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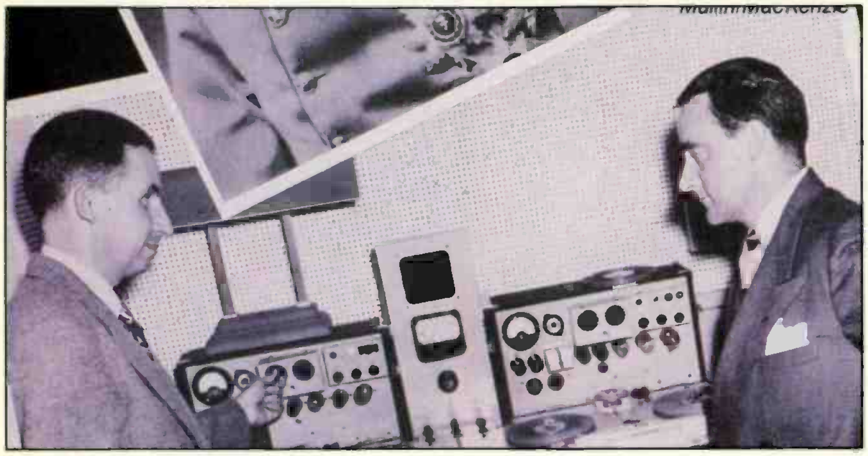

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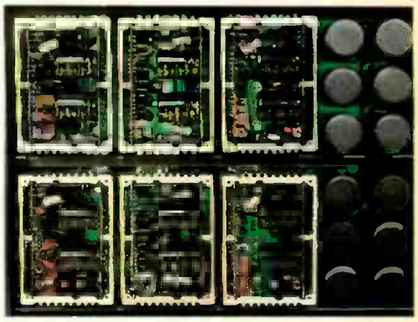

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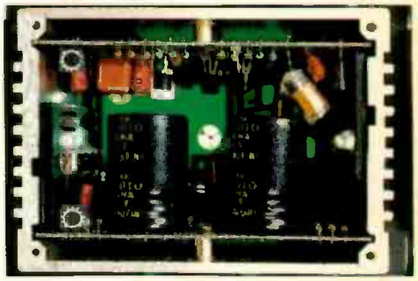

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4 out of 5 Sony car stereo owners would go down the same road again.

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Sherwood announces the latest thing in second generation CD audio technology: Affordability

The compact disc just may be the most heart-stopping concept in sound since stereo. But the most heart-stopping feature of compact disc players has been their price. Now, with Sherwood's new CDP-100, you can relax about money and really get excited about sound.

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All CD's require filters, because the decoding of digital sound generates a sampling frequency which must be filtered out, or distortions will be heard.

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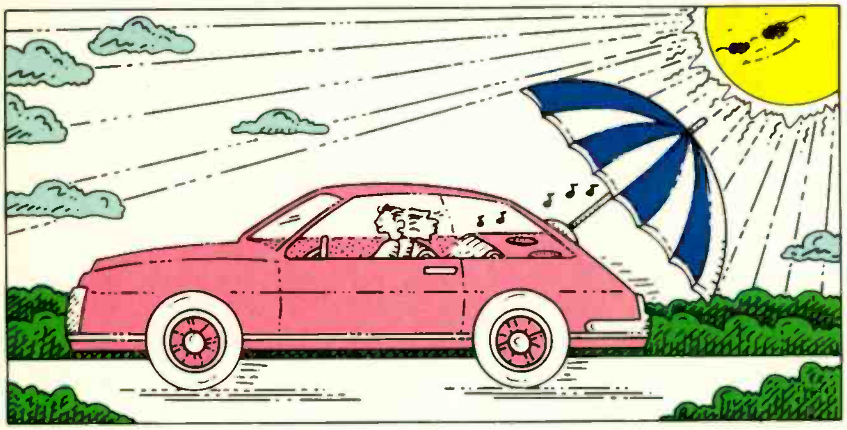
IVAN BERGER

I SCREAM CONES

Illustration: Teresa Anderko



Sun and Speakers

The sun can damage speaker cones, warping some and drying out others. I once had a rear-deck speaker whose black cone was dappled with sun-bleached spots, apparently focused in by the grille, whose small round holes acted like a fuzzy pinhole-camera lens. MTX suggests a solution, already used in their Polyplex speaker line: Transparent polypropylene, which lets the sunlight through instead of absorbing it as heat.

A spokesman for Infinity (which also uses transparent polypropylene) found this logical but added that the biggest enemy of polypropylene is not heat so much as ultraviolet light. Since window-glass filters out UV, this is no problem in most cars, but in convertibles, a scrim should be mounted beneath the grille of such a speaker, to protect it.

If you're building your own car system from home drivers, don't confuse polypropylene with Bextrene—the latter is a fine material for home use, but not for the heat of a parked car in summer.

Illustration: Philip Anderson

Clean Cuts

There are still those who say that clean sound is unimportant in the car, because the high ambient-noise level will mask the system's noise, distortion and absence of some sonic subtleties. Horsefeathers!

Listen to a clean, powerful car system, and you'll realize the masking doesn't happen all that much. The noise that's supposed to do it is of different frequencies and comes from different directions than the system imperfections it's supposed to mask.

Browsing through our July 1975 issue (which contained our first Car Stereo Directory), I found these comments in Richard C. Heyser's review of the ADS 2001 amp/speaker system:

"A *clean* audio system does not suffer as much from limited dynamic range when road noise is present as music systems of more conventional limitations do. [My car's] regular FM receiver and speaker are almost useless for symphonic music at highway speeds unless the windows are rolled up. Quiet passages just disappear. . . . [With the 2001] quiet passages were down but not out. Perhaps the fact that the overall level could be raised to overcome the masking of road noise has something to do with this, but I could 'stay with' complex music dynamics better with the 2001 than with the conventional audio system."

Beta/VHS Car-Fi?

The Compact Disc may not be the only new recording medium with potential for use in the car. Aiwa has suggested, in passing, that a Beta Hi-Fi portable could provide hours of music on a single tape, requiring no attention from the driver. And the fidelity, of course, would be superb.

There are some problems, though. You'd have to decide when you made up your tape just what you'd want to hear, and in what order. Not many VCRs provide index locators which let you find the start of each recorded section, and even with those, you'd have to stop and restart the recorder after each selection to record the index mark—no problem if you want one index mark for each opera of the *Ring* cycle, but a nuisance if you want one for each cut of a pop album.

There's also the question of size. The smallest Beta Hi-Fi units are much bigger than most car-stereo units (though not a whole lot bigger than the Nakamichi audio portables that people used to use in cars), and, as far as I know, Beta Hi-Fi is not yet available in the even smaller Betamovie-size transport (not available yet without a camera attached) or the even-smaller Toshiba V-X34 portable.

But what about VHS Hi-Fi, which is just arriving? The VHS cassette is bigger than the Beta—but, nonetheless, VHS portables are here (from Canon, Panasonic and others) that are smaller than any current Beta Hi-Fi models. The VHS-C tapes are even more compact, but they only run for 20 minutes—no time advantage there! The new ultra-compact 8-mm video format is also limited in time (90 minutes so far, with the possibility of 120 minutes someday), and no Hi-Fi sound system has yet been suggested for it.

Stereo AM

"RCA Broadcast Systems demonstrated a proposed AM system at the recent National Association of Broadcasters meeting. . . . Mono receivers would be able to receive a single component signal with no degradation in performance."

Audio, August 1975

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IVAN BERGER

FANGS ACROSS THE SEA

Illustration: Michael A. Donato

His Master's Snake

We all know the famous picture of the dog looking into the gramophone horn. It's been used as a logo for decades, by companies all over the world, which once were related: RCA here, Britain's HMV ("His Master's Voice," named after the painting they were first to use), JVC (Japan Victor Co.), and so on. But in India, the dog is considered unclean and so is replaced on record labels by a cobra, with a supporting cast of antelopes, tigers and turtles—or so I understand from a review of a recorded-music history book, *The Incredible Music Machine,* edited by Jacques Lowe. (The review appeared in *TLS, The Times Literary Supplement* of London.)

Walkman Progress

World freestyle ballet ski champion Jan Bucher shows how modern integrated circuits have shrunk the Sony Walkman, compared to the Class-A, all-tube original prototype behind her.

Subjectivity

As hardware and recordings improve, the differences one must listen for can become quite small. While differences no one can hear are not worth pursuing, how audible must a change be to be worthwhile?

If you *can* hear the difference (even if others you trust say they don't), and if you can hear it consistently, even when you weren't expecting to, then the difference is real. That leaves two questions: Is the difference really an improvement? And if so, is it worth its cost to you? With subtle differences, the first is often hard to call; the second, which depends on the price, your income, and your priorities, is only a little easier.

If you *can't* hear the difference, then you're faced with a dilemma. Should you trust others' ears and buy it—with the risk that the difference either never did exist or that you'll never learn to hear it? Or should you pass it by, trusting that the difference never will be audible to you? It's a rough decision, especially as some subtle differences take a while to become aware of.

The choice is yours—and purely subjective.

The Importance of Being Imaged

Until stereo came in, the main focus of hi-fi design was on improving purely monophonic aspects of sound quality—reducing noise and distortion, extending and smoothing frequency response, expanding dynamic range. With stereo, two new factors entered: *Ambience*, the ability to reproduce the space in which the recording took place, and *imaging*, the reproduction of instrument locations within that sound field. As distortion, noise and frequency response come more and more under control, increasing attention has been devoted to these two new factors, especially imaging. To some audiophiles, it seems, imaging has become *the* touchstone by which the quality of equipment and recordings should be judged.

I agree with those who feel that imaging and ambience add to listening enjoyment and enhance the concert-hall illusion. But I don't quite agree with those who feel that imaging reproduces a concert-hall reality. I attend an average of 20 live musical events per year (all classical), and I find that, from most seats in the concert hall, imaging is far less precise than it is on good home systems.

In the concert hall, imaging is only really sharp when you sit fairly far up front, at least in the front half of the hall. From some seats there, the orchestra also subtends a wider angle than most home systems' speakers do, which makes the image much broader, as well. I usually sit farther back, where the sonic blend is better, the ambience richer—and the ticket prices cheaper. (Paying more would mean hearing less, by cutting me down to fewer tickets.)

So imaging is often better at home—and a good thing, too, as that's your only clue to what is happening in the sound stage. In the concert hall, you can just look; in fact, you have to close your eyes to become consciously aware of what is happening sonically. (It's often for less "hi-fi" than you'd think.)

It's the illusion, not the reality, that tight imaging fosters. That's just fine—as long as we know the difference.

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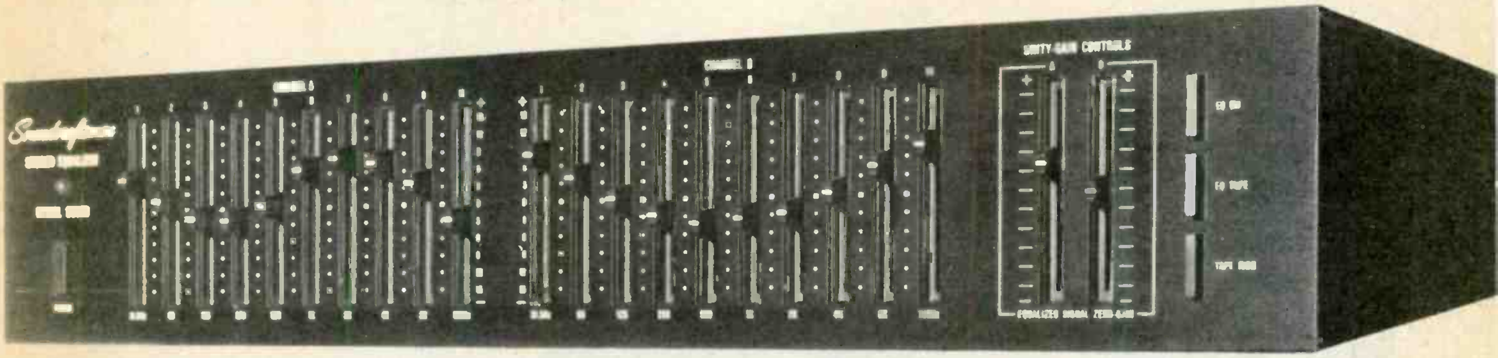

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The SE550 features 10 individual bands of frequency adjustment, covering the ENTIRE RANGE of human hearing, for EACH channel. Tape Monitor, Tape Equalization and EQ Bypass controls are located conveniently on the front panel. There is even a handy A.C. outlet on the rear panel for your tape recorder. Most importantly, the performance is **pure Soundcraftsmen!**

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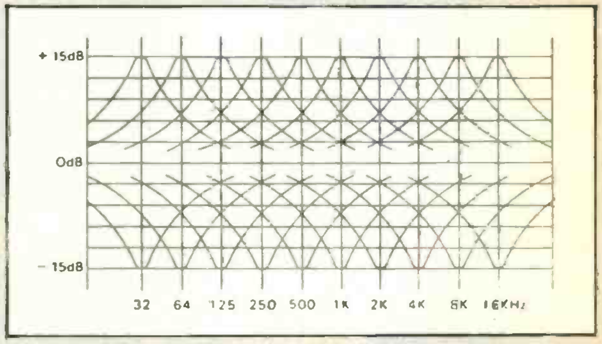

The linear filter action shown above contributes to the SE550's minimum phase shift and low distortion, unequalled in equalizers in its price range. ±15dB/Octave, 18dB Unity Gain range.

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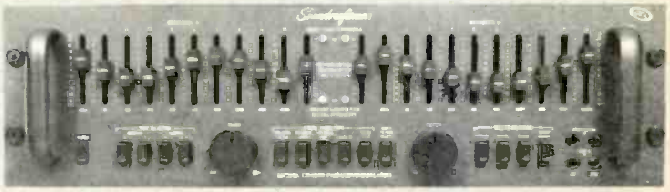

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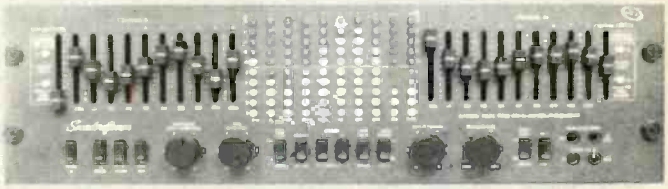

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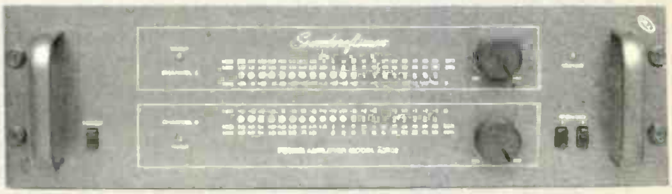

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BERT WHYTE

IN THE SHRILL OF THE MIKE

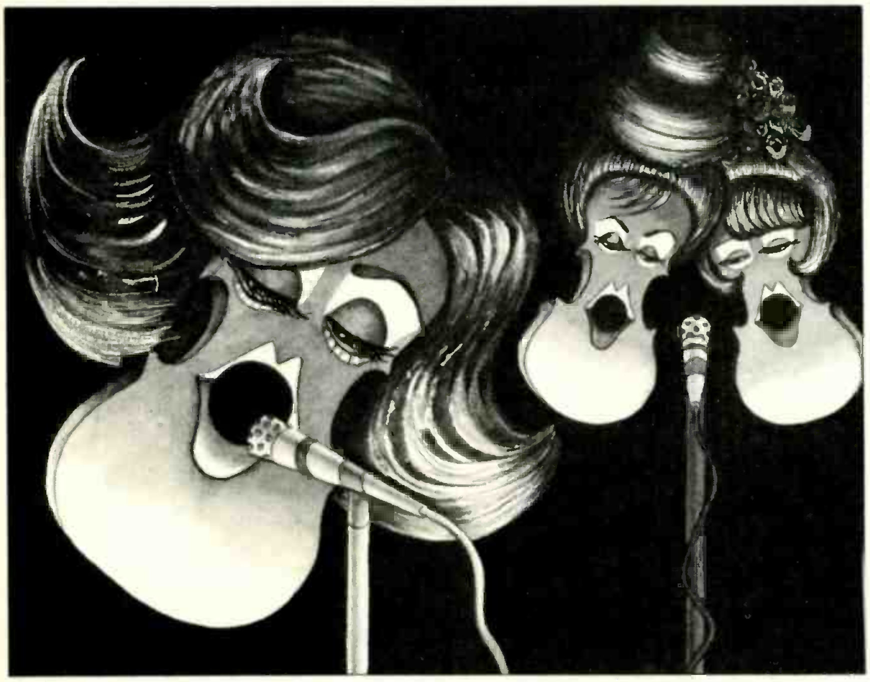

Illustration: Jennifer Skopp

The Compact Disc was introduced into the American marketplace a little over a year ago, with great fanfare and some rather extravagant claims. "Perfect sound forever" was a particular bit of hype that ruffled the sensibilities of many audiophiles. Few could deny the new system was a brilliant technological achievement, but almost from day one, the quality of the CD's sound was the subject of heated controversy.

On the one hand, the CD was lavishly praised for its ruler-flat frequency response, 90-dB dynamic range, inaudible distortion, unmeasurable wow and flutter, and—above all—the total absence of ticks, clicks, and pops. Music was finally to be free of the tyranny of noise. On the other hand, a voluble group contended that digital sound was seriously flawed, a premature and retrograde step which badly degraded the music signals. This anti-digital group claimed that digital recording significantly attenuated—or even destroyed—ambient and reverberant information. Further, they maintained that inadequate sampling rates and low bit density, plus problems with the A/D and D/A converters and anomalies in anti-aliasing filters, resulted in spurious effects which seriously marred the sound. There were specific complaints about overbright sound and orchestral instruments (most especially the strings) that were shrill, strident, edgy, and glassy—in a word, unnatural. The main bone of contention was that these anomalies were inherent in the digital recording process. Unfortunately, the claims were bolstered, early on, by the very substantial number of CD recordings exhibiting these negative qualities and indeed having a very poor sound.

The vociferous anti-digital forces have not accepted the idea that most of the bad CD sound is due to poor recording techniques and the inadequacies of ancillary analog recording equipment, from microphones to mixing consoles. Now, almost 18 months after the launch of CD recordings and players, there have been significant improvements in the technology of the players and a welcome reduction in their cost. There have also been refinements in the mastering and processing of CD recordings and a notable increase in the availability of CDs with high-quality sound.

Yet, it must be noted that lists of recommended CD recordings in audio publications comprise fewer than 50 titles. Whether this dearth of CDs with high-quality sound is a result of hidebound adherence to analog recording methodology or a failure to comprehend the more rigorous demands of digital recording (both as to equipment and microphone techniques), the sad fact is that far too many CDs with atrocious sound are still being released.

Most readers of this column know that I have also been reviewing CDs for *Audio* for some time. You will have noted that I've not been very kind to a number of recordings. Please understand that I have not singled out any particular company for poor sound; almost every record company issuing CDs is guilty of making some really awful-sounding discs. What recording transgressions I report are mainly due to a predilection of some labels for certain recording techniques which almost inevitably lead to poor sound.

Another aspect of record reviewing which must be particularly irritating to many readers is the often wide disparity of opinions among critics in various publications. By the same token, it is interesting and somewhat reassuring when critics, oceans apart, agree on the sonic merits of a recording.

This column had its genesis after I became incensed with the incredibly poor sound of Deutsche Grammophon's CD of Richard Strauss' "Metamorphosen" and the famous "Death and Transfiguration," with Herbert von Karajan conducting the Berlin Philharmonic Orchestra. Here is a recording in which von Karajan's performance has been widely—and justifiably—praised as magnificent and a veritable tour de force. The playing of the superb Berlin Philharmonic is simply glorious, but the sound quality is so poor that it is hard to believe. The overall sound is thin, which is exaggerated by the somewhat overly reverberant acoustics. The oppressive multi-microphone technique compartmentalizes each section of the orchestra and completely squashes any sense of atmosphere. The worst aspect is the sound of the first and second violins. I have heard more than enough shrill, strident, and steely string tones on CDs from many companies, but the sound here is a grotesque caricature of real-life violins. Moreover, the wonderful ensemble playing of the string section only serves to emphasize these dreadful shrieks. I just cannot imagine the DGG *tonmeisters*—the producer and the artists and repertoire director—sit-

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CD recordings will improve. No technical constraints can prevent this, no matter what the anti-digital forces contend.

ting in an audition room presumably equipped with a reasonably good-quality playback system, listening to this awful recording and approving it. I have always had the greatest respect for Deutsche Grammophon, which has made thousands of great recordings over the years. However, since they adopted multi-microphone techniques some years ago, an unfortunately high percentage of their recordings have suffered from overbright, edgy string sound. This situation existed before digital recording, and now that it is in daily use, the problem is exacerbated. You may recall that about a year ago I reported that the president of DGG had admitted, in *Billboard* magazine, to recording problems with digital sound, and he stated that DGG would modify their techniques to remedy this. Thus far, I find no evidence of these changes.

