higher loudspeaker efficiency can be a better route to improved headroom than amplifier power.

And don't forget that the federal occupational safety and health act indicates that 85 dB long-term average is the maximum sound power level to which we should be exposed over an 8-hour period if our hearing is not to be degraded. And some authorities feel that this requirement is too generous (see Consumer Reports, October 1975). For every 5-dB increase, the allowable exposure time is cut in half. ARC Tympani IIIA's tri-amped with 60-watt amps (which normally run at less than 1 watt average output) can generate about 100 dB room sound pressure levels; how much do you want? At 100 dB (average) we would be limited to 1 hour's listening. We audiophiles seem to be victims of an expensive misconception; who perpetrated it? [Maybe we did it ourselves. —Ed.]

Comment: Despite a personal belief in the need for high peak powers (and ownership of a Phase Linear 700), I find Tom Mashey's approach to this question interesting. It is often hard to find the point of diminishing returns in component selection, and this method seems to help locate this point for power amplifiers. The concept of buying headroom rather than mere watts is an important one, since it hints at a related factor of equal importance and one that the audiophile has even less control over—that of speaker efficiency. Today's best speakers are almost all relatively inefficient heirs to the AR revolution of the 1950's. With (a little) program material available with wide dynamic range, and with some electronic gear available to expand the dynamics of existing software, it is becoming more of a problem finding systems that will handle a realistic dynamic range without demanding tons of power and a high price tag, regardless of whether it's viewed in terms of raw watts or headroom. There is a market for something like a full-range Heil AMT, and perhaps it is from that direction that the next audio "revolution" will come. — Jim Brinton

Table 1. Some Popular and Otherwise Amplifiers

Amplifier	FTC Rated Power, watts (1 ch @ 8 load)	List Price,[1] Nearest $10	Headroom Above One Watt,[2] dB	$List/ RMS Watt (1 Channel)[3]	$ List/dB Headroom[4]
Accuphase P300	150	750	21.8	5.00	34.50
Ampzilla	200	800	23.0	4.00	34.80
ARC Dual 76A	75	1200	18.8	16.00	64.00
ARC Dual 150	150	2000	21.8	13.33	91.90
BGW 250B	90	500	19.5	5.60	25.60
BGW 500D	200	840	23.0	4.20	36.50
BGW 750A	200	980	23.0	4.90	42.60
BGW 1000	250	1400	24.0	5.60	58.30
Bose 1801	250	990	24.0	3.96	41.30
Citation 12	60	300	17.8	5.00	16.90
Crown D60	28	270	14.5	9.64	18.70
Crown D150A	80	480	19.0	6.00	25.00
Crown DC300A	155	800	21.9	5.16	36.50
Dunlap-Clarke 500	150	800	21.8	5.33	36.80
Dunlap-Clarke 1000	250	1200	24.0	4.80	50.00
Dynaco Stereo 150	75	360	18.8	4.80	19.20
Dynaco Stereo 400	200	725	23.0	3.63	31.50
Dynaco Stereo 410	200	600	23.0	3.00	26.10
Futterman H-3A	60	350	17.8	5.83	19.70
Futterman H-4	100	500	20.0	5.00	25.00
Infinity 500DSP	250	1850	24.0	7.40	77.20
McIntosh 2305	50	500	17.0	10.00	29.40
McIntosh 2105	105	650	20.2	6.20	32.20
McIntosh 2300	300	1300	24.8	4.00	52.50
Paoli 60M (Stereo Pair)	50	600	17.0	12.00	35.30
Phase Linear 400	201	500	23.0	2.50	21.70
Phase Linear 700B	345	800	25.4	2.30	31.50
Quatre	125	330	21.0	2.60	15.70
Quintessence I	75	850	18.8	11.33	45.30
Quintessence II	150	1200	21.8	8.00	55.10
SAE B31B	50	250	17.0	5.00	14.70
SAE B4DM	100	600	20.0	6.00	30.00
SAE B3CM	200	1000	23.0	5.00	43.50
SAE B25/2500	300	1250	24.8	4.17	50.50
Sansui BA3000	170	900	22.3	5.29	40.40
Sansui BA5000	300	1300	24.8	4.33	52.50
Stax DA300	150	3600	21.8	24.00	165.40
Technics SE9600	110	800	20.4	7.27	39.20
Yamaha B-1	150	1600	21.8	10.67	73.50

1. Not all prices are "fair traded" or otherwise fixed. Dynaco is a good example: the Stereo 400 is usually available for about $460, or $2.30/watt and $20/dB.
2. Headroom referenced to 1 RMS watt = 10 x $\log_{10}$ (FTC power, RMS watts one channel), dB.
3. This is: (List Price) ÷ (FTC RMS power @ 8 , one channel).
4. This is: (List Price) ÷ (Value from Note 2).