In terms of classical recording on CD, DGG is by no means the only offender. While it is true there are now more CDs available with good sound, the *percentage* of worthwhile titles among the hundreds being released is still woefully small. However, CD recordings are bound to improve, since there are no technical constraints to hinder such progress—no matter what the anti-digital forces contend. These sonic improvements will be almost exclusively in recording technology. While the companies pressing CDs will undoubtedly turn out a better product with stricter quality control, note that, from the beginning, most CDs have been remarkably free of glitches and other defects.

Lest you think I'm just a nit-picking old curmudgeon, let me admit that the divergence of critical opinion I mentioned earlier extends to me and other critics I respect a great deal.

For example, Angus McKenzie, who is associated with *Hi-Fi News and Record Review* and is one of Britain's most prestigious critics, both agrees and disagrees with me. On a Philips CD of the Bruckner Ninth Symphony, with the Concertgebouw Orchestra, both he and I find the acoustics a bit too reverberant—but he finds the strings smooth while I find them steely. On a Denon CD of Haydn and Boccherini cello concertos, he found the solo cello "marginally too close," while I felt Denon's engineers had gone too far the other way.

On the London/Decca Mahler Ninth Symphony, with Solti conducting the Chicago Symphony Orchestra, both Angus and I felt that the high strings were edgy. Though I felt there was still some really spectacular sound in many parts of the recording, Angus thought it "the sort of CD that anti-digital people might well play and then try to blame digits rather than sound balance." Yet, despite these sonic defects, this Mahler Ninth won a Grammy award for "best-engineered classical recording"! (I heartily concur, however, in Sir Georg Solti's picking up another Grammy for "best classical recording." The performance is truly stupendous.)

I know that Angus uses Quad ESL-63 speakers in his evaluations. It just so happens that I have been using both ESL-63s and the new Duntech PCL-3 planar loudspeakers to review CDs. These are about the most revealing speakers extant, and I couple them with Janis W-1 subwoofers for extended bass and more power handling. I also use a pair of B & W 801F speakers, because they are the official monitors for Decca, EMI, DGG, Philips and others. Thus, I can hear sonic qualities and recording balances as perceived by the recording engineers.

Obviously, my tastes in equipment overlap with those of Angus, so it's little surprise that he and I appear to be in general agreement on the sound qualities of CDs we both have reviewed. What differences we perceive may be due to our listening room acoustics. And, although we sometimes audition with the same speakers, different preamplifiers, amplifiers and other equipment might contribute to our divergence of opinion.

On the other hand, a comparison of reviews of identical CDs by many other critics makes me wonder if we are listening to the same recording!

One thing is certain: The Compact Disc has proven to be a viable format, a superior storage medium for recorded music which, in its highest manifestations of quality, affords audiophiles the equivalent of original master recordings. For the very first time, there are recordings that can tax the capabilities of even the most advanced and exotic audio component systems. ▲


SOUNDS RIGHT
Bill Taylor

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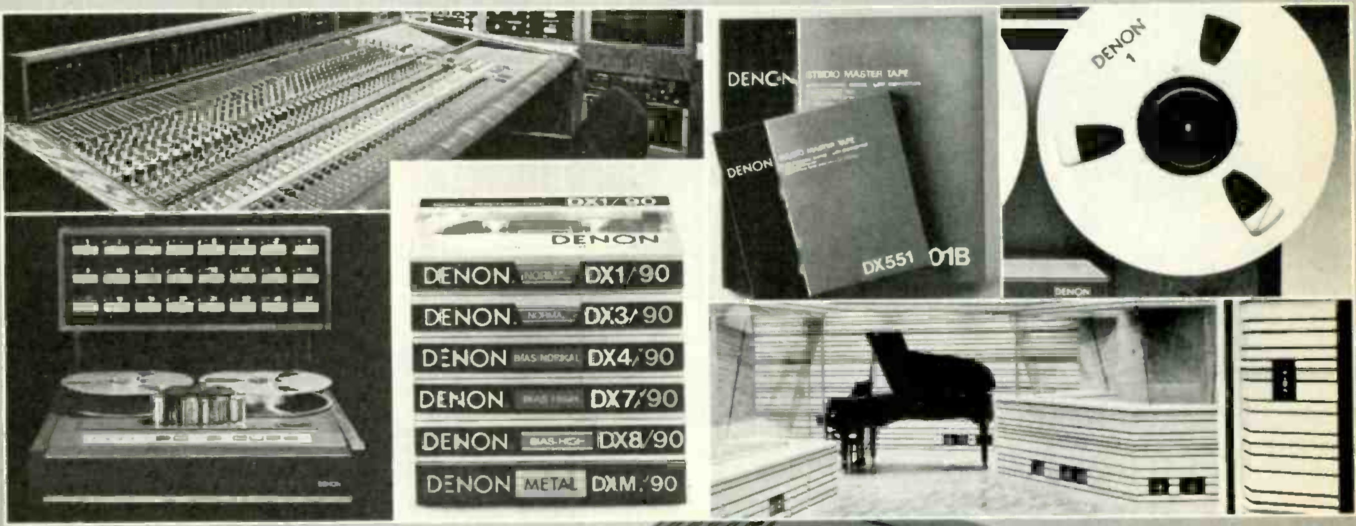

DENON

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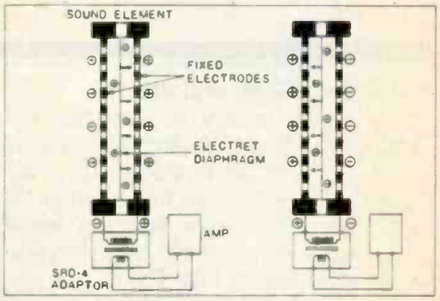
The SR-Lambda Professional Earspeaker System was originally designed by the West German automotive manufacturer Daimler-Benz for their research and quality control engineers to use in car noise analysis. From a musical point of view, the end result of the SR-Lambda Professional is so outstanding that STAX is now making it available for home & studio use.



If we speak of a headphone, it usually means a dynamic one employing a dynamic transducer. In the dynamic transducer the driving force is applied only to the one part of the diaphragm which, therefore, must be stiff enough not to be deformed by air load. However, stiff materials considerably increase the diaphragm mass resulting in significant deterioration of transient response. In addition, the ununiform force applied over the diaphragm area leads to what is called "cone break-up". Hysteresis distortion caused through the magnet inevitable in the dynamic transducer cannot be ignored, either.

The electrostatic transducer adopted in the STAX earspeakers consists of two parallel-arranged fixed electrodes and several microns thick (2 microns in the SR-Sigma, the SR-Lambda and the SR-X/Mk3 and the SR-5N. 4 microns in the SR-84 and the SR-34) high-polymer film diaphragm suspended in the middle of the electrodes. The low-mass film diaphragm is supplied with biasing voltage from the energizing adaptors or from the SRM-1/Mk2. In the electret type earspeakers like the SR-84 and the SR-34 the diaphragm is permanently charged minus. When the fluctuating voltage of the audio signal is applied to the electrodes, the diaphragm is pulled by the electrode which has the opposite charge of the diaphragm's and simultaneously pushed by the other electrode which then has the like charge of the diaphragm's. The continuous flow of alternating voltage in interpretation of audio signals causes the diaphragm to vibrate in faithful compliance with the amplifier output without time lag, assuring undistorted sound waves. This is why the STAX electrostatic earspeakers sound so good. The figure above shows the driving mechanism of the SR-84 and the SR-34.

SR-34

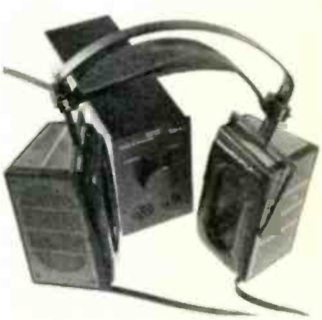
Cost vs. Performance
Electret Earspeaker

SR-84

Lambda Junior
Electret Earspeaker

SR-Lambda

Semi-Panoramic Imaging
Electrostatic Earspeaker



SR-Sigma

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TAPE GUIDE

HERMAN BURSTEIN

Tape Sensitivity and dbx NR

Q. I plan to buy a cassette deck with Dolby B and C, and also plan to buy a dbx noise-reduction unit. Will there be any problem in adjusting the dbx NR unit to work with the deck? How will I adjust it for tape sensitivity?—Mark Eisert, Erie, Pa.

A. I foresee no problems in getting the dbx unit to work properly with your deck. In the unlikely event that a problem occurs even if you have carefully followed the dbx instruction manual, this type of question should be addressed to your audio dealer or to dbx.

No sensitivity adjustment is required for dbx, although such an adjustment is necessary in the case of Dolby NR if good tracking and, therefore, good treble response are to be obtained.

I trust you do not plan to record with both Dolby (B or C) and dbx simultaneously. With the approximately 30 dB of noise reduction achieved by dbx, further noise reduction is probably superfluous and is apt to lead to problems, including poor Dolby tracking. On the other hand, it may be interesting to experiment with simultaneous operation of both NR systems. Sometimes things that are not supposed to work do work—and vice versa.

"Thin" Sound at Low Volume

Q. When I play my tapes at very low volume, the sound seems to be very thin, not rich in tone. My preamp doesn't have a loudness control. What can I do to help improve the sound at low volume?—George Chang-Kit, New York, N.Y.

A. When music is reproduced below its original level, there is an apparent loss of bass to the human ear. This is known as the Fletcher-Munson effect. Therefore, many preamplifiers (separate or as part of a receiver or integrated amplifier) incorporate a loudness switch which automatically boosts the bass relative to the rest of the audio spectrum when volume is reduced. Whether such automatic boost is the right amount—neither too much nor too little—is another question. It appears that most preamps do not answer this question satisfactorily. A few do, by incorporating both a volume control and a *continuous* loudness control (rather than a switch). The volume control is used to adjust the sound level to that which approximately corresponds to the original level; the loudness control is used to reduce the listening level to a comfortable one and at the same time automatically provides bass boost of more nearly the correct amount than does a mere loudness switch.

If you lack a loudness control, you can try using the bass control to boost the bass when you play music at low level. If this isn't satisfactory, you will probably find that much better results can be obtained with a graphic equalizer, which enables you to finely select those portions of the audio spectrum you wish to emphasize (or de-emphasize).

Open-Reel NR

Q. Why is it that the vast majority of open-reel tape decks do not incorporate a noise-reduction system of any sort?—Hillel Brandes, Grantsville, Md.

A. As a general principle, noise-reduction systems are most audibly effective with noisy tape decks. Inasmuch as the signal-to-noise ratios of fine open-reel decks reach well above 60 dB and even into the 70s—without benefit of NR—their manufacturers have tended to eschew such systems.

In the beginning, virtually the only NR system available for home use was Dolby B, which offered an improvement of about 8 to 10 dB in S/N. The *audible* improvement with cassette decks, which had S/N in the high 40s or low 50s, was quite marked, but it was less so with the superior open-reel decks. Furthermore, every NR system has some undesirable side effects, chiefly pumping and breathing (volume changes and bursts of hiss), although by now these side effects have been reduced to insignificance for most listeners. Then, in the case of the Dolby NR systems, matching of input and output levels is required to avoid what is called mistracking, which results in some loss or excess of treble at the very high end. Altogether, then, it appears that most manufacturers of open-reel decks have elected not to gain a modest audible improvement in S/N in exchange for higher cost, possible side effects, and special adjustments to avoid mistracking.

Of course, today we have Dolby C with its improvement of approximately 20 dB in S/N and dbx with its improvement of approximately 30 dB—both virtually free from side effects to most listeners. Hence, it appears desirable and profitable for open-reel decks to include an advanced NR system. By doing so, they could achieve S/N well into the 80s and 90s in terms of dB—and this would rival digital performance. Why this isn't happening may have to do with the manufacturers' evaluations of the market.

Magnetization Worry

Q. I recently read that one should never turn on a tape deck when it is already in the record mode. That is just what my little girl innocently did, and I am wondering whether my deck is irrevocably ruined. I demagnetized the heads, using a cassette-contained demagnetizing device, and have not noticed any problem with recording or playing tapes since then. However, I am not all that confident about my ear's ability to detect losses of high frequencies, etc., and wonder whether I am going to have to replace a deck I like or run a serious risk of degrading all the tapes I play.—Porter C. Holman, New York, N.Y.

A. There might be a slight chance of magnetizing the record head if the power were turned on just when a very high signal level was fed to the head, although I am inclined to doubt it. Bias current, which is several times the magnitude of the audio signal, presents more of a magnetization threat from a current surge when one enters or exits the recording mode, but a properly designed deck protects the record head against such surges.

If head magnetization did take place, a good-quality demagnetizer should take care of the problem. If you are still worried, despite the evidence of your ears that the deck works properly, you might have a service shop check it out. If the shop has a magnetometer, do not be alarmed if the head exhibits a slight amount of magnetism. It is very difficult, or even impossible, to reduce head magnetism to zero.

If you have a problem or question on tape recording, write to Mr. Herman Burstein at AUDIO, 1515 Broadway, New York, N.Y. 10036. All letters are answered. Please enclose a stamped, self-addressed envelope.

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EDWARD TATNALL CANBY

KNOCKED OUT NETWORKS

Illustration: George Blume

Last month's discussion of "old-band" FM radio in the 1940s was an unofficial segment of my continuing "audiobiography," but so much of the vivid FM background returned to mind that things got a bit out of hand in that respect. If you will consider that the factual account I offer is backed by my own personal recollections, which illuminate so much for me that I did not then understand, I'll continue in the same vein. We might well have had an incredibly different FM right now. We almost did.

It is worth saying again that the early and elegant old-band FM radio broadcasting, from 1939 until soon after the war, was the true start of hi-fi, years before the "component" movement got underway. It was the first real *public* hi-fi, if on a small scale. Since last month I've found a lot to bolster that idea in a superb book about FM's great inventor, *Man of High Fidelity: Edwin Howard Armstrong*, by Lawrence Lessing. It was published not long after Armstrong's death, but the original 1956 edition was superseded in 1969 by a revised and expanded paperback version, published by Bantam. This revised version takes FM right up to the stereo era, and it is still available through The Armstrong Foundation (1342A S.W. Mudd Building, Columbia University, New York, N.Y. 10027, $1.00 each). It should be intensely interesting for any audio enthusiast with FM in his blood.

To be sure, Major Armstrong's work in radio merely culminated in FM, dating from 1933. Much earlier, and also covered in the book, came those absolutely fundamental radio circuits, the regenerative and then the superhet; with them was that basic audio principle, the amplification of a signal by means of the vacuum tube—a thousandfold, a millionfold, and on. In the end, Lee de Forest, the "audion" tube man, won a battle in the Supreme Court over regeneration, but there isn't much doubt in knowledgeable engineering minds as to who really got there first. (Now don't write Letters to the Editor on *that* subject! It has been hashed out in millions of words already.)

At least *Man of High Fidelity* suggests that, in the mid-'50s, author Lessing was aware of our newly burgeoning hi-fi biz and not averse to writing for a newly expanding audience, even if the term hi-fi doesn't really apply to Armstrong's earlier discoveries. The title does indeed reinforce my own memory, as of last month, of the extraordinary sonic quality available in that earliest FM. One of my questions is answered neatly by Lessing—how come such remarkable quality in the associated FM equipment, amps, speakers? It was Armstrong himself. His fingers were into every bit of the developing FM operation; he was fanatical in his insistence on "the best" and in a position to enforce his views, through his FM licensing and his own meticulously detailed personal tests, from studio mikes right through to FM loudspeakers. He worked directly with his manufacturers on all this—no wonder the results were remarkable.

As far as I can now figure, it was in the fall of 1940 that I heard FM for the first time. It came—just about the time the "old band" was allocated—direct from the Major's own station, W2XMN in Alpine, N.J., the one with the big tower across the Hudson. That station went on the air in mid-1939, via one of the five pre-old-band experimental channels. It was a whopper, high power, up in the top range along with the well-known "clear-channel" AM outlets of 50,000 watts and more. And Armstrong worked fast: In that same year he got others to plan a series of similar powerhouse FM stations in other regions, with his very active aid and cooperation; already there were 150 applications for FM stations waiting. For five channels! Under a favorable FCC, television was booted out of just one of its 13 experimental channels, the lowest, making room for FM to expand to 20 channels. Within a year or so there were 500 FM station applications backed up, and more on the way.

New England was a focal point—two of the big 1939 stations began there with a provisional 2 watts, awaiting full power. The Yankee Network set up on a mountain some 40 miles from Boston with its 2 watts and immediately was found to cover the territories of three major AM stations! The same astonishing coverage showed up nearer New York, via an entrepreneur named Doolittle, on Meriden Mountain, which is nicely located between Hartford and Springfield to the north and New Haven to the south, thus blanketing the populous Connecticut River Valley. With full power, *what then?* This was real revolution.

Even more important, perhaps, was a favorite new application of FM radio, the microwave directional beam, now

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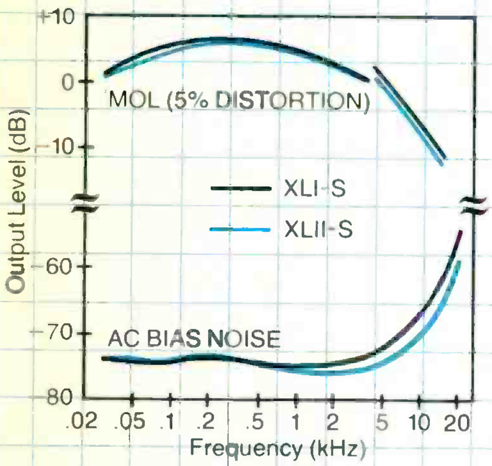

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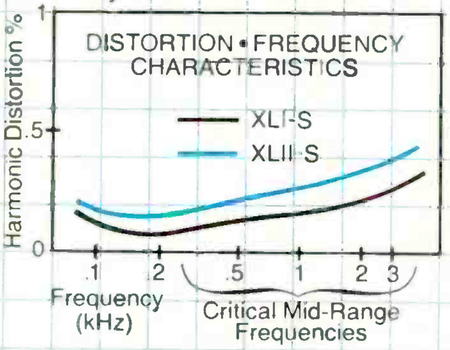

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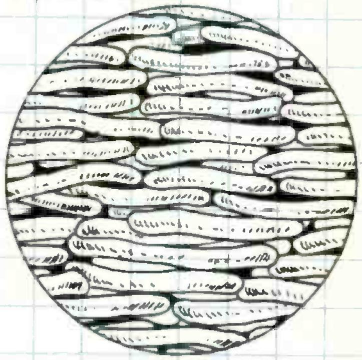

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Which is why Maxell high bias XLII-S and normal bias XLI-S are unsurpassed at reproducing the sound qualities found on today's finest recordings. Regardless of whether your frame of reference is analog or digital audio discs.

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IT'S WORTH IT.

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Armstrong worked fast, setting up one powerhouse station and getting others to set up similar ones in other regions.

familiar to all of us. It was impractical via AM. Static, interference and so on. With FM it was as good as a hi-fi cable, and cost much, *much* less for station interconnections. That 2-watt station near Boston, like others to come, was not fed via phone lines, or cable, but by simple microwave, studio to transmitter. Very soon, there was microwave FM from the top of Mt. Washington in New Hampshire.

With all this, why not an FM-plus-microwave country-wide set of networks, coast to coast, and all of top hi-fi quality at relatively low cost? Marvelous thought! There was terrific enthusiasm for it among those who realized the implications.

That, it seems, was what was in the works, and in a hurry, back just before 1940. It accounted for the pile of FM applications as much as FM's own superior sound quality and noiselessness did. A whole new broadcast setup with a 1940 quality not far from what we have now, even with our satellites and all the rest, the whole laced together via microwave connectors—a series of super-high-power regional FM stations, accurately covering relatively fixed areas. Wow! What an inspiration for those who wanted to get in on the FM ground floor!

Don't forget that whereas AM stations on the same wavelength tangle hopelessly (and with those nearby on one side or the other), FM stations ideally do not interfere. It's one or the other, not both. And in those days there were no skies full of jet planes to confuse the FM signal. Remember that the AM networks, in all their vastness, were interconnected mainly via phone lines plus, eventually, the expensively constructed coaxial cable—all these connections on a rental basis. The whole business was ever so neatly bypassed by microwave with FM.

Do not suppose, then, that there was nothing but enthusiasm for this exciting changeover to a new and superior radio system! If you know the big-time commercial world, you know what was going on. How about a couple of billion dollars of vested interest on the part of America's largest communications establishments? How about those big operators who rented out their connecting lines at a fat megaprofit? The entire and hugely successful AM radio system at that point was based on the combination of AM broadcasting and the network concept—stations interlinked *not* via microwave, nor the non-existent satellite, nor magnetic tape, the same, but guess what? In effect, AT&T.

We have no business being critical of this system itself. Radio and long-lines phone-company hookups had grown together after only a dozen-odd years into America's biggest communications, entertainment, and advertising medium. Is that a sin?

Nor, until FM, was it a sin that (by no coincidence at all) the parameters in these interconnected elements of the AM system were of a similar degree: Uniformly lo-fi, from beginning to end and on a huge scale. The system obviously worked. The public appreciated it, obviously, and the promoters made cash. It was so successful that for most of those years there was really no change in the basic radio sound. People were used to it and they got the messages they wanted, as well as the messages which the broadcasters and ad people wanted them to get. It was big business.

And then, suddenly (it seemed), this new FM with its unassailable advantages! You could have forecast the explosion. When things came to a head, Armstrong had his 500 applications just waiting for a place in the new station roster on the "permanent" FM band, ready for a jump onto this new hi-fi radio bandwagon with technology that invalidated the *entire* AM network concept! What—you expect AT&T, RCA, CBS, MBS, and the like to applaud politely?

Well, why didn't they license themselves for FM and simply convert, as comfortably as possible? Not likely, even for lesser commercial powers. In the face of this sort of deadly challenge, inertia is overwhelming, aided by every kind of rationalization in respect to the obvious values of present product and the highly doubtful benefits of the new. What else? ("The public doesn't want better sound" was a major argument, as it was later when our own hi-fi began to get around.)

As for the large corporations, they are laws unto themselves, and most do not work in any amicable fashion at all. GE, for its own reasons, went along

With FM, the microwave directional beam was as good as a hi-fi cable, and cost much, *much* less for station interconnections.

with Armstrong as an FM licensee. Zenith too. Not the big fellows—and especially not RCA, where the whole network idea had originally developed through NBC.

RCA apparently figured it would get along very well without Mr. Armstrong if it applied its considerable talents towards fending him off. License? Royalties? The *last* thing a huge establishment does is pay royalties to some lesser power! And especially not to a single inventor, entirely on his own. That was Armstrong.

I remind you of an additional set of facts by means of which you may further guess the kind of thing that was going on and draw your own conclusions. Have you recently listened to any high-power FM stations? You are aware that many are remarkably low in power. The rationale is handsome. Height versus power, so that each of many FM stations in an area will have the same effective clout at your home tuner. FM was for local people—right? It brought a new concept of, er, democracy in radio entertainment. (Shades of today's cable and public access!) Very nice idea.

But the fact is that here we are, some 40 years later, quite without those *big* FM stations and their new network system that was so clearly "in the works" back in 1939 and 1940. Who now controls most of the large-scale broadcast networking of today, if via different means and mostly for TV? None other than the same large corporations, more or less, which owned the AM network system in 1940. Strange. And where are the big FM-only networks that Armstrong clearly had in mind and very nearly in fact? Nowhere. The later low-power FM system, if I am right, makes them quite impractical.

FM, we are often told (but not by its inventor), is for small, independent operations, for minorities (like classical-music listeners!). Even our present commercial FM stations are isolated, each to its own territory. *Is this really FM's true best use?* It has been *made* true, arbitrarily. Behind the sweet, persuasive words, back in the 1940s, there was a struggle to the death. And Major Armstrong lost. Not everything, but plenty. He gave up in January of 1954. Dead of a fall from his high apartment window.

We are not so badly off, it must be said, under the present mandatory FM system, which has gone on to evolve with some logic to fit the need. But the irreversible frame, absolutely excluding Armstrong's major FM expectations, was set up in a hurry way back then, just in the nick of time to stop what FM might have been and maybe should have been—real commercial-network big time.

You can imagine your own details, but Lessing lays them out splendidly in *Man of High Fidelity*, to make your eyes pop with astonishment. So long after, in retrospect, this story has the ring of truth. I am glad I wasn't Major Armstrong. **A**

KEN POHLMANN

THE FUTURES MARKET

Illustration: Bob Scott

At midnight on December 31, 2000, we will enter the third millennium A.D. While it may be a bit early to buy your party hats and noisemakers for that gala occasion (which most people will mistakenly celebrate a year early), audio companies are already well along in terms of research and development for the 21st century. During a recent visit to Tokyo, I was privileged to enter the inner sanctum at Sony and discuss new product development with their chief engineers. As you might expect, most, in fact virtually all of the discussion centered on digital technology. If this column were entitled "Analog Adventures" or something, I don't think Sony's engineers and I would have had very much in common. Their emphasis is clearly on digital, and their product development programs promise high-technology times for consumers.

During an introductory meeting, Sony President Norio Ohga stressed his company's sense of historical perspective and its declared ambition to pioneer audio developments and preserve for itself a place in audio history. For example, it was on the 100th anniversary of Edison's cylinder that Sony decided to develop the next consumer audio medium. That decision, of course, culminated in the introduction of the Sony-Philips Compact Disc in 1982. That now-familiar disc is just the beginning of an ambitious format expansion called CD ROM (Read Only Memory). As a low-cost memory, CD ROM would use the 550-megabyte storage space on a Compact Disc for a variety of applications, including 2- or 4-channel audio, digital pictures, and computer graphics. Everything from dictionaries, textbooks, magazines, and shopping catalogs to computer programs and video games could be disseminated.

The existing CD format will remain intact, but in CD ROM the data area currently used for audio will be used for general-purpose, digital-data storage. The subcode on the track will not be changed. Players will be substantially the same, but digital outputs and video interfaces will have to be added as built-in features or made available as accessories. Presto—your CD player will become a mass-data storage device, and each disc will hold a ton of information. That 20-gram piece of reflective plastic will cost a lot less than the equivalent 500 to 1,000 conventional floppy discs it will replace. It will save a lot of space, too. With a 12-cm disc holding 12,000 sheets of documentation, we could all be walking encyclopedias. Which reminds me—CD Walkman, look for it soon. I saw a battery-operated prototype player, half the size of a book, and it sounded great. And, yes, the special LSI ICs used to achieve size reduction in the portable players will permit proportional cost reduction. And the cost of discs—on the way down, too. CD ROM will greatly extend the CD's product life, but Mr. Ohga noted that he expects the CD to be a viable format only *until* the 21st century; with the rapid pace of storage technology development, the CD is just the beginning. . . .

The next evolutionary step for the CD is the DRAW system, which is a write-once medium. Similar to film in a camera, a disc is used to record once. DRAW would use a format compatible with the CD, but would require an enhanced player/recorder. The prototype DRAW disc is a magneto-optical disc on which a laser beam is focused through a current loop; it uses a 30-cm disc with a pit density of 3×10^5 kilobits per square inch ($KBPI^2$), yielding 1.89 gigabytes of storage.

Recordable and erasable disc systems are also under development, and I was privy to demonstrations of prototypes. Like the DRAW disc, the erasable disc is magneto-optical, and it offers the read/write advantages of a floppy disc but with much greater storage capacity (the prototype holds 5.2 gigabytes). Cost would initially limit this medium to high-end computer systems, although the appeal of a recorded library on one disc, with access time of 100 mS, might attract more than a few high-end consumers. And perhaps professional recording studios would welcome the chance to abandon tape recording in favor of digital disc.

Will we thus roll into the third millennium on discs? Yes, but at least a few of us will be carrying tape machines as well. Just when you thought it was safe to buy a Compact Disc player as the last piece of audio gear you'd ever have to buy, they had to start work on the technology for a digital audio cassette. Manufacturers are currently meeting to discuss the question of format, and they likely will decide on a standard by the end of the year. The billion-dollar question is: Should a stationary or rotary head be employed in the consumer digital audio cassette? While many people feel instinctively more comfortable with the simpler-looking stationary-head system, home video recorders have proven the reli-

[redacted]

ability of the rotating-head design. From an engineering standpoint, both systems offer advantages as well as a few pitfalls; the smart money is allocating R & D to both systems.

The stationary-head digital cassette recorder as prophesized by Sony would use ⅛-inch tape (with stricter tolerances) and a shell similar to the standard analog cassette shell. A recorder could sample at 32, 44.1 or 48 kHz at 2.38, 4.76, and 5.18 cm/S respectively; it is expected that 44.1 kHz will emerge as the standard rate. Quantization would be 16-bit (12-bit at 32 kHz), and playing time on a cassette would be 2 to 4 hours. Twenty data tracks would be used, with a recording density of 63 $KBPI^2$. The secret of longitudinal recording is the thin-film recording and magneto-resistive playback heads. This technology is already proving itself in professional multi-track digital audio recorders.

The rotating-head system would also use ⅛-inch tape, but the helical scan would permit a slower tape speed of 7.2 mm/S, the shell would be about half the size of a standard cassette (70 × 50 × 10 mm), and maximum playing time would be 3 hours. Sixteen-bit quantizing would be used at 32, 44.1 or 48 kHz, with Reed-Solomon error correction. The drum diameter would be 30 mm, with a wrap of 90° and 12-micron track pitch; head life is estimated to be 5,000 hours.

With both the rotary- and stationary-head systems, the wide bandwidth would permit storage of still pictures. Just as the LP is giving ground to the Compact Disc, the days of the analog cassette are numbered. . . .

While disc and tape systems will remain popular for years to come, the third millennium will see both the proliferation of new media and the enhancement of existing systems. New developments in television and video, cable, and satellite systems are afoot. The videotape recorder will be supplanted by a digital VTR with digital audio tracks, of course. Digital television receivers have been developed; noninterleaving scanning will double the number of lines to give a higher resolution picture; large, internal memories could be used for still-picture projection, and multiple pictures on one CRT—up to nine simultaneous chan-

Just when you thought a CD player would be the last piece of gear you'd ever need, companies have begun work on digital audio cassette recorders.

nels—are already possible. In the future, CATV systems will be used to distribute digital audio and data transmission. The Sony CADA (CAble Digital Audio) system uses one CATV channel to transmit a variety of program services, including one channel of CD-format audio, 32 channels of monaural low-fidelity audio, facsimile data, computer software, and videotext. DBS (Direct Broadcast Satellite) systems will give households access to transmissions from geostationary satellites. The Japanese broadcasting network, NHK, has a satellite which has begun transmission, the BS-IIa at 110° east. Sony is marketing a 50-cm parabolic antenna to catch the 12-gigahertz microwave signal and a PLL FM tuner to demodulate the signal into video and audio components. For more remote areas, 75-cm and 1.2-m dishes are available. The tuner uses demodulation circuits similar to those used in Sony's CD-701 CD player. Two audio modes are available from the satellite system: The A mode offers 4 channels of 10- or 14-bit sampling at 32 kHz, and the B mode has 2 channels sampling at 48 kHz with 16-bit quantizing. In addition to NTSC television broadcasts, high-definition television could be transmitted on existing channels with data compression and compensation. The parabolic dish may be easily installed by the consumer and aligned with a simple diagnostic display on the television screen. The price of the antenna and tuner (in Japan) is about $1,150, putting the price of an earth station within many consumers' reach.

Thus, unparalleled technology is rapidly becoming available to the consumer. Digital disc and tape systems (both playback-only and recordable), digital video recorders and televisions, new cable services, and Direct Broadcast Satellite systems are all entering the consumer marketplace. Our access to entertainment and information will be multiplying year after year. Though my visit to Sony underscored that corporation's commitment to new product development, companies worldwide are similarly looking ahead. The 21st century is still a few years away, but after a tour of Sony's research labs, I can state that I have seen the future. And it is now. ▲


NBC
Legends shouldn't be secondhand.

History of Magnetic Recording

Thirty years ago, magnetic tape pioneer John Herbert Orr stood before a committee of the Alabama state legislature, trying to explain exactly what he did to produce a brand-new recording medium. "Son," drawled the chairman, "Y'all mean to tell us that what you do is take a strip of plastic and coat it with *barn* paint?" By the beginning of the 1980s, strips of plastic covered with iron (not barn) paint had become far more than a scientific curiosity, or the toy of audiophiles. The computer age, the universality of audio cassette recorders, and the popularity of home video recording had put those plastic strips covered with red paint well on the way to becoming, as past TDK President Sho Okiyama

observed recently, "the writing paper of the 21st century."

Even today a strip of recording tape may not look like much. But behind it lies 90 years of intrigue and imagination, adventure, discovery and just plain fun, a story whose chapters are too unlikely to pass for fiction yet hard to accept as fact. It's also a timely story, because several noteworthy anniversaries take place this year, ranging from the development of recording tape in Germany and the founding of one of the world's largest manufacturers of recording tape in Japan exactly 50 years ago, the U.S. introduction of the compact audio cassette and the first home video recorder 20 years ago, the introduction of U-Matic VCRs 15 years ago, to the invention of Betamax 10 years ago.

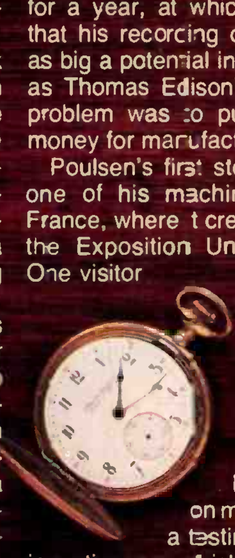
Apparently, the first person to think of magnetic recording was Oberlin Smith, who in 1888 wrote an article containing the basic ideas for *The Electrical World*, an American magazine. After describing the use of woolen thread impregnated with iron powder, Smith confessed that the lack of a laboratory prevented him from testing his thesis.

The practical side of the story begins in 1893, in Copenhagen. Valdemar Poulsen, son of a judge, was about to graduate from the University of Copenhagen as an electrical engineer, with the promise of a job with the Copenhagen Telephone Co. before him. As a class project, Poulsen proposed a device which flew in the face of established scientific theory at the time—a device for recording sound on piano wire by means of magnetization. Of course, physicists of the day knew that it was possible to magnetize wire, but they also knew—or thought they did—that the impulses would flow along the wire and quickly disappear or evaporate into the air. Nevertheless, the Poulsen idea showed imagination and effort, and it earned him a top grade.

Poulsen had envisioned his Telegraphone, as he called it, as a means for improving the efficiency of already overloaded telephone lines, and it was this idea which attracted the interest of the telephone company. There is evidence that Poulsen and a fellow student, Peder Oluf Pedersen, produced a working model as early as 1894, but it wasn't until December 1898 that he received a patent for it. In order to pursue the Telegraphone, young Poulsen, drawing on his family's resources, quit his job with the phone company.

By the following summer, Poulsen had been manufacturing wire recorders for a year, at which time he realized that his recording device had at least as big a potential in the business world as Thomas Edison's Dictaphone. The problem was to publicize it to raise money for manufacture and promotion.

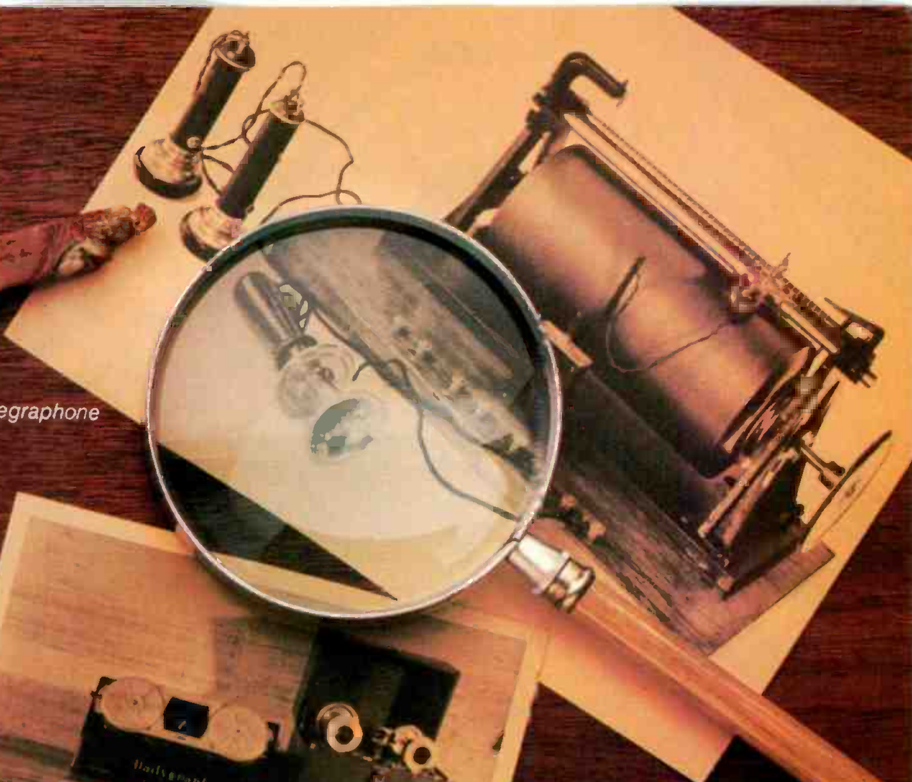
Poulsen's first step was to pack up one of his machines and head for France, where it created a sensation at the Exposition Universelle in Paris. One visitor who was intrigued by the Telegraphone's possibilities was Emperor Franz Josef, the septuagenarian head of the Austro-Hungarian Empire. He insisted on making a recording—a testimonial to Poulsen's inventiveness which survives today.



Shortly thereafter, Poulsen set sail for America, where he hoped to establish a company which could do a proper job of manufacturing and selling the Telegraphone throughout the world. For a variety of reasons, the American Telegraphone Company got off to a rocky start, running through its initial capitalization of $5 million (an enormous sum in those days) in eight years without, apparently, producing a single recorder. Then, something happened: A New England industrialist, Charles Dexter Rood, acquired control of the company and moved its factory to his home town of Springfield, Mass. Five years later, the factory was turning out several different variations of Poulsen's original design and selling them to such customers as Rensselaer Polytechnic Institute, E.I. du Pont de Nemours & Co., and the Imperial German Navy.

Another of American Telegraphone's customers was the Atlantic Communication Company, then engaged (1912) in erecting a giant shortwave transmitter and antenna complex at Sayville, Long Island. Ostensibly an American firm, Atlantic's station was linked to POZ, a station near Nauen, Germany, and there was suspicion that the company was trying to conceal ownership by the German company, Telefunken. The Sayville station, designed to carry commercial messages between North America and Europe, utilized the most advanced radio equipment and techniques, including automatic transmission systems which used paper tape and piano wire (the latter system, in fact, was an American Telegraphone).

With the outbreak of World War I in August 1914, radio amateurs along the East Coast began hearing strange transmissions from Sayville. There were commercial messages which made no sense and long series of numbers. And there were transmissions so fast that no operator could take down the Morse code signals, not to mention sounds which didn't seem



Telegraphone

Dailygraph/Telegraphone

like Morse code transmissions at all. "A musical note like the buzzing of a titanic bumblebee which sped through space," one writer described it.

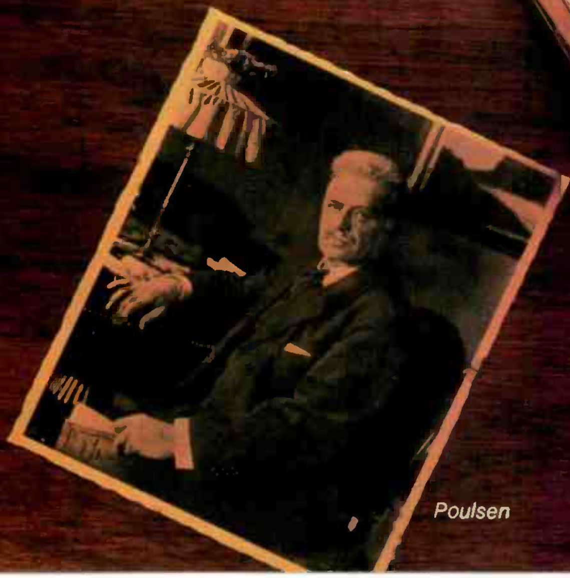
There were rumors that Sayville was transmitting instructions to the U-boats then prowling the North Atlantic and that the coded messages were, in fact, intelligence reports. The rumors grew stronger when the submarine *Deutschland*, in the months shortly before U.S. entry into the war, paid goodwill visits to several American ports and members of the press who visited her saw two Telegraphones aboard.

Just why the Telegraphones were there became obvious one morning late in June 1915. Charles Apgar, a New Jersey radio experimenter, puzzled by the high-pitched whistles emanating from Sayville, had managed to record some on a hand-cranked Edison cylinder phonograph. Forgetting to rewind the machine, he played one back and was astounded to discover, as the cylinder slowed down, that the whistle resolved into the normal dots and dashes of Morse code.

For two weeks, Apgar recorded Sayville transmissions, and then he took his find to L. R. Krumm, the chief radio

Sayville, N.Y.

Rood



Poulsen

Magnetophon

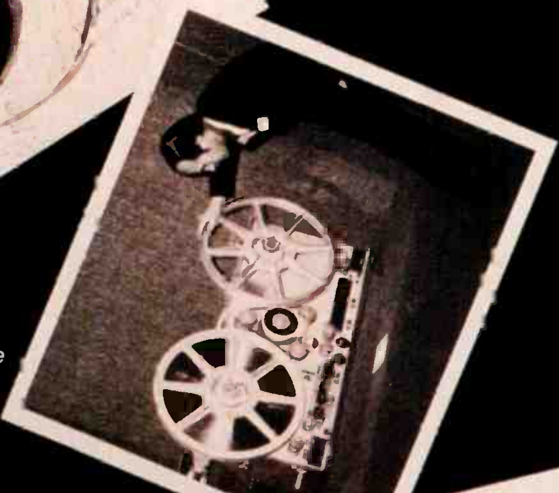
inspector of the Bureau of Navigation in New York. What Krumm heard caused him to summon W. J. Flynn, the Secret Service's top agent in New York. Ten days later, the U.S. Navy seized the Sayville station and clamped a lid of secrecy on it which was to last more than half a century—until the Freedom of Information Act enabled the National Archives to make the cylinders and other data available.