Table 2. Ranking of Amplifiers Based on Cost Factor
Least to Most Expensive

$List/FTC Watt (8)	$List/dB Headroom
1. Phase Linear 700B	1. SAE B31B
2. Phase Linear 400	2. Quatre
3. Quatre	3. Citation 12
4. Dynaco Stereo 410	4. Crown D60
5. Dynaco Stereo 400	5. Dynaco Stereo 150
6. Bose 1801	6. Futterman H-3A(60)
7-8. Ampzilla	7. Phase Linear 400
7-8. McIntosh 2300	8-9. Crown D150A
9. SAE B25/2500	8-9. Futterman H-4
10. BGW 500D	10. BGW 250B
11. Sansui BA5000	11. Dynaco Stereo 410
12-13. Dunlap-Clarke 1000	12. McIntosh 2305
12-13. Dynaco Stereo 150	13. SAE B4DM
14. BGW 750A	14-15. Dynaco Stereo 400
15-19. Accuphase P300	14-15. Phase Linear 700B
15-19. Citation 12	16. McIntosh 2105
15-19. Futterman H-4	17. Accuphase P300
15-19. SAE B3CM	18. Ampzilla
15-19. SAE B31B	19. Paoli 60M (Stereo Pair)
20. Crown DC300A	20-21. BGW 500D
21. Sansui BA3000	20-21. Crown DC300A
22. Dunlap-Clarke 500	22. Dunlap-Clarke 500
23-24. BGW 250B	23. Technics SE9600
23-24. BGW 1000	24. Sansui BA3000
25. Futterman H-3A	25. Bose 1801
26-27. Crown D150A	26. BGW 750A
26-27. SAE B4DM	27. SAE B3CM
28. McIntosh 2105	28. Quintessence I
29. Technics SE9600	29. Dunlap-Clarke 1000
30. Infinity 500DSP	30. SAE B25/2500
31. Quintessence II	31-32. McIntosh 2300
32. Crown D60	31-32. Sansui BA5000
33. McIntosh 2305	33. Quintessence II
34. Yamaha B-1	34. BGW 1000
35. Quintessence I	35. ARC Dual 76A
36. Paoli 60M (Stereo Pair)	36. Yamaha B-1
37. ARC Dual 150	37. Infinity 500DSP
38. ARC Dual 76A	38. ARC Dual 150
39. STAX DA300	39. STAX DA300

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Guide to the BAS Speaker, Volume 3

October 1974 — September 1975

This guide is in the form of a table of contents covering Volume 3 of the Speaker. A table covering Volumes 1 and 2 appeared in the December 1974 issue. The following abbreviations are used: S — guest speaker, P — publication, N — short note, R — recommended recording.

S: Steve Goldstein, Nick Anagnostis, Sandy Ruby, Rich Malesweski, and Peter Mitchell—a panel discussion on dealer/customer interface
P: Guide to The BAS Speaker and BAS Publications: May 1972-September 1974
P: SCA Interference, Cause and Cure, Alan Southwick and Kevin P. Mostyn
P: The Burwen DNF-1200—a BAS user's report, James Brinton and Joel Cohen

Jan. 1975, No. 4
R: Recording Highs and Lows
N: Musical Performances Versus Recordings (Ranada)
N: Remarks on Amplifier Testing (Shanefield)
N: The Dahlquist DQ-10 (Leventhal)
N: Comments on "Comment on Signal Processing" (Jaeger)
N: A Simple Multipath Indicator for Almost Everyone (Zwicker, comment Brinton)
N: Comments on "Tonearm Damping" (Graham) (see also 1/75, Pub; 2/75, pp. 4-8, 13; 3/75, p. 5; 4/75, pp. 3-5, 17; 5/75, pp. 5-6, Pub; 6/75, pp. 7-8)
N: My Experience with the Decca International Tonearm (Foster) (see also 2/75, p. 3)
N: December New York Audio Society Meeting—report on Audio Technica (Shanefield)
S: Arnold Schwartz—Micro-Acoustics QDC-lE cartridge and CBS Labs test records
N: Spec sheet for Thermo Electron microphone capsule (see also 2/75, Pub, pp. 4-9; 3/75, p. 5, Pub; 4/75, pp. 5-6, Pub; 5/75, pp. 7,11; 6/75, p. 9; 7/75, pp. 3, 8-12; 8/75, pp. 2-4, Pub; 9/75, pp. 4-7)
P: The Role of Damping in Tonearm/Cartridge Performance, S. L. Phoenix (see also 2/75, pp. 4-8, 13; 3/75, p. 5; 4/75, pp. 3-5, 17; 5/75, pp. 5-6, Pub; 6/75, pp. 7-8)
P: White or Pink: Adding a Little Noise to Your Life—How to Build a Noise Generator, Rene Jaeger (see also 2/75, p. 8; 4/75, Pub)
N: Stylus Overhang Template (Foster)