What the Germans had been doing with their Telegraphones was exactly what Poulsen had proposed as a means of improving telephone efficiency. He had suggested that messages be recorded at normal speed, played over a telephone line at a much faster speed, recorded on a second Telegraphone, and then replayed at normal speed. The idea was that messages could be transmitted in a quarter to a tenth of their original time, thus cramming more onto existing phone lines. The trouble with the idea was that it made no provision for two-way conversation—but that hadn't been necessary for the German Navy.

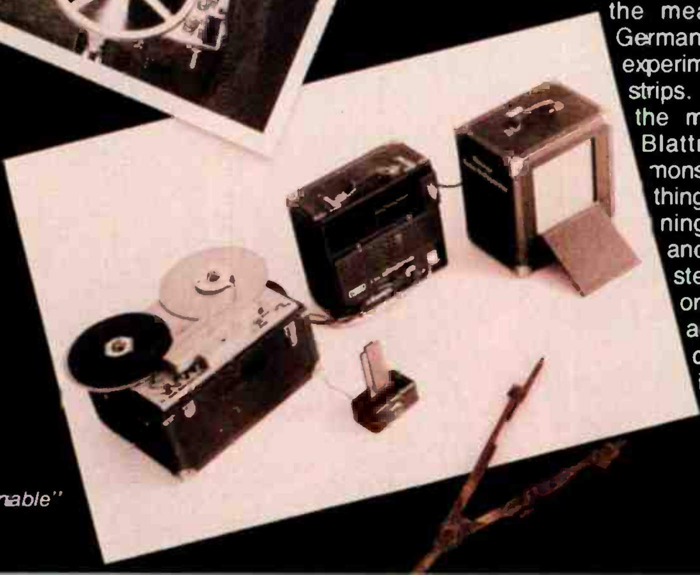
Actually, the Germans had been American Telegraphone's biggest customers. During the war, the Army Signal Corps had attempted to buy machines for its own use, but the company had delivered only a few defective ones. In 1918, the Poulsen patents expired, and American Telegraphone slid into a long period which produced lawsuits and charges against its president, Rood, rather than the Telegraphone recorders.

It would be another decade and a half before Poulsen's wire would give way to magnetic tape as we know it. In the meantime, a succession of German inventors and companies experimented with wire and metal strips. Of these efforts, perhaps the most spectacular was the Blattnerphone, a 6-foot-high monstrosity that looked something like two ancient Irish spinning wheels joined together and standing on end. It used a steel band, 6 mm wide, which one edited with metal shears and joined with solder. Purchased by the BBC in 1931, it was still in use in the 1940s when, as former BBC engineer H. Burrell

First Tape



Lorentz-Stille



"Portable"

Hadden recalls, "We lived in terror of those soldered connections coming apart, which they did every now and again. When that happened, strips of steel were lashing about and you ducked for cover to avoid being decapitated." It took two strong men to change reels on the Blattnerphone. In addition, this machine's speed accuracy was notoriously unreliable, varying according to room temperature and relative humidity, the day of the week and how much steel ribbon was on which spool.

In 1932, Badische Anilin und Soda Fabrik undertook a joint venture with AEG to develop a magnetic recording system along the lines of the Blattnerphone, but less expensive, more reliable and with better performance characteristics. BASF, then a division of the I.G. Farbenindustrie chemical combine, would develop a recording medium; AEG would make the playback equipment.

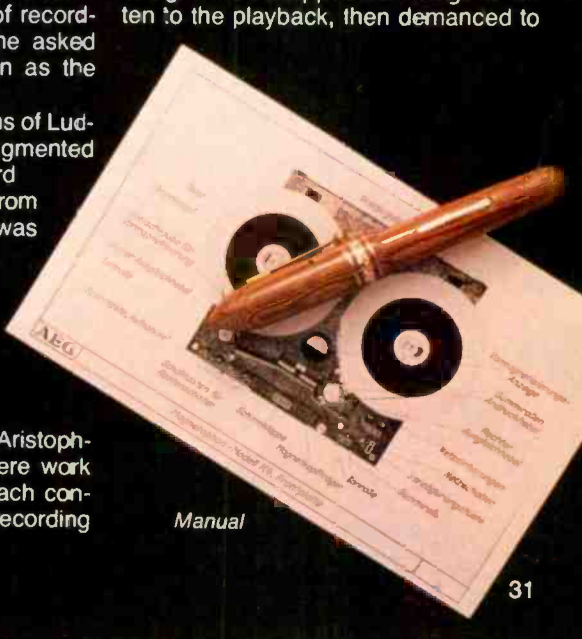
BASF had recently signed a contract with Fritz Pfleumer, an independent inventor who, in 1928, had proposed coating a strip of film or paper with a magnetizable powder. So, using Pfleumer's technology, the company managed to produce some 165,000 feet of tape, in time for AEG to demonstrate its recorder at the 1934 Berlin Radio Fair. For some reason, the formal demonstration was cancelled at the last minute, and AEG and BASF took their respective products back to the laboratory for more work. The following year, however, both were ready, and the new recording system was one of the highlights of the 1935 Radio Fair.

The next year, 1936, Sir Thomas Beecham and the London Philharmonic Orchestra were touring Germany. On the evening of November 19, they were scheduled to appear at the Feierabendhaus in Ludwigshafen to perform for BASF's workers and their families, and BASF's engineers thought this would be a wonderful opportunity to try out their new recording system. The musicians arrived two hours early, for rehearsal, and Sir Thomas was in a testy mood. It didn't get any better when, just as the orchestra was getting ready to rehearse the Mozart symphony scheduled for that evening, the mayor of Ludwigshafen stepped out on stage and proceeded to make a speech. It finally came to an end, and the orchestra began to play. Only then, when the conductor was able to evaluate the really fine acoustics of the hall, did his mood begin to improve.

At that point, somebody told him that the concert would be recorded using a brand-new film technique instead of discs. Sir Thomas always took a keen interest in the technical side of recording and music-making, and he asked to hear the playback as soon as the concert was over.

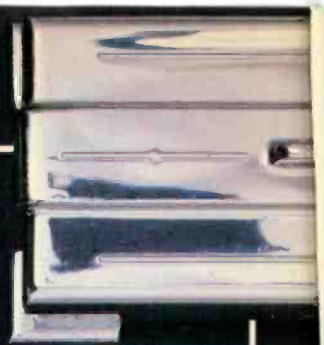
At 8 o'clock, the good citizens of Ludwigshafen took their seats, augmented by music-lovers who had heard about the concert seemingly from all over Germany. (Beecham was a noted interpreter of Mozart, and besides, this tour included two works by Frederick Delius receiving their first performances in Germany.) The lights went down, and Sir Thomas started with Vaughan Williams' "Wasps of Aristophanes" Overture, also a premiere work for the tour. The tape reels each contained less than 20 minutes recording time, so the engineers waited until the second item on the program, the Mozart Symphony No. 39. They had set their levels, and as the orchestra played, the reels turned. The tape ran out before the music ended, and Sir Thomas was well into Delius' "Summer Night on the River" before they were able to rethread the reels. They then proceeded to capture the next two items on the program, "On Hearing the First Cuckoo in Spring" and a spirited performance of Rimsky-Korsakov's "Coq d'Or" Suite.

When it was all over, there was tremendous applause. The BASF directors had scheduled a gala banquet to honor the conductor, and a number of important people had been invited to attend. But Beecham wasn't anywhere in sight. He'd stopped backstage to listen to the playback, then demanded to

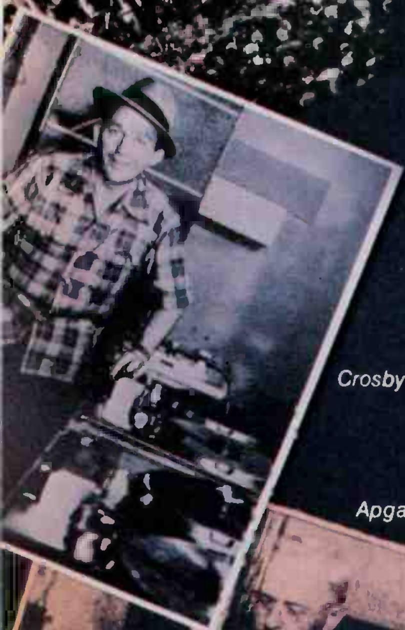


Manual

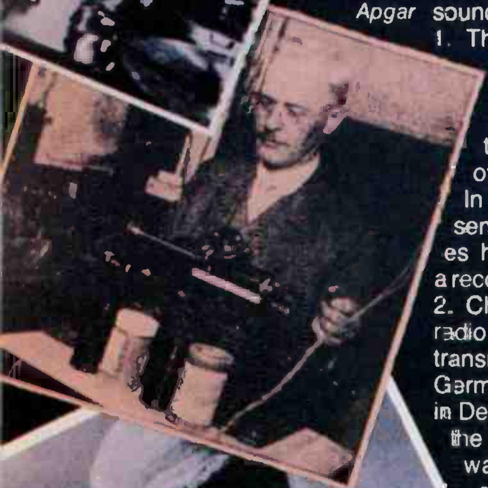
Beecham



Magnetic Recording: An Aural History



Crosby



Apgar

The seven cuts on this collector's-item Eva-Tone Soundsheet record represent important milestones in the history of magnetic recording. They have been assembled from archives around the world and include some sounds believed lost forever.

1. The first voice you hear is that of the Emperor Franz Josef of Austria, speaking at the Paris Exposition of 1900. It is the oldest magnetic recording known to exist and was made by the inventor of the Telegraphone, Valdemar Poulsen. In it, the Emperor acknowledges Poulsen's scientific achievement and expresses his thanks for the opportunity to make a recording.

2. Charles Apgar—the man who exposed a radio station in Sayville, Long Island, as transmitting intelligence information to the Germans—told a nationwide radio audience, in December 1934, how he managed to crack the "code" the Germans were using. (It was actually wire-recorded telegraph code, sent at high speed.) The occasion was the opening of a radio museum at Rockefeller Center in New York City.

3. This message, in Morse code, was recorded by Apgar on an Edison cylinder machine in June 1915. When the U.S. Navy seized the radio station at Sayville, it also clamped a lid of secrecy over the Apgar recordings which was not lifted officially until the 1970s, under the Freedom of Information Act. This rare sample was provided by the Antique Wireless Association of Holcomb, N.Y.

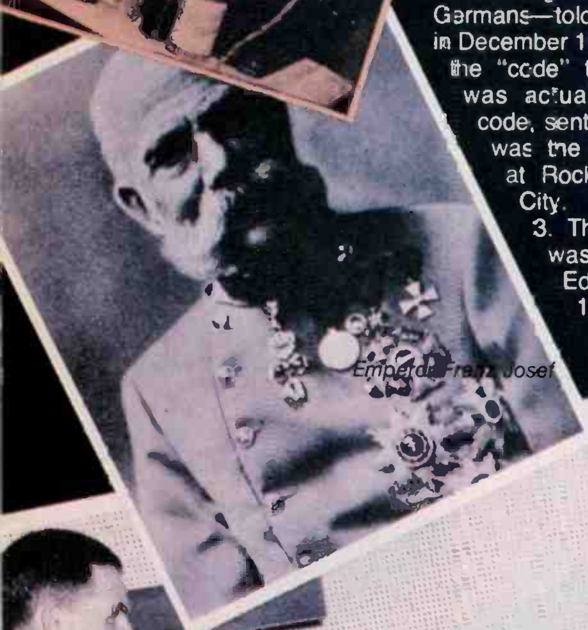
4. On the night of November 19, 1936, the London Philharmonic Orchestra and its conductor, Sir Thomas Beecham, were scheduled to perform at a concert hall in Ludwigshafen, Germany. Engineers at BASF, whose chemical plant was located there, thought it would be a wonderful opportunity to test their new magnetic recording tape. What resulted was a remarkable sonic document: A candid portrait of one of the world's great conductors in his prime before a live audience—a first on magnetic tape—and a demonstration of just what the new process of tape recording could do. The musical excerpt is from the second item on the program that night, Mozart's Symphony No. 39.

5. In 1931, the British Broadcasting Corporation acquired a magnetic recorder which used a ribbon of steel as the recording medium. Used to record King George V's Christmas Message that year, the ungainly recorder quickly became a mainstay of the BBC's new Empire Service. The man responsible for its operation was Lynton Fletcher, who later became head of BBC Sound Recordings. In a recording actually made on a Blattnerphone, Fletcher recalls what it was like.

6. For the first time, in his own words, Jack Mullin recounts the steps which led up to his discovery of the Magnetophon, a high-fidelity tape recorder, at the end of World War II. Mullin points out that the decision he took that day changed his life forever. It also changed the broadcasting and recording industries in America and around the world.

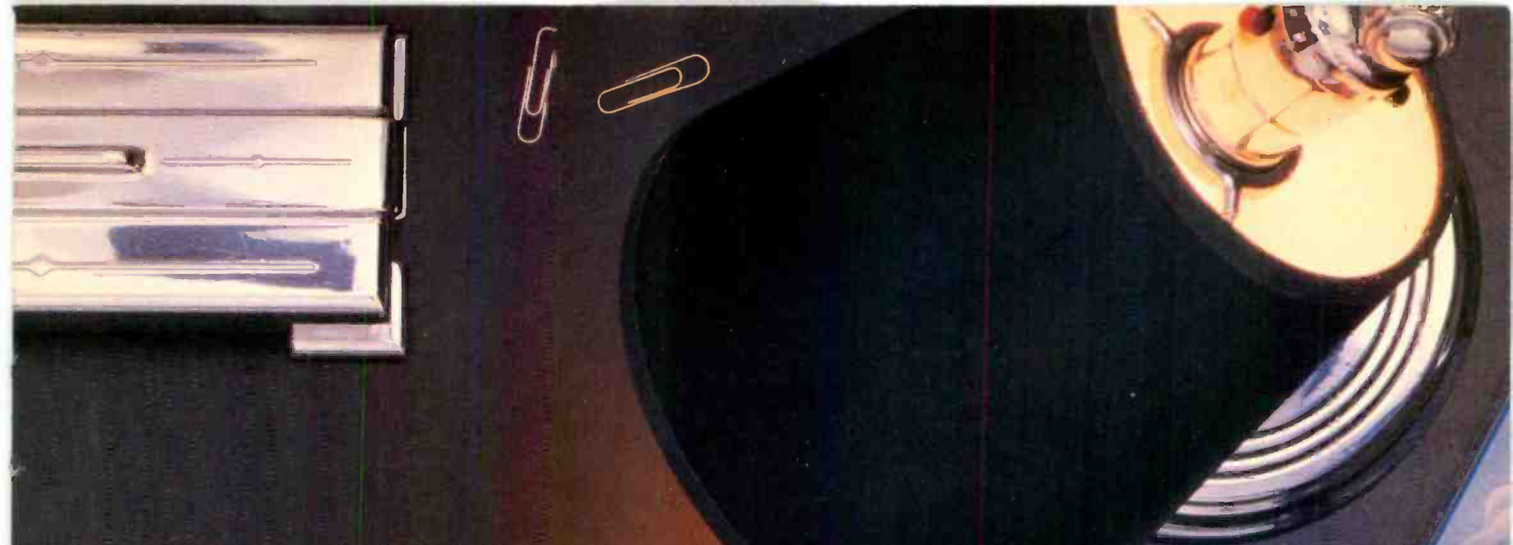
7. Toward the end of August 1947, as an experiment, Jack Mullin recorded this, the first Bing Crosby radio show of the 1947-1948 season, using one of the Magnetophons and captured German recording tape which he'd brought back from Europe. Mullin edited the tapes into a finished program which then was transferred to disc for broadcast on the night of October 1, 1947. This recording is from a copy Mullin kept as a souvenir of the event. (Used by permission of HLC Properties Ltd.)

R.A.



Emperor Franz Josef

Mullin/MacKenzie

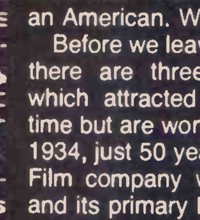


hear parts of it again and again. One director anxiously reached his secretary and said, "Six hundred people are waiting for Sir Thomas." By the time he had his fill of listening to the miraculous new medium and discussing it with the technicians, Sir Thomas wasn't interested in banquets. He got into his car and headed straight back to his hotel.

This was the first-ever tape recording of a live concert, and BASF recently re-created that concert in the rebuilt Feierabendhaus (the original was destroyed during World War II). As a result, a digital recording of the complete program from that historic night exists.

By the late 1930s, radio stations throughout Germany were busy building libraries of recorded music—mainly classical, and ranging from short piano pieces to complete operas—all on tape. In Britain and the United States, music, particularly classical, meant either live performances on the networks or late-night concerts featuring noisy 78-rpm discs, with breaks every three or four minutes. Although it seems incomprehensible today, nobody outside Germany paid any attention to the taping activity there.

In the United States, one day in 1939 a junior at the Illinois Institute of Technology was faced with a problem: His cousin was studying singing and needed a low-cost device which would enable him to hear himself as he practiced. There were disc recorders, of course, but the recording time was woefully short, the cost of discs high and the machines bulky and difficult to operate. So Marvin Camras began experimenting with a device which could record sounds on piano wire, something like Poulsen's. By the time he graduated the following year, Camras had developed a machine which would record a wide variety of sounds for electronic playback. That wire recorder, which he took to class to show his professors, landed Camras a job with the Armour Research Foundation. And during World War II, that foundation would land a contract to supply wire recorders to the Navy (altogether, some 10,000 recorders between 1942 and 1945). Among Camras' achievements was his independent discovery of a.c. bias. [See the article, "Dynamic Bias Control with HX Professional," in this issue.] Unbeknownst to him, he had been preceded by others (including Dr. Hans-Joachim von Braunmuhl, a German radio engineer, in 1938 and an American, W. L. Carlson, in 1927).



Before we leave the 1930s, however, there are three other developments which attracted little attention at the time but are worth mentioning today. In 1934, just 50 years ago, the Fuji Photo Film company was formed in Japan, and its primary business has been the manufacture of photographic and motion picture film. The firm is also celebrating one 20th and two 25th anniversaries this year. It has been 25 years since Fuji produced its first videotape (it still supplies tape to Japan's NHK television network) and opened a U.S. office. And 20 years ago, Fuji started making audio tape (8-track cartridges, with open-reel tape the next year, 1965, and compact cassettes in 1968).

In 1935, the Tokyo Electro-Chemical Company (TDK) was formed in Japan to exploit a patent for ferrite cores. At the beginning, the company and its products had nothing to do with magnetic recording; the ferrite products were used in radios and industrial and communications equipment. It would not be until 1952 that TDK would turn its attention to the manufacture of recording tape and magnetic heads for tape recorders. But this firm would make up for lost time during the next three decades, with a string of innovations which, by the early 1980s, would make it one of the largest manufacturers of recording tape in the world.

In 1936, Luigi Marzocchi (hardly a household name, then or now), a Milanese inventor, came up with a brand-new idea in recording which was to make reasonably priced home video recording possible 40 years later. Apparently unaware of the developments in Germany, Marzocchi developed the idea of mounting two or more electromagnetic heads in a single assembly which rotated at an angle to the tape's travel. This laid down a series of helical tracks across the width of the tape rather than a single, longitudinal track. Through this process, Marzocchi hoped to cram more signals onto a given length of tape. Late in the 1960s, an American inventor, Chester Newell, would resurrect the idea.

Just about this time, AEG attempted to interest General Electric in a license for the Magnetophon, as the tape recorder was then called. GE's experts, however, decided the product had no future.

During World War II, AEG and other German manufacturers developed a family of audio recorders designed for

Continued on page 36

DYNAMIC BIAS CONTROL WITH HX PROFESSIONAL

J. SELMER JENSEN and S. K. PRAMANIK

Not all of a tape recorder's bias comes from the bias oscillator—some comes from the signal being recorded. HX Professional lets that work for, not against, the requirements of good recording.

History has many examples of how a true and deep understanding of a physical phenomenon has been found for the first time through an attempt to solve an apparently unrelated problem. Then, when the problem is solved through this new understanding of its fundamentals, the solution seems so obvious that one wonders why no one thought of it before. And often, when the solution is implemented, it leads to improvements in areas not thought of when the problem appeared, or even when it was solved. All of this applies to the discovery and implementation of the HX Professional tape recording process.

The problem whose solution largely contributed to the invention of HX Professional, while unusual, was not unknown. A quick, accurate, and cost-effective method for fine-tuning cassette recorders was needed for the assembly line. What was thought to be just such a method for adjusting bias and equalization to get flat frequency response was the use of a multi-tone, or comb-frequency, signal.

Such a signal consists of several sine-wave components of different frequency, all at the same level, mixed to form a composite test signal, as shown in Fig. 1A. When this signal is recorded and played back, it should be a simple matter to monitor the output on a spectrum analyzer and make adjustments so that the level of each frequency is equal, as in the input signal. When the adjustment is complete, the recorder would presumably be set up for flat frequency response.

The only problem with this method is that it does not work. No matter how carefully a recorder is adjusted using a comb-frequency signal, conventional frequency-response measurements on the same machine yield a curve something like the one in Fig. 1B. Tape saturation (the condition when tape is magnetized to its uppermost limit so that no further increase is physically possible) leads to a similar result. But, since the same thing happens at low recording levels, any suggestion of tape saturation as the cause has to be discarded. This effect is not confined to any particular recorder or tape formulation, but may be easily reproduced on any standard machine, whatever its price, quality or specifications.

Obviously, the reverse is also true. A recorder set up to give a flat frequency response using a standard sine-wave signal gives a response which looks like Fig. 1C, if tested with a comb-frequency signal. Since speech and music signals are almost never a single frequency, but consist of combinations of large numbers of tones, more like a comb-frequency signal, the frequency response recorded on any normal recorder with real-life signals also looks more like Fig 3. The amount of deviation from flat frequency response depends on the high-frequency content of the audio signal and is constantly changing. The error that is produced may be called dynamic frequency-response error. This error is also not confined to any particular kind of recorder, but may be reproduced on any standard machine.

To understand what happens, it is necessary to go back to fundamentals

J. Selmer Jensen is a freelance designer associated with Bang & Olufsen in Struer, Denmark, while S. K. Pramanik uses his engineering background in long-range planning for the firm.

Illustration: Gene Greif

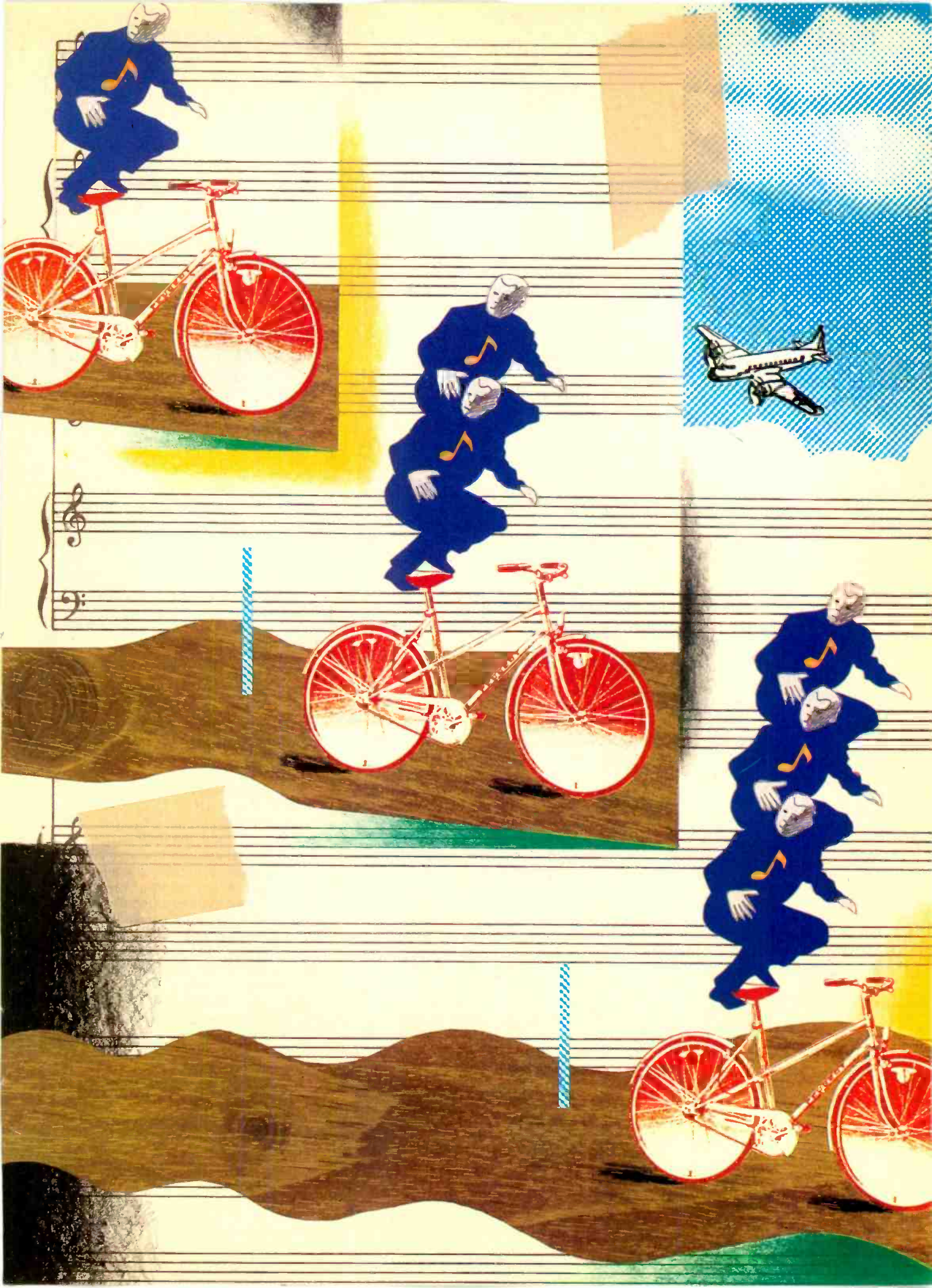
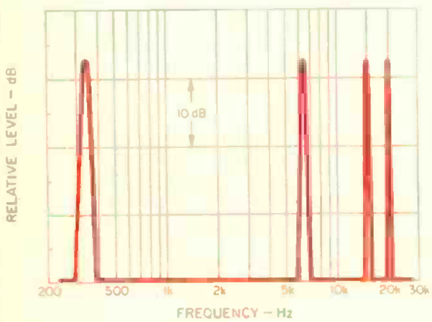
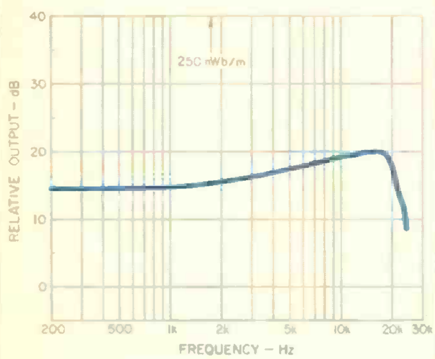


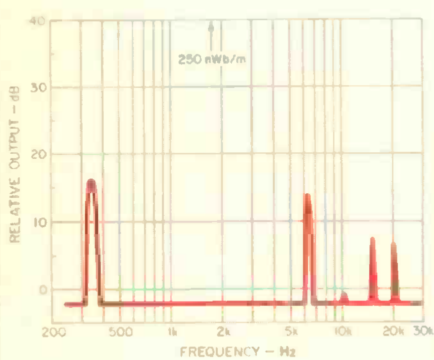
Fig. 1—Theoretically, adjusting a tape deck for flat record/playback response with a comb-frequency signal (A) should result in flat response. In practice, it yielded a peaked curve (B) due to dynamic biasing. On a deck set up for flat response, comb-frequency response declines at higher frequencies (C).



A



B



C

and examine the physical properties of tape and the recording process itself.

The Physics of Recording

Magnets are known by most people as pieces of metal that attract anything made of iron and are attracted to or repelled by other magnets. But magnets are also useful pieces of hardware, forming the basis for (among other things) motors and electrical generators—and for magnetic, or tape, recording.

If a current is passed through a coil, a magnetic field (or flux) is created around the coil, similar to the magnetic field created by a permanent magnet. The strength of the field depends on the amount of current, the number of turns of wire in the coil, and other factors. Obviously, the strength of the field that is generated can be regulated by controlling the electric current in the coil. If a suitable magnetic material is held in the flux, it will become magnetized, to a degree that depends on the strength of the flux passing through the magnetic material as well as on the properties of the material itself.

Conversely, if a magnet is moved near a coil of wire, a generated current can be taken from the coil. The amount of current depends on the strength of the magnet, its distance from the coil, the number of turns of wire in the coil, and so on.

These two fundamental facts are the basis of all magnetic recording and reproduction and, in the consumer field, of recording on and playback from cassette tape.

Recording is the process of creating a tape magnetized along its length to a degree which varies exactly as the sound signal received by the microphone. The microphone converts the sound it receives into an identical electrical signal, which is amplified and fed to the recording head in the recorder. In the recording head, the current passes through a coil, while the tape, of a suitable magnetic material, moves past the coil. The flux generated by the coil magnetizes the tape to a level proportional to the signal so that the audio signal gets recorded.

Similarly, during playback, a tape with the recorded audio signal passes by the playback head, generating in that head's coil an electrical signal similar to the pattern of magnetization on the tape. With luck, the voltage from a playback amplifier connected to the head will be an exact replica of the audio signal that was originally recorded. When amplified and fed to a loudspeaker, the reproduced sound will then be exactly like the original sound received at the microphone.

Although these are the basic physical laws of recording, in practice things are a little more complex. A modern cassette recorder is, in fact, quite an intricate piece of machinery, where each part interacts with all the others in a very precise manner. The degree of precision is a measure of the performance of the recorder, which, in a high-quality machine, can reproduce a very convincing copy of the original audio signal.

Recording on Tape

Recording tape is made of a thin layer of magnetic material deposited on a ribbon of plastic film. The magnetic material is not homogeneous, but is formed from millions of tiny particles, each of which is a magnet. The properties of these magnets depend on the material of which they are made (such as ferric oxide, chrome dioxide or iron powder) and are the reason for the familiar tape-type designations. Their physical shape and size, together with their density in the magnetic layer, determine the properties of the recording tape. It is important to remember that we are dealing with these tiny magnets, and that the physical laws that apply to magnets in general also apply to these magnets.

For the purposes of this article, we will assume that the playback chain can be made as perfect as we wish, and concentrate only on the process of recording the tape.

The audio signal to be recorded is constantly changing, and if these changes are to be accurately recorded as different levels of magnetization, then the flux must be concentrated at a very small portion of the tape. The coil in the recording head is therefore

Theoretically, adjusting bias with comb frequencies should yield flat response. The only problem is, it doesn't work.

formed around poles, which focus the recording field at a very thin-line air gap. The tape transport is made so that the tape slides past the air gap at a constant speed. It would thus appear that, provided we can feed an accurate copy of the audio signal to the recording head, we should get the required recording. But again, this is too simple. To understand why, we must look a little closer into the physics of the tiny magnets on the recording tape.

The strength to which a material is magnetized is, of course, related to the strength of the flux to which it is subjected. In turn, the flux generated is related to the current in the coils formed around the pole pieces in the recording head. But in both cases, the relationship is not linear. In other words, the strength of the resulting magnet is not always proportional to the flux, and the flux is not always proportional to the current in the coil.

The relationship between the residual strength of the magnet and the flux is shown in Fig. 2. The curve, derived from a hysteresis loop, shows that, for an increasing flux, the strength of the magnet increases at first at an increasingly rapid rate. Once beyond a certain point, however, the rate of increase slows, and finally magnetization reaches a maximum value above which no further increase occurs. The magnet is then said to be saturated. The important fact is that there is only a small part in the middle of the curve that is a relatively straight line, and it is only in this region that magnetization is proportional to the flux.

If the different magnetization levels required for a recording can be limited to the linear part of the hysteresis curve, an undistorted recording should result. Audio signals are both positive and negative, so recording will normally be made in the nonlinear portion of the curve near the axis. If a separately generated signal, called a bias current, is added to the audio signal, the average level of the audio signal may be raised so that only the straight portion of the curve is used for recording. In the early days of magnetic recording, a constant d.c. signal was used to bias the audio, but for the last 50 years, a bias current consisting of a high-frequency a.c. current has been used. This is called high-frequency (or H.F.) bias, irrespective of its actual frequency.

If a very-high-frequency signal is mixed with the audio signal, the sum looks like Fig. 3. The audio looks as if it is riding on the peaks of the high frequency. If the sum is fed to the coils, then the audio signal will be recorded at a higher part of the hysteresis curve, as shown in Fig. 4. If the high-frequency bias is at the correct level, a low-distortion recording is possible.

To obtain the best results, different formulations of tape require different levels of bias, because the shapes of the hysteresis curve for the different tape formulations are not the same. This is why many recorders permit the user to adjust bias for the type of tape being used, or, alternatively, the recorder is factory-adjusted for certain recommended types of tape. Once set, the bias, supplied by an oscillator, remains at a fixed level, which may be called the fixed bias of the recorder.

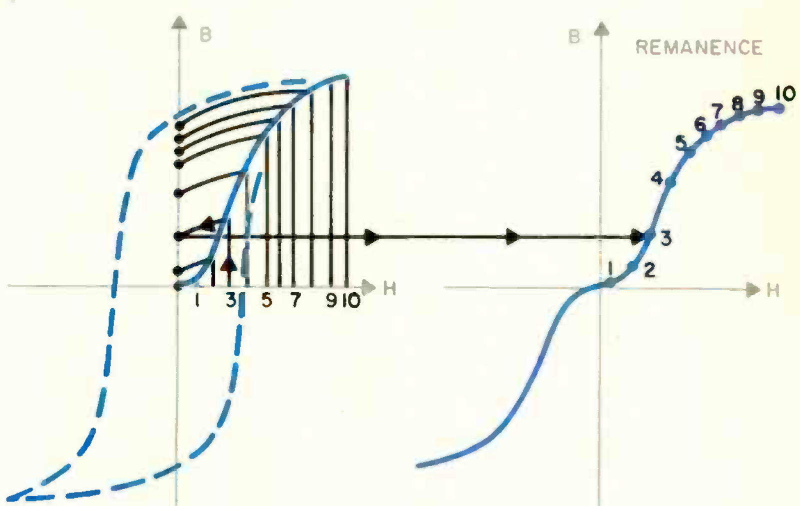
Bias for the lowest possible distortion is also different for different frequencies. In addition, bias affects other parameters, such as sensitivity and maximum output level (MOL).

Sensitivity is the ratio of the output signal to input signal, with all other variables kept constant. If the input is kept constant and the bias is changed, it will be seen that the output will vary, as shown in Fig. 5. Not only that, but the shape of the curve is different for different frequencies, as shown.

The same is true of MOL, the maximum output level that can be reproduced from tape. Above this level, the magnets on the recording tape are saturated, and distortion increases dramatically if a recording at a higher level is attempted. Again, MOL is dependent not only on bias but also on frequency, as shown in Fig. 6.

These factors are now getting complex, especially if we note that minimum distortion and maximum output do not occur at the same bias level. Of course, we always wish to record at the highest level consistent with acceptable distortion to keep tape noise or hiss as far below the recorded signal as possible. Thus, a correct setting of the fixed bias, while very necessary for good results, is always a compromise between low distortion and high recording level, for both high and low frequencies. For optimum results, setting fixed bias is best done by an experienced technician using accurate

Fig. 2—This transfer function shows the relationship between record-head flux ("H") and remanent magnetic field ("B") when recording without bias. Note how the curve's shape alters the relationship between signals of different amplitudes.



instrumentation, and, in fact, the spectral content of the type of music to be recorded should also be taken into account.

The Comb-Frequency Paradox

Now that we know "all" that there is to know about the physics of recording, we are now in a position to solve the paradox of the comb and single sine-wave frequency responses. We saw that bias, as used for recording, is a very high frequency compared to the audio signal. Thus, if we wish to record a bandwidth of, say, 20 kHz, it would be normal to use a bias frequency of

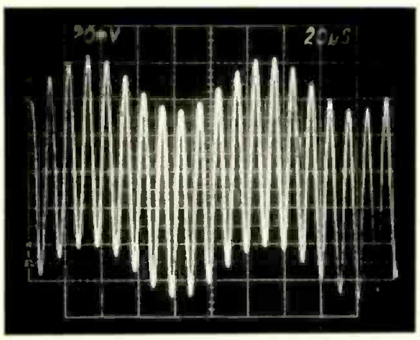


Fig. 3—A low-frequency audio signal riding on a high-frequency bias wave.

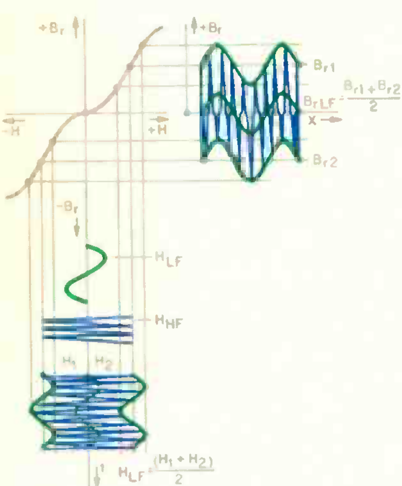


Fig. 4—How bias shifts the audio signal to the linear portions of the hysteresis curve, lowering distortion.

five times that frequency, or 100 kHz. The criterion is that the bias frequency must be sufficiently high as to allow the low frequency to ride on the peaks of the high-frequency signal.

If this is so, then bias at a frequency of 10 kHz will be fully adequate to bias an audio bandwidth of 2 kHz, and 1 kHz for 200 Hz, etc. But when the audio signal is a mixture of low and high frequencies, the low frequencies do not know whether high frequencies were put there by the recorder's designer to act as bias, or whether they are just a part of the audio signal itself. When a high frequency, whatever its source, is superimposed on a lower frequency, the high frequency will tend to raise the point on the magnetization curve where the low frequency is recorded, just as bias does. Thus, in an audio signal composed of many frequencies, each frequency acts either partially or fully as bias for all lower frequencies.

When the high-frequency part of the audio signal acts as bias, the bias seen by the lower frequencies will be the sum of the original fixed bias to which the recorder was adjusted plus the biasing effect of the higher frequencies. Therefore, bias will constantly change with the high-frequency content of the audio signal, and, for the low frequency, all parameters related to bias (such as sensitivity, distortion and MOL) will change with the high-frequency content in the same audio signal.

That this is true is seen from the case of the comb and sine-wave frequency responses. If the bias in a recorder is adjusted to a flat response with a swept sine wave, then all frequencies see constant bias while the test is conducted, that is, the fixed bias to which the recorder is adjusted. When multiple frequencies are present simultaneously, each frequency below the highest will be subjected to altered bias, which is the fixed bias plus the biasing effect of all the higher frequencies. As bias changes, the sensitivity for any frequency will not remain the same as before. The output at the different frequencies will therefore change, and the frequency response, as seen on an analyzer, will no longer be flat. In other words, we have dynamic frequency-response error.

It may not be out of place to repeat that this is what happens with all recorders that use fixed a.c. bias. This includes not only cassette tape recorders, but also reel-to-reel machines, studio machines and high-speed duplicators, although the amount of dynamic frequency-response error will vary from one type of machine to another and for different tape formulations. The amount of error is related to the ratio between the audio and bias currents fed to the recording head. The smaller this ratio, i.e., the closer the magnitudes of the audio and bias currents are to each other, the larger the error will be.

Active Bias

To sum up the problem, we have seen that the loss of high frequencies when recording at high levels is due less to tape quality than to the fact that there is an increase in the effective level of the bias current when high frequencies are a part of the audio signal. If active bias is too high, then sensitivity at high frequencies decreases, and the output at these frequencies drops. The larger the content of high frequencies, the greater the drop. Once this fundamental principle governing high-frequency performance has been established, the answer to our problem becomes almost obvious. This has been implemented in the recording circuit, HX Professional.

The total bias seen by the low-frequency component of any audio signal, as described earlier, is the sum of the fixed bias and the biasing effect of the high-frequency part of the same audio signal. It will be remembered that it is the immediate value of this sum which determines the recording conditions for the audio signal. It will be useful to use another term for the sum of the bias and the biasing effect of the audio current, and we will call this sum active bias.

Experiments using a high-quality sound source with high treble content and a cassette recorder using ferric tape show that active bias can vary by as much as 6 dB at different parts of the recording. This is equivalent to saying that bias is incorrectly adjusted by that amount, at least for some part of the recording. The consequences are obvious for anyone familiar with the procedure of adjusting bias. The disappointing result, a loss of treble performance—particularly with the less expensive tape formulations at high recording levels—is most often attributed to poor tape quality, tape saturation or other causes, rather than to a constantly changing bias.

Low frequencies see a uniform level of high-frequency bias, provided active bias is kept constant. This is accomplished when bias from the oscillator is reduced until active bias returns to the level of the "fixed" bias whenever high frequencies are present in the audio signal. The term fixed bias, of course, now loses its original meaning, as bias from the oscillator no longer remains fixed. So we define another term, no-signal bias, which is the bias level to which the machine is set with zero signal at the input, and it is equivalent to fixed bias in a conventional machine. We shall return to this, and see how no-signal bias can be optimized more effectively with the HX Professional circuit.

Keeping active bias constant implies two operations: First, monitoring the active bias continuously, and second, changing oscillator bias as necessary to keep active bias constant.

The black portion of Fig. 7 shows a typical recording circuit in a conventional recorder. The signal output from the recording amplifier is mixed with the high-frequency bias current, typically five times the frequency of the highest audio frequency to be recorded. Bias current or, more correctly, no-signal bias current, is set to the optimum level for the tape in use. The mixed audio and bias current is then fed to the recording head.

What is added to implement HX Professional is a high-impedance monitor for active bias. The ideal place to measure active bias is, of course, at the point where it acts, at the recording head. The sum of the audio and bias currents is first passed through a filter, and the voltage is monitored to determine the flux being generated by the head. At this point some wise men will

When the audio signal contains both high and low frequencies, the highs act as added bias for low frequencies.

shake their heads and say we should be measuring the current, as it is well known that the flux generated is proportional to the current, and not to the voltage.