Feb. 1975, No. 5
N: Tonearm Resonance (Mitchell)
N: Phono Preamp Noise (Mitchell)
N: Is TIM Distortion Audible ? (Holman) (see also 4/75, p. 8)
N: Simple Multipath Distortion Detection Rediscovered (Cohen)
N: More on Tonearm Damping (Brinton)
N: Erratum: Pink-Noise Generator (Brinton)
N: The Trials of Nate Garfinkle (And Us)— comments on phono cartridges and American versus European pressings (Garfinkle)
N: Reader Comment on FM Tuners (Mashey, Brinton)
R: Recording Highs and Lows
S: Jim Brinton, Al Foster, Bob Graham, Peter Mitchell—A-B equipment comparisons
P: A Quasi-Complementary Discussion of Microphones (Including the Thermo Electron 814), Peter W. Mitchell

Mar. 1975, No. 6
N: The QDC-1 Phonograph Cartridge (Brinton, et al.)
N: ADC-XLM Versus Shure V-15 Type III (Foster)
N: Damping a Dual 1019 (Cohen)
N: Notes on the Thermo Electron 814 (Mitchell)
N: The Pioneer Reverberation Amplifier (Cohen, Foster)
N: Going FM with "Brand X" (Zwicker, Brinton, Brinton)
N: An Excellent Book—review of Audio Quality by G. Slot (Mitchell)
N: Transcriptors Vestigal Arm (Lipshitz)
N: A "Mod" for the Citation XI (DeMond)
N: Pairing Loudspeakers (Stewart)
S: Howard Souther (Koss)—how stereo headphones are designed and manufactured (see also 9/75, Pub)
P: Son of a Witch-Glitch Switch, Dan Shanefield (see also 6/75, p. 7)
P: A Case for the 814, Alan Southwick (see also 4/75, p. 5)

Apr. 1975, No. 7
- N: Experiments with Digital Time Delay (Brinton, et al.)
- N: Wooden Damping (Mashey, comment Brinton)
- N: The 814 Column—comments on the 814 microphone (Southwick, Brinton)
- N: CBS Test Records Again Available (Shanefield)
- R: Recommended Demo Disc—Acoustic Research ENY-AR-1 (Shanefield)
- N: Videophile Note—availability of Cartrivision VTR (Cohen)
- N: Another Cartridge Heard From—Empire 2000E/III (Garfinkle)
- N: TIM Revisited (Carver)
- N: Rabco Frustrations—ST-4 turntable (Shedd)
- N: Unpopular Recommendations From Popular Science—critique of loudspeaker tests (Shanefield)
- S: Rene Jaeger—why the audiophile cannot get through the maze
- P: Improving the Thermo Electron 814 Microphone, Peter W. Mitchell
- P: Tuners: Pioneer TX-9100 Versus McIntosh MR-78—a BAS test report, Alvin Foster
- P: White and Pink Noise Revisited, Rene Jaeger and Alan Southwick

May 1975, No. 8
- N: BAS Tuner Clinics (Brinton)
- N: BAS Member Equipment Survey—A First Look (Joyce Brinton)
- N: Tonearm Damping—erratum and comments on STP (Graham, Brinton)
- N: Backcoating Versus Tape Wrap (Foster, comment Brinton)
- N: An Excellent Source for Ampex and Scotch Tape (Richardson)
- N: A Socket for the 814 (Brinton)
- N: Sequerra Replaced as Backers Take Over (Leonard) (see also 7/75, p. 4)
- N: Your Radio Shack SPL Meter—Better Than You Think (Brinton)
- S: Bob Tucker and Ed Laurent (Dynaco)—discussion of Dynaco products
- P: Improving the Performance of the AR Tonearm, S. L. Phoenix
- P: Feedback on Phono Noise—Micro-Acoustics Versus Shure, Harry Zwicker (see also 7/75, pp. 15-16)