While this is theoretically true, in practice such a measurement fails to take into account losses in the magnetic and electrical circuits of the tape head. For various reasons, these losses are not proportional to the current, and magnetization of the tape is therefore also not proportional to the current. This is a failing of certain systems designed to improve recordings, which base the improvement on a measurement of recording current.

So, in the HX Professional system, the voltage across the head is monitored and integrated to give a calculated value of the useful flux generated in the tape head. Flux is actually proportional to this calculated current, as the influence of head losses on the voltage across the head is very small. The calculated value of flux is therefore a very close approximation of the effective magnetizing field. Thus, if the characteristics of the filter are suitable for the purpose (that is, it is designed to reflect the level of active bias accurately and constantly), it can be incorporated into a feedback loop that will keep active bias constant.

The Filter

The characteristics of tne filter may be found by experiment. Since we wish to minimize any changes in frequency response caused by the high-frequency content of the audio signal, we may be tempted to proceed as follows:

Using a low-frequency input signal of, say, 200 Hz, bias is adjusted to give the lowest possible distortion of that signal. Then, the low-frequency signal is recorded on tape at a fairly high level, say, 20 dB below the level at which the tape is saturated (that is, 20 dB below MOL). Its output level is measured as a voltage on the output terminals of the recorder. The same frequency is then recorded at the same level, but this time with a high-frequency signal superimposed, let us say 15 kHz, at a level sufficiently low to ensure that saturation does not occur.

When this is done, it will be seen that the output level of the low frequency falls, because sensitivity has changed due to the change in active bias. The amount by which it falls will be seen to depend on the relation between the two frequencies, as well as their relative levels. For this particular case, we can now reduce the bias current until the output of the low-frequency signal returns to the same level as the one it had before any high frequencies were superimposed.

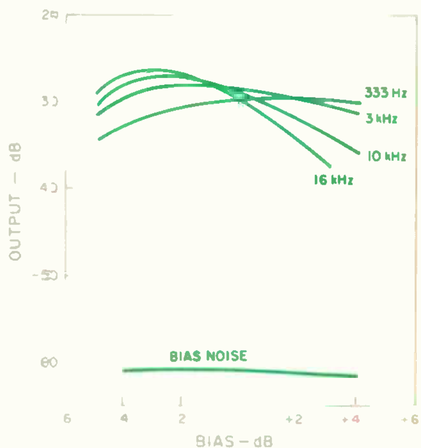


Fig 5—The relationship between tape sensitivity and bias level varies with frequency.

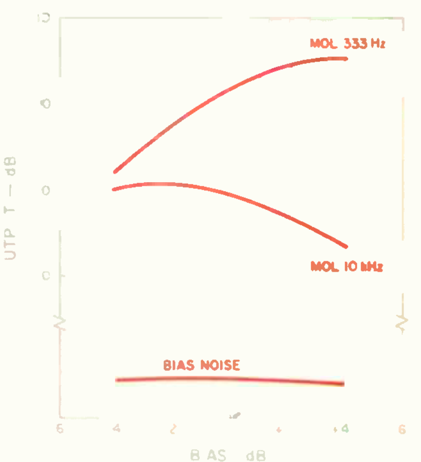


Fig. 6—MOL also differs with both bias level and signal frequency.

We have now achieved the condition, albeit manually, where no change in frequency response occurs due to the presence of the high frequency. The amount by which the oscillator bias needs to be reduced is then the biasing effect of the higher frequency on the lower. This procedure might be repeated for a number of different frequencies, at various input levels, when it should then be possible to work out a mathematical relationship between the ratio of the frequencies and their relative levels.

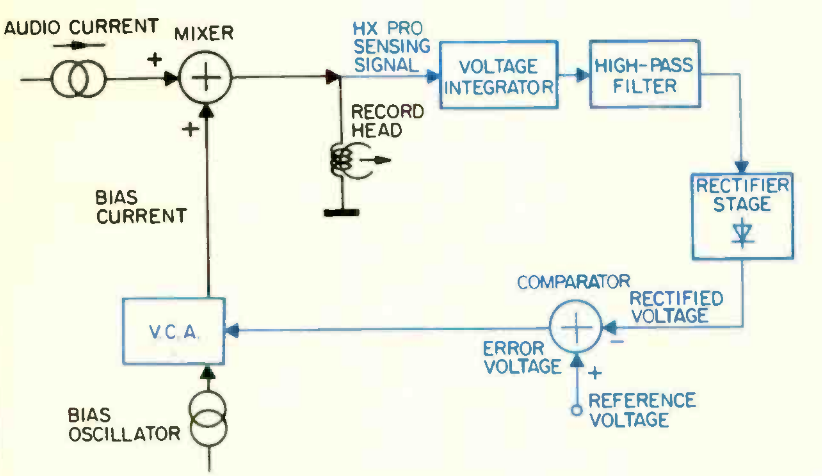
However, using a filter designed to this relationship does not lead to a flat frequency response. A slightly altered procedure is required, which will give the primary condition of a conventional flat frequency response and considerably reduced dynamic frequency-response error. The procedure to find the true value of active bias is similar in principle but uses extrapolated points on bias-related parameters as reference, rather than a simple frequency-response parameter. However, if the relationship derived from this procedure is fairly constant at various frequency ratios and relative levels, then a filter for this purpose may be economically constructed.

It is found experimentally that the biasing effect of a sine-wave signal on a signal very close to it in frequency is virtually zero. As one of the frequencies increases, its biasing effect on the lower frequency increases at 6 dB/octave, provided they are both at the same level.

It turns out that the filter we require is one of the simplest among electronic circuits. In fact, it is so close to being a simple filter at 6 dB/octave that any attempt to get a more accurate form, at least for cassette tapes, is superfluous. In other words, if a low-pass filter, passing all frequencies below the highest the machine is designed to record, is put into the control loop, the active bias can be correctly set for all audio frequencies. And this setting adjusts itself, by its very nature, to all static bias levels and for all tape formulations.

Once the form of the filter has been determined, our problem is solved. It only remains to construct a suitable circuit that will implement the filter as part of a feedback loop to control the bias level. For a competent circuit designer, this really should present no particular problem.

Fig. 7—In conventional recording circuits (shown in black), low-frequency response can be diminished by the biasing effects of high audio frequencies. With the addition of the HX Professional circuits (shown in color), bias level is controlled by the total high-frequency signal (audio plus bias) at the recording head.



The Circuitry

It will come as no surprise at this point to see the final circuit, which is shown in Fig. 7. As stated earlier, the audio line feeding the recording head is conventional except that the signal is sensed at the head, to derive the signal required for HX Professional. An advantage of measuring at this point is that it allows the audio signal path to be kept totally free of any manipulation by the HX Professional circuit and therefore free from any possibility of degradation. Further, any necessary manipulation of the signal, such as pre-emphasis or noise-reduction circuits, is automatically taken into account when the signal is monitored at this point.

The signal monitored at the head, after passing through an integrator and the filter, is rectified to give a d.c. voltage proportional to the active bias. This is then compared to a previously set reference voltage. The presence of any high frequencies in the signal will alter the level of the rectified voltage by an amount dependent on the amplitude and frequency composition of the signal and the characteristics of the filter. When the rectified voltage changes, it will differ from the reference voltage, and a control signal proportional to the difference is generated. The control signal is used to alter the gain of the voltage-controlled amplifier, which in turn alters the bias current from the oscillator.

The reference is a stable, adjustable d.c. voltage set to a value that gives the required no-signal bias current. The difference between the rectified signal and the reference voltage is used as a control signal to adjust the bias level from the oscillator. It can be seen that in the absence of any audio signal, no-signal bias current at the tape head can be accurately adjusted for any tape formulation simply by changing the value of the d.c. reference voltage. Once this adjustment has been made, the circuit requires no further adjustment or correction.

The bias circuit for HX Professional differs from the conventional in that a voltage-controlled amplifier is placed between a conventional oscillator, which is also used in the erase circuit, and the point at which the audio signal is added to the bias in the recording

HX Professional and Dolby HX use similar principles but differ in their aims as well as in their implementations.

circuit. This amplifier, as its name suggests, changes its gain under the control of a d.c. voltage to control the amount of bias current that is fed to the mixer. The d.c. voltage used to control the amplifier is, of course, the signal that is derived from the feedback circuit, which senses the signal at the tape head.

What now happens is that, for an audio signal composed of high and low frequencies, the active bias increases, and oscillator bias is reduced by a corresponding amount. The low frequencies see a total bias equal to the sum of the reduced oscillator bias and the biasing effect of the high frequencies. By definition, and courtesy of the HX Professional circuit, this value remains constant. The high frequencies see the reduced bias from the oscillator, but are far less sensitive to the biasing effect of the high frequencies themselves. In other words, they see a reduced level of active bias.

As we have seen earlier, high frequencies require a lower level of bias for optimum recording conditions than low frequencies do. Thus, the lower oscillator bias is advantageous for the high frequencies in the audio signal, and results in better MOL, besides lowering the dynamic frequency-response error. Together, these two factors lead to a dramatic improvement in the quality of recorded high frequencies, particularly when high recording levels are used. The improvement is more marked on less expensive tapes, but also substantial with the most expensive formulations.

HX Professional also has other advantages as byproducts. As mentioned, conventional recorders use a "fixed" bias adjusted to a value which is a compromise between levels that give the lowest distortion at low frequencies and the highest MOL at high frequencies. A compromise is necessary, as the optimum values for these characteristics occur at different levels of bias. The compromise is, of course, chosen to be somewhere between these two optimum values.

After implementing HX Professional in a prototype recording circuit, it was realized that the conventional compromise may be considerably reduced. Since the high frequencies take care of themselves, i.e., oscillator bias falls to accommodate high frequencies, no-signal bias may be adjusted close to the optimum value for the best low-frequency distortion. This lowers overall distortion in the recording at the same time that high-frequency recording is improved.

Finally, it was found that the tape overload characteristic for high frequencies, at levels above those where tape saturation begins to occur, is more gentle with the HX Professional circuit. Distortion rises at a slower rate as the normal maximum recording level is exceeded, permitting higher recording levels and a better signal-to-noise ratio without audible distortion at unexpected peaks in the audio signal.

HX Professional vs. Dolby HX

A description of HX Professional will be incomplete without mentioning the circuit from which it gets its name, Dolby HX. Although the names are similar, as are some of the principles on which the two circuits are based, they are in fact quite different in their aims as well as in implementation.

K. Gundry of Dolby Laboratories, the inventor of HX, realized that a wide-band audio signal has a self-biasing effect and that this is part of the cause of high-frequency losses in recording. The problem led him to develop a circuit where oscillator bias is changed when high frequencies are present in the audio signal, as is done in HX Professional. But his aim was to permit the maximum level of high frequencies to be recorded—in other words, to get the highest possible level of MOL. Hence the name HX, Headroom eXpander system.

However, in order to maximize MOL, oscillator bias must be reduced by more than is necessary to keep active bias constant. Also, a frequency-response error (in a sense opposite that of a conventional recorder, and at an unacceptable level) is introduced due to overcompensation. This was also recognized, and an ingenious correction was introduced.

Since Dolby noise-reduction circuits already measure the high-frequency content of the audio signal, in Dolby HX the same circuit was used to derive a signal to control oscillator bias. In addition, this control signal was also used to alter pre-emphasis to continuously correct the dynamic frequency-response error. The resulting circuit required fairly complex design and adjustment for both the oscillator and pre-emphasis to track correctly, and the problem became even greater when using different tape formulations.

Although dynamic frequency response, even with correction, was substantially less accurate than with HX Professional, HX did in fact function marginally better than HX Professional in improving MOL. The reason it did not become more popular was probably because tape recorder manufacturers were not willing to cope with the complexity of the adjustments required for correct operation.

HX Professional was developed at the same time as the Dolby circuit, although independently, but it was released later. And it is so fundamental to recording technology that Dolby Laboratories not only took part in the final stages of development, but agreed to license the circuitry, on behalf of the inventors, to manufacturers not only of cassette recorders but also of other recording devices (such as high-speed duplicators).

This explanation of the function of HX Professional is necessarily simplified in the interests of an explanation of the broad principles at the cost of rigorous detail. The authors hope that readers will take this into account. More exact formulations will be found in the references below. ▲

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ACCUPHASE C-280 PREAMP AND P-600 AMP

Manufacturer's Specifications

Preamplifier

Frequency Response: Line inputs, 1 Hz to 500 kHz, +0, −3 dB; MM and MC phono inputs, RIAA, 20 Hz to 20 kHz, ±0.2 dB.

Maximum Output: 10 V.

THD (New IHF Standard): 0.005%.

TIM Distortion: 0.0022%.

Phono Input Sensitivity: MM, 0.5 mV; MC, +26 dB setting, 0.025 mV; MC, +32 dB setting, 0.0125 mV, all for 0.5-V output at 1 kHz.

Phono Input Overload: MM, 300 mV; MC, +26 dB setting, 15 mV; MC, +32 dB setting, 7.5 mV.

S/N Ratio: 82 dB, A-weighted, for 5-mV signal at MM input.

High-Level Sensitivity: 31.5 mV.

Phono Input Impedance: MM, 47 kilohms paralleled by 150 pF; MC, 10/30/100 ohms, selectable.

Dimensions; 18-7/16 in. (468 mm) W × 6¾ in. (171 mm) H × 15-9/16 in. (396 mm) D.

Weight: 39.8 lbs. (18.1 kg).

Price: $3,550.00.

Amplifier

Power Output: 300 watts rms per channel, 8 ohms. (For other ratings, see Table I.)

THD: 1 to 2 ohms, 0.02%; 4 to 16 ohms, 0.01%.

IM Distortion: 0.01% at rated output.

Frequency Response: 0.5 Hz to 250 kHz, +0, −3 dB, for 1-watt output at maximum level-control position.

S/N Ratio: 125 dB, A-weighted, with inputs shorted.

Damping Factor: Stereo, 300; mono, 150, both at 50 Hz into 8 ohms.

Input Impedance: Unbalanced, 20 kilohms; balanced, 600 ohms, switch-selectable.

Input Sensitivity: High-impedance setting, 2.0 V; low-impedance setting, 1.0 V; bridged mono, high-impedance setting, 1.83 V; bridged mono, low-impedance setting, 0.91 V.

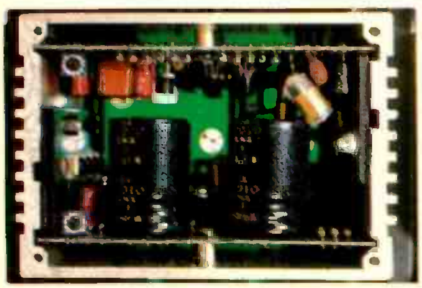
Dimensions: 18⅞ in. (480 mm) W × 9⅛ in. (232 mm) H × 18¾ in. (476 mm) D.

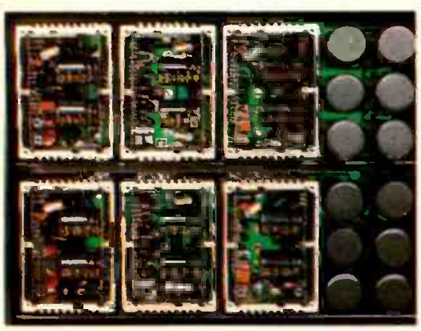
Weight: 84.7 lbs. (38.5 kg).

Price: $3,550.00.

Company Address: c/o Madrigal Ltd., P.O. Box 781, Middletown, Conn. 06457.

For literature, circle No. 90





Accuphase's P-600 amplifier and C-280 preamplifier, the company's flagships, offer knockout cosmetics with high performance to exacting specifications. Their designs do not follow the American high-end audio trend towards minimalistic circuit topology and few user controls. Rather, these two products have an unusual level of circuit complexity and control flexibility. No fewer than 11 power ratings are listed for the amplifier, including a rating of 450 watts per channel into a 1-ohm load! High performance is most certainly the name of the game here—but not without a few quirks, which became evident during our testing procedures.

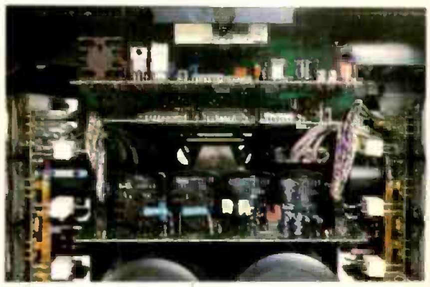
Preamplifier Layout

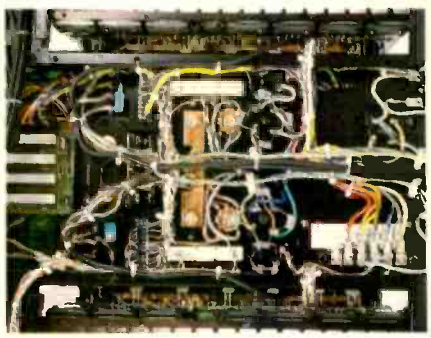
The C-280 preamplifier comes in an imposing 39-pound chassis with a visually stunning, persimmon-finished wood exterior. The wood has a glossy finish and lovely grain with a unique reddish-black, ebony-mahogany color. Underneath the wooden housing, aluminum sheet-metal panels form the sides, front, and rear of the chassis. The front panel and hinged access door are gold-anodized extrusions bolted to the chassis. Additional sheet-metal channels support the two power transformers and a large motherboard. The assembly is quite rigid, with good support for all heavy components, and service accessibility is maintained. Self-tapping screws are used, which could leave small metal particles inside the chassis, although none were found.

At first glance, the four controls on the C-280's faceplate make it resemble a minimalist preamp design. The push-to-open subpanel door, however, drops down to uncover switches for a.c. power, subsonic filter, and mono/stereo mode. These are followed by selectors for moving-coil input impedance, tape monitor, and tape-output defeat, as well as gain trimmers for each channel and a two-position "Compensator" (loudness) selector. When the subpanel is closed, all that remains are two large rotary controls, for source selection and volume, which bracket rotary switches labelled "Head Amp" gain ("Off/MM," "+26 dB" and "+32 dB") and "Attenuator" (full mute, attenuation "Off," "−20 dB" and "−30 dB"). A central window above the subpanel has red LED status displays for a.c. power, loudness compensation, high-pass filter, mono mode, tape monitor, and record out. Tone controls have been eliminated, Accuphase's only concession to minimalism. The C-280's rear panel features seven inputs (two phono, three line, and two tape) and four outputs (two tape and two main) with an additional XLR output jack, rated at 600 ohms impedance, for each channel.

LEDs confirm the settings of all pushbutton switches, and a nonvolatile (battery backup) logic circuit stores the settings when the unit is off. All controls, except for the volume and gain trimmers, activate relays. An effective mute circuit operates for 1 S each time a selector is changed. The detented controls, ticking relays, status indicators, and muting produce a feeling of precision when operating the Accuphase C-280.

Internally, a total of 14 smaller circuit boards plug vertical-





Every element of the C-280 preamp's construction is superb—circuit boards, soldering, even *internal* use of gold-plated connectors.

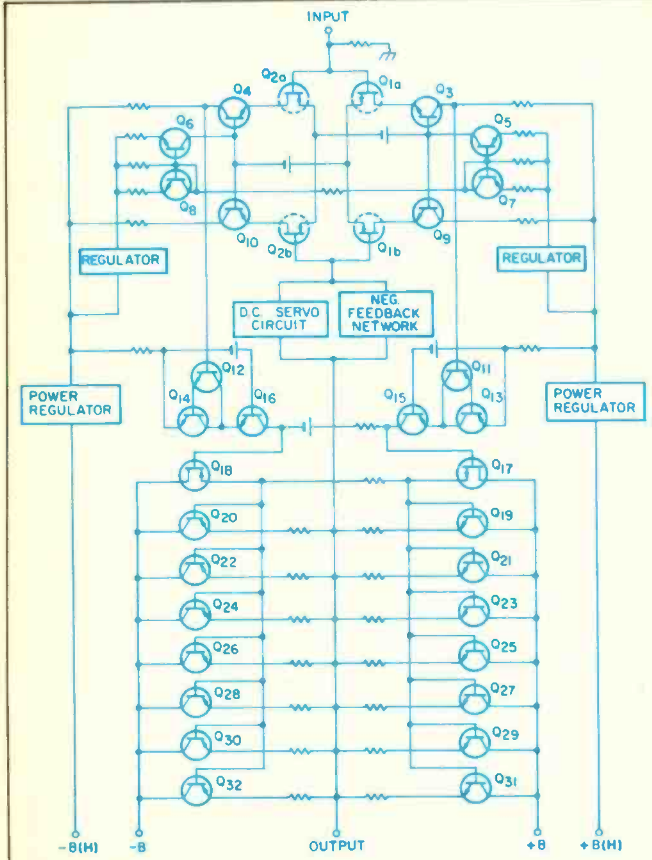


Fig. 1—Partial schematic of P-600 amplification stages.

ly into the motherboard. This profusion of circuit boards provides the necessary surface area to house the 225 transistors, 16 FETs, 33 ICs, and 167 diodes used in the C-280's design. Many separate parts are used, as if complex IC op-amps were being synthesized from discrete transistors on every p.c. board. One of these boards, holding 21 reed relays, runs parallel to the rear panel to control program selection as close as possible to the input/output connectors. Relays are sealed inside pressurized nitrogen-gas housings and utilize either gold-plated or silver-palladium alloy contacts. Just behind the front panel sits the relay-controlling logic board with its nickel-cadmium battery backup system. In between these upright boards are six extruded aluminum-chimney amplifier modules, each housing two small circuit boards. Small LEDs, used as voltage-dropping diodes for setting bias, glow inside the boxes like tube filaments. The C-280's three gain stages—a pre-pre-amplifier, phono amp, and line amp for each channel—are assembled from these modules.