June 1975, No. 9
- N: Speaker Impedance Measurements (Cohen) (see also 8/75, pp. 8-9)
- N: Radio-Electronics Strikes Out—a critique of test methods (Mitchell)
- N: A-B Testing Revisited (Klein) (see also 8/75, p. 9)
- N: An Embarrassingly Simple Method of Tonearm Damping (Stevens)
- N: Capacitance and Your Phono Cartridge (Dynaco)
- N: TE 814 Notes—equalizer, windscreens (Mitchell)
- N: The Dangerous Loudspeaker-danger of tape erasure (Mitchell) (see also 9/75, p. 13)
- N: More on the Cartrivision Video Tape Recorder (Cohen)
- R: Recording Highs and Lows
- S: Ron Dunlap—design of Dunlap-Clarke amplifiers, speaker impedance measurements
- P: Making a Compact Headphone Amplifier (or Two), Peter W. Mitchell (see also 8/75, pp. 2, 10-11)
- P: Audio Myths, Daniel Shanefield
- P: Phase Distortion and Transient Response, Dennis Colin

July 1975, No. 10
- N: Ordering European Records (Robinson)
- S: Fred Barrett—Sequerra Company history and the Model 1 FM tuner
- N: Atlanta Audiophiles—Audio Forum (Hill)
- N: In Praise of Tennstedt
- N: How to Really Suppress RFI in Audio Equipment
- N: The 814 Column—sockets, phantom powering, wiring, impedance mismatch with MPR-1 (Mitchell)
- N: Time and the Tape Recorder Turns Counter (Zwicker)
- N: Speaker Measurements (Mitchell)

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N: Phono Cartridge Noise: A New Low—ADC cartridges (Zwicker)
P: Comments on Records, Cleaning, and the Discwasher (Maier, Zwicker, Borden, Brinton) (see also 9/75, p. 13)
P: The Allison:One Speaker—a BAS test report (Brinton, et al.)

Aug. 1975, No. 11

N: Options with the 814 (Mitchell)
R: British Record Recommendations (Mitchell)
N: A New Magazine—Sound Advice (Riggs, Mitchell)
N: Measuring Speaker Impedance (Davis, comment Cohen)
N: Adjusting Volume Levels (Leventhal, comment Mitchell)
N: Phono Load Capacitance (Riggs, comment Mitchell)
N: Mobile FM (Horrall, comment Mitchell)
N: Are Some Red Apples Really Green ?—comments on 6/75 headphone amp article (North, comment Mitchell)
N: Addendum to Allison:One Review (Brinton, Mitchell)
N: Some Interesting Test Data on Recording Tape (McKenzie, Mitchell)
S: Sam Walinsky and Richard DeFritas (Hybrid Systems)—time delay reverb device
S: Joel Cohen—time delay device
S: David Ranada and David Satz—music, performance, and recordings
P: A Transformerless Balanced Line Preamp for the Phantom 814 Microphone, Peter W. Mitchell (see also 9/75, pp. 2, 4-7)
P: Using the BAS Oscillator, Peter W. Mitchell (see also 9/75, p. 3)

Sept. 1975, No. 12

N: Errata on A Transformerless Balanced-Line Preamp for the Phantom 814 Microphone (8/75)
N: Errata on Using the BAS Oscillator (8/75)
N: Allison:One—letter from Roy Allison (comment Brinton)
N: A Transformerless Balanced-Line Preamp for the Phantom 814 Microphone Revisited (Davis, comment Brinton)
N: Checking for Sloppy Loudspeaker Quality Control (Nichol)
N: A Nichol Sound Level Meter (Nichol)
N: A Cheap Earphone (Nichol)
N: Everything's Up-to-Date in Buffalo—Buffalo audio scene (Temple)
N: Some Sound Advice for Sound Advice—comment on A-B test techniques (Shanefield)
N: More on Sound Advice (Mashey)
N: Record Catalog Available—Canadian Broadcasting System record Catalog (Gupta)
N: Serendipity with a Technics Turntable (Leonard)
N: Attention Rabco SL-8E Owners—Rabco modifications (Slindee)
N: Discwasher Fluid (Mashey)
N: Speaker Magnetism Strikes Again—speaker magnets affect color TV (Mitchell)
S: Dennis Colin, Mark Davis, Rene Jaeger—theory and demonstration of phase shift
N: More on Phase "Error" Cancellation in Tape Recorders (Davis)
P: BAS Test Reports:
(1) A Preliminary Look at the Koss Electrostatic Speakers, Alvin Foster
(2) Tuner Comparisons—Sequerra One, Kenwood 700T, Kenwood KT-8007, Citation XV, McIntosh MR67, Larry Hardin
(3) Comparison Test: Tandberg 9100X and Sony 377, Mark Davis.
P: Membership Preference Questionnaire