The C-280's dual power supplies maintain this separation of function. Separate transformers for each channel have three center-tapped windings feeding 24 rectifiers and 12 filter capacitors. This gives separate unregulated d.c. lines for each of the six amplifier modules. Final d.c. regulation in this unusually complex power supply is performed inside the amplifier modules.

Every element of the C-280's construction is superb. Circuit boards are glass-epoxy, 0.002- and 0.031-inch thick, with finished edges. Signal traces, solder mask and component designations appear on both sides. Soldering quality is excellent, and the extensive hand wiring is done with skill and care. Low-loss, foam-core coax running between the C-280's input relays and low-level modules is soldered cleanly (foam's low melting point has resulted in sloppy wiring in other audio components). Some internal wiring ends in multi-pin circuit-board connectors which are all gold plated. It is refreshing and unusual to find high-end units having gold plating *inside*, rather than only on the external connectors where the customer will see it.

Preamplifier Circuit Highlights

Each of the six modules in the C-280 employs a dual-differential input stage which feeds a common-base, complementary push-pull Class-A output amplifier in cascode connection. A d.c. servo-control IC is incorporated in each of these amplifiers to allow the C-280 to be d.c.-coupled, from moving-coil phono input to main output, with negligible d.c. offset.

The line amplifiers are duplicated, with polarity inversion, to produce balanced outputs, ostensibly to allow for low noise pickup over long cable runs to the amplifier. While this could be useful in hostile environments, Accuphase's selection of a 600-ohm output impedance for the C-280 preamp and the P-600's 600-ohm input impedance (at their balanced XLR connectors) is based on a Bell Laboratories/Western Electric standard, developed in the '30s, for use with telephone transmissions. Although present-day professional audio equipment utilizes balanced lines, professional line outputs are designed with much lower output impedance (on the order of 50 ohms) so they can drive multiple amps without loading losses.

Amplifier Layout

The P-600's great size and weight are very impressive; its 99-pound shipping weight far exceeds current United Parcel Service limits. This power amp, therefore, must be shipped by a freight service. The front panel is flanked by massive handles and a rack-mount frame. A large window provides multicolored status readouts: A large, digital peak-power display for each channel, running from 0.001 to 999 watts; a set of blue display-hold-time indicators, and LED status annunciators for each channel ("Bridge Connection," flashing power-display "Reset Indicator," and "Load Impedance"). The display is bright and, set against the panel's black background, is easily visible across a brightly lit room.

Below the display window, the P-600 has large rotary knobs, styled like the C-280's, controlling "Input Level" to left and right channels in calibrated steps from 0 to −30 dB (and then off). At panel center, large "On/Off" switches for "Power" and "Speakers" flank two rows of small pushbuttons. The upper row's controls display "Hold Time" ("Off," "3 Sec" or "30 Min") and the "Subsonic" filter (10 Hz, 12 dB/octave). The lower row sets the range of the digital display (×1, ×0.1, ×0.01, and ×0.001).

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On the test bench, with more than 1,500 watts being dissipated, the P-600 amp was only slightly warm, and totally silent.

The back panel features selector switches for choosing stereo or bridged mono operation, normal (2 to 16 ohm) or low-impedance (1 to 2 ohm) operation, power-display impedance (to yield power readings based on 2-, 4-, 8-, or 16-ohm loads), and balanced (600-ohm) or unbalanced inputs. The unit's nonstandard binding posts will not accept dual or single banana-plug speaker-cable terminations. (Unfortunately, these posts also eliminated using the very convenient Monster Cable locking speaker connectors favored by co-author Greenhill.) A circuit breaker, switched and unswitched a.c. outlets, RCA phono and XLR input jacks, and a nondetachable a.c. line cord with a two-pronged plug—somewhat undersized for a high-current amplifier (30 amps/channel)—make up the remainder of the back panel.

Like the C-280, the P-600 chassis achieves its strength and accessibility from a complex sheet-metal structure fastened together with self-tapping screws. Mechanical construction quality is first-rate, but the use of self-tapping screws in an expensive amplifier with many heavy parts seems out of place. Externally, the P-600 has a lightweight, gold-colored, extruded-aluminum frame. This serves mainly to dress up the chassis and provides mounting points for the removable sides, top and bottom. Internally, the expected massive heat radiators for the 28 output transistors run vertically, parallel to the side covers. From front to back, between the heat radiators, is a heavy "U" section that carries the transformer and other heavy power-supply components.

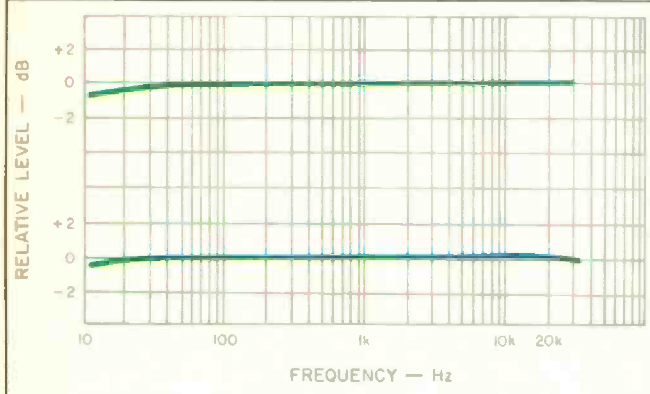

Fig. 2—RIAA response of C-280 preamp for MC at +32 dB setting (top curve) and MM (bottom), for 0.5-V out at tape output.

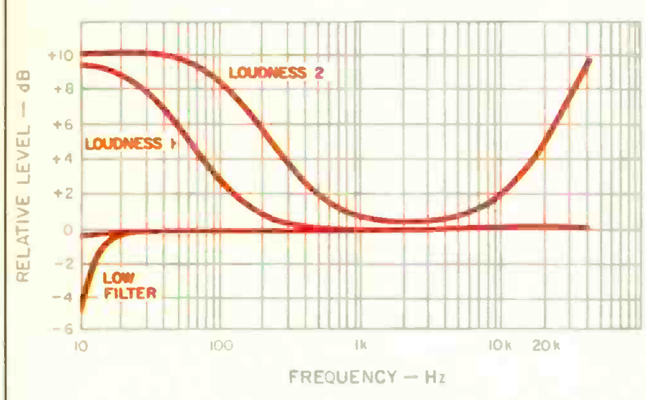

Fig. 3—Characteristics of preamp loudness and filter controls. From top to bottom: Loudness-compensation setting 2 (note treble and bass boost), loudness setting 1 (bass boost only), flat response, and subsonic-filter curve.

Most amplifiers conduct heat from the output devices to the entire chassis to radiate heat effectively. The P-600 exterior, however, always runs relatively cool because it relies only on internal radiators and the air passing through them via the liberally vented top and bottom covers. On the test bench, with more than 1,500 watts being dissipated, the P-600 remained slightly warm to the touch and totally quiet. (We have not yet found any fan-cooled amplifier quiet enough for listening-room use.)

The main amplifier p.c. boards run vertically, parallel to the heat radiators. Each channel's 14 power transistors, two MOS-FET drivers, and thermal-sensing diode are mounted to the heat radiators, with all leads attaching to the top and bottom edges of the circuit boards. To replace a small part on the board, half of these components would need to be removed for the board to be swung away. Flat copper bus bars parallel the groups of seven transistor collectors and emitter resistors. The power-supply and output lines are soldered to the board but terminate in ordinary quarter-inch push-on connectors at the chassis. Hot-running components are held above the board by insulating spacers, although the P-600 amp has a few electrolytic capacitors (rated at 85° C) placed only 1/32-inch away from hot-running emitter resistors. Other capacitors in the P-600 were rated at an unusually high 105° C.

Several other circuit boards—for the metering, logic and power-supply regulation functions—are seated near the front and rear panels. Two of these circuit boards, positioned vertically just behind the front panel, handle the digital power-meter system (using a 12-bit A/D converter and a 4-bit microprocessor) and logic control for switching of impedance ranges.

The P-600 has many "pro" features, but it is rather expensive for most professional applications and also fails to meet pro standards in other ways. For instance, the "rack-mount" flanges cannot be used to mount the amplifier. Not only does the manufacturer warn against this installation, but the mounting holes are round, not oval or notched, as demanded by EIA rack specs. The front plate is held to the chassis with four small self-tapping screws, and the unit's heavy toroidal transformer sits at the back of the chassis, not behind the faceplate (where it could be best supported by rack mounting). The rack-mount flanges are obviously a styling gimmick to evoke a "heavy-duty" image. Such gimmicks are not necessary: The P-600 is a lavish *home* amplifier, and we would prefer that it look like one.

The P-600's meters are beautiful to observe but are more entertaining than helpful. For power-amplifier use, a clipping

The 2-ohm stereo and 4-ohm bridged power measurements didn't tax the P-600—just our power lines!

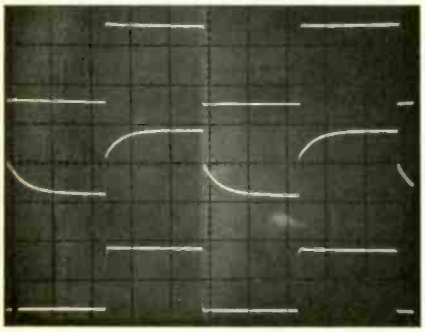

Fig. 4—Response of preamp to 1-kHz square waves with inverse RIAA equalization through MC input (+32 dB setting). From top to bottom: Generator output before equalization, signal at preamp's tape output with no input filtration, and signal at tape output after 200-kHz filtration of input signal (see text). (Scales: Vertical, top trace, 1 V/cm; vertical, middle and bottom, 0.5 V/cm; horizontal, 0.25 mS/cm.)

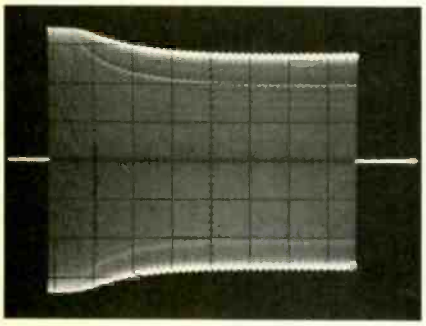

Fig. 5—Amplifier response to 400-mS burst of 20-kHz, at level just below clipping, into 4-ohm load. Note shrinking power envelope as mutual conduction begins, as well as horizontal lines (beginning at 25 mS) indicative of "sticking." (Scales: Vertical, 20 V/div.; horizontal, 50 mS/div.)

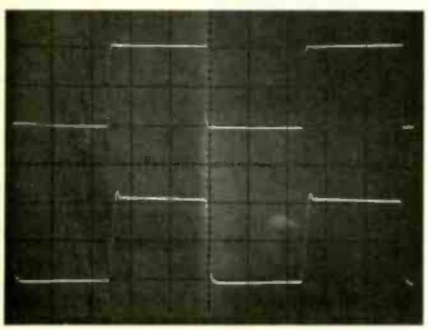

Fig. 6—Amplifier large-signal response to 20-kHz square wave, driving 8-ohm load: Input signal (top) and P-600 output (bottom), 312 watts/channel. (Scales: Vertical, top trace, 1 V/div.; vertical, bottom, 50 V/div.; horizontal, 10 μS/div.)

or distortion light—which this amp lacks—is the single most valuable indicator. The meter peak-hold system is annoying: When it is switched on, the meter is reset to 0 every 3 S or 30 minutes (depending on the "Hold Time" selected), with only higher readings registering between resets. If the 3-S period is chosen, the "Reset Indicator" LEDs flash so frequently that they may be easily confused with clipping indicators, even when the amplifier is not clipping. Given the peak-hold and reset action of these meters, it might be better if each new peak reading started a new 3-S interval till reset, so one would always have time to read each update. The 30-minute hold time (intended to show the peak cutting level on one side of a record) does stop the flashing, but, with the meters storing the highest peak in the past half hour, they effectively cease to function in real time.

The P-600's digital power meters do not sense power (voltage times current) but voltage alone. Their power calibrations are based on the assumption that what is being driven is a 2-, 4-, 8- or 16-ohm resistive load, not the more complex reactive loads of actual loudspeakers. The voltage is sensed before the P-600's output-isolation network, which slightly degrades meter accuracy at high frequencies. The meters, though labelled "Peak Output Power," are not peak-power indicators, nor do they read the rms value of peaks. Instead, they have a time response requiring approximately 6 mS of continuous sine waves to achieve an accurate reading. This approximates the BBC or European PPM (peak program meter) standard. For example, using single-cycle sine-wave pulses, 200 Hz was the highest frequency the meters would measure accurately. At 2 kHz, they read 70% of actual single sine-wave power, and at 20 kHz, only 6% of actual power. They were found to be accurate to within 5%, not outstanding for such an elaborate meter design.

Amplifier Circuit Highlights

The P-600 features a very rugged seven-parallel complementary bipolar push-pull output stage, for a total complement of 28 output devices rated at 200 watts of dissipation each. Figure 1 is a partial circuit diagram, in which Q19 to Q32 form the output stage of one channel.

Output-stage rail voltage levels are determined by a user-settable impedance range switch, backed up by an auto-switch circuit (not shown). Either switch drops the d.c. rails from 82.5 to 44.5 V. This lower voltage limits high power dissipation when driving 1-ohm loads. (The Apt 1 amplifier uses a similar transformer-switching design to drive low-impedance loads.) A pair of small relays adjacent to the transformer perform the actual switching. They are tripped by a current-sensing circuit or the rear-panel switch. Bias current on the output devices does not change when the amp is switched to the low-impedance position, and we found no evidence of crossover notch distortion or any change in subjective sound quality at the lower setting.

A series of additional protection circuits, including VI limiting, cuts drive to the output stage or disengages the massive speaker relays if d.c. offset is detected. User-resettable a.c.-line circuit breakers are employed instead of fuses. Power-supply parts, as well as the owner's household circuit breakers, are protected by a turn-on inrush-current

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The CD491 incorporates a dual capstan transport with twin flywheels to insure perfect movement of the tape across its 3 high performance heads. The dual capstan serves to isolate the tape from the cassette shell while the dynamically balanced flywheels help generate a consistently accurate tape speed. Together they enable the CD491 to reduce wow-and-flutter to an inaudible .025%. The only "wow" you'll ever hear is the reaction of people listening to your Harman Kardon cassette deck.

The CD491 incorporates Dolby HX Pro[1] for extended frequency response, plus Dolby B and C[1] for maximum noise reduction. Three precision heads offer improved performance and the convenience of monitoring while recording. Included is a Sendust head to withstand high record levels without overload and a ferrite playback head for extended high frequency response.

The combined benefits of the CD491's performance features allow for the accurate recording of more dynamic audio signals than previously possible. In fact, the large signal response (frequency response at 0Vu) of the CD491 is a virtually unrivaled 20Hz-20kHz ±3dB. This is especially significant as more demanding forms of software, such as digital audio, become available.

So, while other manufacturers continue to pile on unnecessary features and gimmicks, Harman Kardon continues to develop only fundamentally advanced audio equipment.

(1) Dolby is the registered trademark of Dolby Laboratories Inc.
(2) In 1982, Harman Kardon challenged individuals to bring in their cassette decks to a local HK dealer. All units were cleaned and demagnetized in order to insure fair test results. The Harman Kardon unit was factory packed.

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In 1958 Harman Kardon introduced the world's first stereo receiver.

In 1963 Harman Kardon introduced Ultrawideband Frequency Response and in 1970 Harman Kardon became the first company to use Dolby[1] in a cassette deck.

Today, Harman Kardon audio products continue to be so technologically advanced that "state-of-the-art" falls short of describing them. They have become "state-of-the-mind," the highest level at which the mind can create.

A distinct example of Harman Kardon's state-of-the-mind technology is the hk690i receiver, which leads their line of quality receivers and possesses their most important state-of-the-mind concept to date: High Instantaneous Current Capability.

Harman Kardon has consistently used High instantaneous Current Capability (HCC) in all of their amplifier sections. HCC provides the instantaneous power that is vital to precisely drive and control nearly any loudspeaker system.

With its HCC of 45 amps, the hk690i will develop far more power under peak loads than its rated 60 Watts per channel[2] while maintaining the low distortion and widebandwidth required for accurate sonic reproduction. This means that the hk690i gives you louder, clearer sound than any other 60 Watt[2] receiver.

The digital synthesized quartz-locked hk690i has an Ultrawideband Frequency Response of 0.2Hz to 150kHz, as well as low negative feedback for extremely fast and accurate transient response. The result is the virtual elimination of TIM distortion.

The phono section of the hk690i has a unique dual RIAA equalization circuitry which maintains a constant low level of negative feedback throughout the audio frequency range. An exclusive sample-and-hold MPX decoder decreases high frequency switching noise while eliminating the need for much of the filtering normally required in FM processing.

Among performance features included are: Provisions for two tape decks (with tape copy capability), switchable bass and treble turnover frequencies, a Moving Coil head amplifier, and subsonic and high cut filters.

The hk690i provides the combination of pure power and sonic excellence that the true audiophile demands.

So, while other manufacturers continue to pile on unnecessary features and gimmicks, Harman Kardon continues to develop fundamentally advanced audio equipment.

1. Dolby is the registered trademark of Dolby Laboratories, Inc.
2. 60 Watts RMS per channel into 8 Ohms, 20Hz-20kHz with less than 0.6% THD.

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In operation, the Accuphase preamplifier and power amplifier together are as docile as a table radio.

surge limiter circuit. Resistors in series with the line limit turn-on current; when the filter caps are nearly charged, relays short these resistors.

The drive current requirements of such an output stage could reflect back through bipolar drivers to adversely load the input differential amp. The P-600's power MOS-FET drivers neatly solve this problem, since these drivers require practically no drive current themselves. They do demand high drive voltages, however, and this is provided by a regulated extra-high-voltage supply and a Darlington/cascode pre-driver stage, shown as Q11 to Q16 in Fig. 1. A Darlington circuit is formed by Q11 to Q14, providing a high input impedance.

The dual-differential amplifier input circuit uses FET and bipolar transistors. It is formed by the Q1 to Q2 differential-amp FETs, the Q3 to Q4 circuit, and the Q1a, Q3, Q2a and Q4 cascode amplifier. Conventional signal negative feedback is supplemented by a low-frequency "servo amp" for d.c. stability. A differential input is provided, with professional XLR connectors, but is off the mark with its low 600-ohm input impedance. A 10-kilohm input impedance would have been more useful.

Preamplifier Measurements

All gain measurements were somewhat lower than those claimed by Accuphase, perhaps signifying that the manufacturer measures the C-280's voltage gain from input to output without using the IHF-specified standard source impedance. (For example, the C-280's MC input gain measured 6 dB less than claimed, because the preamp's 100-ohm maximum input impedance loads the 100-ohm IHF source by 6 dB.) Gain from phono in to main out, including the line amps, ranged from +50 dB for moving-magnet phono to +76 dB for moving coil (at the +32 dB MC setting). All measurements of output level, noise, and distortion confirmed the high level of performance claimed by the manufacturer.

The C-280's frequency response measurements are just as impressive. Deviation from the true RIAA response was ±0.1 dB (our measurement resolution), 20 Hz to 20 kHz, for all phono inputs (Fig. 2). Although no tone control circuitry is used in this Accuphase preamp, Fig. 3 shows the low-frequency boost provided by loudness control position 1, the additional high-frequency boost from position 2, and the sharp skirt of the very effective 18 dB/octave subsonic filter used to prevent rumble from reaching the rest of the system.

Phono overload for the MM inputs was a very high 350 mV. The MC input's overload points were lower, in proportion to the pre-preamplifier gain selected (i.e., 35.0 and 17.5 mV for the +26 and +32 dB positions). This indicates that, at 1 kHz, the pre-preamplifier has more headroom than the RIAA section that follows, as it should.

At very high frequencies, where the RIAA feedback equalization reduces the phono section's gain, the unequalized pre-preamplifier section overloads first. This condition is shown in Fig. 4. The top trace is the 1-kHz square-wave generator's output, which is fed through a precision inverse-RIAA equalizer to produce a signal (not shown) having very high positive and negative spikes. This corresponds to the output of an ideal phono cartridge playing back an ideal

Table I—P-600 amplifier power performance (output before clipping, 20 Hz to 20 kHz).

	Specified		Measured		
Amplifier Settings and Load Conditions	Minimum rms Power Per Channel, Watts	Rated Maximum THD, %	Maximum rms Power Per Channel, Watts	Maximum THD + N, %	IHF Dynamic Headroom, dB
Hi-Z					
16 Ohms	150	0.01			
8 Ohms	300	0.01	347	0.0165	1
4 Ohms	500	0.01	617[a]	0.0183	1.6
2 Ohms	700	0.02	700[b]	0.0204	
Lo-Z					
2 Ohms	300	0.02	300	0.0201	
1 Ohm	450	0.02	450[b]	0.034	
Bridged, Hi-Z					
16 Ohms	600	0.01			
8 Ohms	1000	0.01	1155	0.016	1.6
4 Ohms	1400	0.02	1806[a,b]		2.9
Bridged, Lo-Z					
4 Ohms	600	0.02	924		1.9
2 Ohms	900	0.02	1142[a]	0.018	2.1

[a]Amp automatically reset to low-impedance setting.
[b]One channel driven at a time, due to test bench's 30-ampere power limit.

recorded square wave. Although the 1-kHz *sine-wave* output of this source is well within the headroom limit of the MC input at the +32 dB setting, the narrow spikes from the equalized *square wave* overload the pre-preamplifier. It does not recover for about 0.25 mS. When this distorted signal passes through the RIAA stage, it emerges with a rounded edge, as shown in the middle trace of Fig. 4.

If the designers had restricted the bandwidth of the pre-preamplifier to 200 kHz, the nearly perfect square wave shown at the bottom of Fig. 4 would have resulted. Here, bandwidth limiting would produce a "faster" preamp, bizarre as that may sound. Perhaps even a mistracking MC cartridge might not produce sufficient high-frequency noise to overload this wideband pre-preamp, but when combined with r.f. interference, audible distortion might result. Possible engineering solutions include bandwidth-limiting the C-280's pre-preamp stage or the use of a high-gain RIAA feedback circuit which would connect directly to an MC cartridge without the intervening amplification stage. The owner can opt for a transformer step-up, which has, in practice, no input-overload problem.

Amplifier Measurements

The P-600 coasted through the FTC's one-hour, one-third-power preconditioning at 8 and 4 ohms without thermalling out. The front panel became only slightly warm because it is not thermally connected to the heat radiators.

Though this amplifier is rated at 300 watts per channel, the actual steady-state power output easily exceeded the manufacturer's specifications, as shown in Table I. The power supply did not perform like an ideal voltage source (allowing the amplifier to double its power output each time the load impedance was halved), but the P-600 was still

Accuphase achieves high performance through brute force—quality parts, close tolerances, circuit redundancy, and high power.

able to deliver large amounts of power into low impedances. Accurate testing of this amplifier required the services of a very substantial Variac to maintain line voltage at 120 V. For the 2-ohm stereo and the 4-ohm bridged mono measurements, it was necessary to test only one channel at a time, because our test bench setup could deliver only 30 amps continuous; the P-600 was still not taxed, but our power lines were!

Unlike the C-280 preamp, the P-600's large signal output of 300 watts allowed for distortion measurements far above the noise floor. Signal-to-noise ratio, sensitivity, and maximum THD plus noise readings (20 Hz to 20 kHz) confirmed the manufacturer's specifications. The P-600 provided 27.8 dB of signal gain, higher than the standard 26.0-dB gain found in most other power amps. As shown in Table I, measured THD plus noise exceeded the ratings very slightly during tests of the amp's low-impedance operation. There, the P-600 showed maximum THD + N ratings of 0.021% for 300 watts output into 2-ohm loads and 0.034% THD + N for 450 watts output into 1-ohm loads.

Small-signal, high-frequency response of the amplifier extended from 5 Hz to 170 kHz for a 1-dB roll-off with 8-ohm loads, down only 2.0 dB by 250 kHz, well within the specifications. The frequency response varied slightly with the loads, the 1-watt high-frequency −3 dB down point being over 350 kHz into 8-ohm loads, 170 kHz for 4-ohm loads, 125 kHz for 2-ohm loads and 70 kHz for 1-ohm loads.

The P-600 amplifier proved stable with both inductive and capacitive loads, with no reduction of maximum rated power when a 2-μF capacitor was connected across the 8-ohm load in each channel. The 300-Hz clipping test showed excellent performance: The amplitude of harmonics fell steadily as their frequency went up, and, in addition, there was little sign of line harmonics or line-frequency modulation products.

On the other hand, there was at least one condition which could cause the amplifier difficulty, as shown in Fig. 5. With a test signal consisting of a 400-mS burst of 20-kHz sine waves, at a level just under clipping into a 4-ohm load, the amplifier starts out with its power-supply capacitors fully charged, and approximately 560 clean watts (500 rated) available. After about 25 mS, however, the capacitor charge diminishes, and clipping begins. This puts the output stage in a state of mutual conduction, with the complementary halves of the output section conducting current simultaneously, thus working against one another and behaving like a partial short circuit across the power supply. More power is then consumed, further aggravating the condition (25 to 200 mS). Evidence of the struggle is seen in the decreasing clip level and the horizontal "sticking" lines below the clip level. By 200 mS of the tone burst, current draw from the power line rises from an initial value of 11 amps to about 25 amps, and line voltage falls. If the tone is not cut off at 400 mS, the P-600 hums loudly and eventually switches automatically to the low-impedance transformer-tap position.

When driven by 20-kHz sine waves with even slight clipping, the P-600 shows signs of "sticking" (an amplifier's tendency to continue clipping after the input signal has fallen back below the level which would normally make it clip) and mutual conduction at the same time. In fact, this latter condition limits the P-600's high-frequency power bandwidth (−3 dB or half-power frequency) to 100 kHz. Mutual conduction occurs at 2 μS/cycle about 10% of the time during clipping at 20 kHz. At the lower frequencies, more typically found in music, it will happen less often. Many power amps with bipolar transistors have this tendency. Although the condition could shorten output-transistor operational life, the large output stage of the P-600 promises long, trouble-free life in normal use.

Figure 6 shows the large-signal rise-time, which was measured at a very fast 2.0 μS. The maximum slew rate was 50 V/μS (symmetrical). The measured IHF slew factor, when rating the amp at 300 watts into 8 ohms, was 5. Figure 6 illustrates the P-600's square-wave response for a 20-kHz input signal driving the amplifier to just below clipping. The leading edge shows a small amount of overshoot, with a slight bit of rounding on the trailing edge. Both are within 10% of the square wave's period, indicating artifacts only above 200 kHz—an excellent performance.

Use and Listening Tests

In operation, this combination of preamp and powerful amplifier is as docile as a table radio. Thanks to elaborate relay circuitry, there is never a turn-on or turn-off thump, no mechanical 60-Hz buzz from the three power transformers, and no annoying noise from a cooling fan. Even the amp's turn-on surge drawn from the power line is minimized by a slow charge and relay shunt circuit, so house lights do not flicker when the P-600 is clicked on.

The only difficulty in using the C-280/P-600 combination is finding a place large enough to put it. Installation requires a large, well-supported area for the two units, about 38 inches wide and 24 inches deep. This space must also permit unrestricted airflow to the power amp, support the combined 124 pounds of weight, and allow the preamp's beautifully finished cabinet to be seen. After setup, these units proved to be unequaled attention getters, looking powerful and expensive. The large controls, digital display (on the amplifier), and clear markings invite knob-twiddling and button-pushing.

How do these Accuphase components sound? Their wide dynamic range made the most memorable first impression. The greater-than-normal gain in both preamp and amp intensify this effect, and also make the loudness compensation boost the frequency extremes more than usual. The P-600's power reserves allowed co-author Clark to get clean, undistorted sound from his highly efficient reference monitors even at 117-dB levels—louder than acoustic instruments playing in a concert hall, though still not as loud as a real drum set playing 10 feet away. The great dynamic range of Compact Discs could also be appreciated. With the P-600 driving Greenhill's modified Dahlquist DQ-10s, nominally rated at 4 ohms impedance, its meters jumped from 2 to 840 watts during the explosive entrance of the firebird on the Telarc CD of Stravinsky's the "Firebird: Suite" (CD-80039). This sonic peak possessed a degree of transient speed and dramatic attack not heard before. It was clean and undistorted, with a striking vividness, vitality and power. Even small loudspeakers, rated for less powerful

Of the two, the P-600 stands out. It is an outstanding amplifier, with exceptional definition at all power levels.

amplifiers, came alive with so much available power. At milliwatt levels, the amp/preamp's resolution of detail at low volume was outstanding, rendering the full resonances of Willie Nelson's throaty tenor on Columbia's exceptional Compact Disc, *Always on My Mind* (CK37951).

The P-600 amplifier was run in a number of gain-matched open comparisons with Greenhill's reference amplifier. Both amps demonstrated excellent depth of imaging and retrieval of instrumental resonance, as well as rendering a rich, full bass at both ends of the power range. The P-600 showed a wider and deeper sound-stage image and a slight boost in the warmth region.

The preamp was compared subjectively to Greenhill's reference solid-state preamplifier, which has a gain structure similar to the C-280's but an MC phono input load impedance higher than the C-280's 100 ohms. Using the P-600's meters, the two preamps were gain-matched to a test record (played using a Marovskis MIT-1 MC cartridge). After lifting the MC pickup off a record, both preamps were dead quiet. Sonically, the Accuphase proved to be slightly brighter, less dynamic, and not as revealing of instrumental resonances. The reference preamp also had slightly better depth of imaging. Crossovers and other electronics could not be placed on or near the C-280's cabinet without audible hum in the MC phono mode.

In another system, one C-280 preamplifier and two P-600 amplifiers were used, with an electronic crossover, to power separate sections of Apogee ribbon speakers. The amps, set to their low-impedance positions, drove the 1.5-ohm (nominally rated) midrange ribbons and bass panels without difficulty. However, the Accuphase amplifiers and preamplifier sounded more detailed, but brighter and harsher, than the Krell KMA-100 amps and Mark Levinson ML-6A preamp normally used in that system.

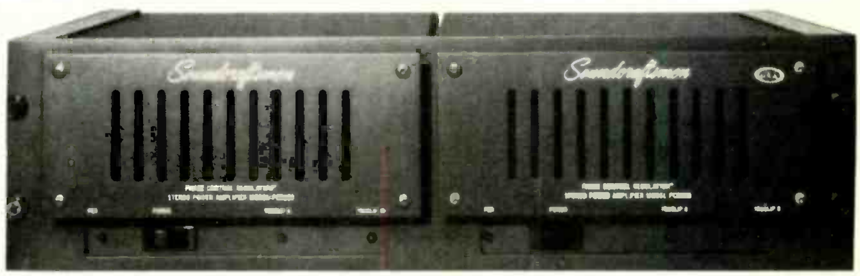
The C-280 preamplifier and P-600 amplifier impress us as an unusually complex but highly competent amplifier system. The large number of electrical parts and the mutual conduction at clipping generate a few concerns about reliability, but the superb quality of parts and cool operation should ensure long component life. Overall, the Accuphase approach achieves high performance here through brute-force design—many quality parts with close tolerances, circuit redundancy, and extremely high power—rather than through engineering innovation. Accuphase's conservatism relies little on cleverness or high-tech treatment of signal flow, circuit topology or individual parts. Overall testing revealed pre-preamp overload in the C-280 and mutual conduction in the P-600, but superb performance in all other bench tests.

The Accuphase P-600 and C-280 are true high-end audio components with stunning cosmetics, stringent specifications, and hot performance. Of the two units, the P-600 stands out. Sonically, it is an outstanding amplifier, capable of exceptional definition at all power levels. What Accuphase has created in the very powerful P-600 is the synthesis of microprocessor logic, extremely high current circuitry, and audio at all levels in a single chassis. The intermixed technologies are made to work together as if they were designed with one goal in mind.

Laurence L. Greenhill and David L. Clark

2

SOUNDCRAFTSMEN PCR800 AMPLIFIER



Manufacturer's Specifications

Power Output: 205 watts per channel, 20 Hz to 20 kHz, 8-ohm loads; 300 watts per channel, 4-ohm loads; 275 watts per channel, 2-ohm loads; 600 watts mono (bridged) mode, 8-ohm loads.

Total Harmonic Distortion: Less than 0.05%.

SMPTE-IM Distortion: Less than 0.05%.

TIM Distortion: Unmeasurable.

Frequency Response: 20 Hz to 20 kHz, ±0.1 dB.

Slew Rate: Greater than 40 V/µS.

Rise-Time: Less than 2.2 µS.

Dimensions: 4⅞ in. (12.4 cm) H × 8½ in. (21.6 cm) W × 12 in. (30.5 cm) D.

Weight: 18 lbs. (8.2 kg).

Price: $449.00.

Company Address: 2200 South Ritchey, Santa Ana, Cal. 92705.

For literature, circle No. 91

Among the outstanding characteristics claimed for Soundcraftsmen's new PCR800 amplifier is the ability to deliver high power even when the speaker load impedance drops to zero ohms. The amplifier is equipped with a unique, thermocoupled feedback system which utilizes multiple, precision temperature sensors throughout. When overheating takes place, an electronic sensing system accelerates the speed of the cooling fan, but, more importantly, if the fan alone cannot keep temperatures below safe limits, Soundcraftsmen's newly developed Phase Control Regulation (PCR) takes over and actually lowers the supply voltage being fed to the output transistors to reduce power dissipation, thereby reducing temperatures within the amplifier's output devices.

Considering its high power-output capability, the PCR800 is remarkably compact. The upper part of the front panel projects forward from the rest of the amplifier, and it is separated from the major assembly by a slab of foam which serves as an air filter for the ventilation fan. During normal operation, the fan revolves very quietly at a fairly slow speed. If the internal temperature increases substantially, the fan switches to its higher speed, at which point it becomes quite audible.

The only control on the front of the amplifier is an on/off rocker switch, augmented by a green "PCR" light which blinks while the amplifier is on. Faster-than-normal blinking tells the user either that the fan is in high-speed mode or that PCR action (about which more in a moment) is taking place to maintain continuous operation at optimum high-power output. Two red "Truclip" LEDS illuminate when the amplifier is clipping and, therefore, indicate that a distorted waveform is appearing at the output terminals.

The input jacks, at the rear of the amplifier, are the standard phono-tip type. Speaker terminals are color-coded and spaced for standard double-banana plugs. The left- and right-channel "hot" terminals are also spaced for a

The amplifier circuitry is conventional, but the power-supply system, Phase Control Regulation, is innovative.

double-banana plug, to simplify bridging the amp to mono for greater power. Soundcraftsmen's series of "DX" preamplifiers can invert the phase of one channel's output, so no further inversion is necessary at one input of the amp when using it in bridged mode. If two amps are to be used in the bridged mode without such a preamplifier, an external bridging adaptor would be necessary.

Circuit Highlights

The circuitry of the PCR800 is rather conventional in its topology, employing the familiar differential-amplifier input stage, and bipolar amplifier and driver stages followed by four power MOS-FETs per channel as output devices.

The most innovative aspects of this design are in the power-supply system, a new approach to efficient amplifier design called Phase Control Regulation, or PCR. Soundcraftsmen's first model to employ the principle is this powerful PCR800 (205 watts per channel into 8 ohms, 300 watts into 4 ohms), a deceptively small power amp that weighs a mere 18 pounds.

As Soundcraftsmen explains it, the major thrust of legitimate engineering effort in amplifier design has focused on power-supply design improvements. After all, the power supply of an amplifier is the energy source that, indirectly, drives the loudspeakers. The most desirable characteristics of an "ideal" power supply would be huge power capacity, low output impedance, and good transient response. The power supply employed in the Phase Control Regulation amplifier has all of these attributes plus the added benefit of using substantially less expensive circuitry.

Essentially, PCR is a highly efficient means of controlling the average power supplied to an amplifier's output stages. By rapid switching, it connects and disconnects an a.c. supply and its load for a precisely optimized fraction of each 60-Hz cycle of line voltage. When the amplifier is delivering a small amount of power (light load), only a small fraction of each a.c. cycle is used to provide power. When power demand is heavy, the power of the full a.c. cycle is delivered to the output stages. (See Fig. 1.)

To fully understand the operation of the PCR supply, a brief review of conventional, or linear, power-supply circuitry may be helpful. In this approach, illustrated in Fig. 2, the 120-V a.c. line voltage is supplied to a power transformer which provides line isolation and adjustment of the a.c. voltage level at its output. This voltage is full-wave rectified by a bridge rectifier consisting of ordinary diodes. The output of the diode bridge rectifier supplies pulsating positive and negative d.c. voltages, which are then filtered by large capacitors to provide the actual positive and negative voltages used to power the output transistors.

In the PCR800's power supply, the transformer output voltages are not applied to a diode bridge rectifier but to SCRs (silicon-controlled rectifiers). Unlike conventional diodes, SCRs have extra "gate" elements to which control voltages can be applied. By varying the control voltage's phase, an SCR can be regulated to conduct for varying portions of each a.c. cycle—any angle from 0° (nonconduction) to 180° (conduction over half the a.c. cycle, much like a conventional diode). The 'scope photo of Fig. 3A illustrates how the SCRs are turned on for only a small part of each a.c. alternation—the condition which would prevail when the amplifier load is small. In Fig. 3B, the amplifier load (power output) has increased to medium levels, and the SCRs' firing period (denoted by the flat "breaks" in the a.c. waveform) has increased somewhat. Finally, under conditions of heavy load (high power output), the SCRs conduct almost continuously, as would ordinary rectifiers (Fig. 3C).

The SCRs' output, like that of ordinary rectifiers, is pulsating d.c. which must be smoothed by filter capacitors. Here, though, the filtered positive and negative supply voltages are constantly compared to a precision reference voltage, and an exact error-eliminating signal is applied to the Phase Control Regulator. This regulator controls the conduction time of the SCRs, maintaining the output voltage at a precise, fixed level (Fig. 4).

Phase Control Regulation can also perform other functions, such as increasing reliability through circuit protection and compensating for variations in line voltage. For example, thermal sensors positioned near the output transistors, as well as within the windings of the power transformer itself, will monitor temperature; if the temperature exceeds a predetermined level, that fact can be used to reduce the SCRs' conduction time, lowering supply voltage to the output stages. Lowering the supply voltage in this manner reduces dissipation in the output devices, allowing them (or the power transformer, if it was overheating) to cool.

Because of the fixed voltage references built into the PCR system, power-line voltage variations can be monitored in

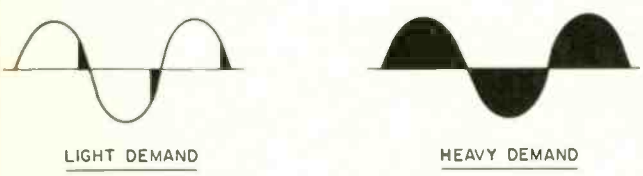


Fig. 1—With light demand, Phase Control Regulation delivers power-supply voltage only for a portion of each a.c. cycle; with heavy demand, the entire cycle is used.

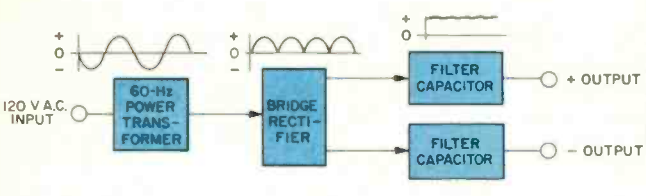


Fig. 2—Conventional power supply.

The ideal power supply would have huge capacity, low output impedance, and good transient response. The PCR800 has all of these.

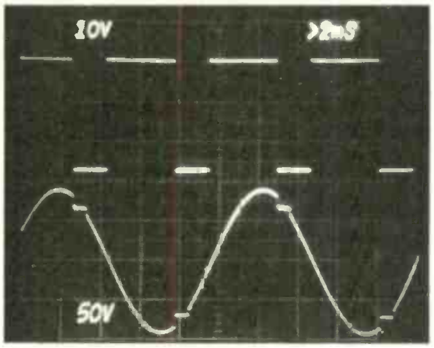
much the same way, and the amplifier's supply voltage so regulated that virtually full power output can be delivered, even in a brownout. Conversely, if power-line voltage should rise to, say, 125 or even 130 V, the power-supply SCRs' angle of conduction would be reduced to maintain constant supply voltage to the output stages with no chance of exceeding their current or dissipation ratings.

Since the Phase Control Regulation circuitry is not in the audio signal path, it does not in any way degrade audio signal quality. Of course, if for any reason the SCRs have to lower the supply voltage, the maximum undistorted power output that the amplifier can then deliver will also be reduced—but that simply means earlier clipping or amplifier overload, with no danger to the amplifier itself or to any of its component parts. In fact, if a dead short is placed across this amplifier's speaker terminals—which can easily occur when an "invisible" strand of speaker cable bridges between the common and hot (+) output terminals—all that will happen is that the supply voltage will smoothly but rapidly drop from its ±70 V down to ±10 V or even lower. Remove the short circuit, and the voltage rises up smoothly again, to its full value, as the SCRs resume conduction over a much greater angle of the a.c. input waveform, and normal operation is restored.

Most amplifiers are deliberately designed with poor power-supply regulation. As the load demands more power, their supply voltages drop or sag, making less voltage available. This type of design usually results in an amplifier's being able to provide very high power levels for very short peaks, but not when those peaks are repeated rapidly or high volume is sustained for a long period. The PCR approach results in a very tightly regulated power supply for the output stages. IHF dynamic headroom is going to be lower for this type of amplifier than for those employing "soft" or poorly regulated power supplies. But bear in mind that high dynamic headroom should not necessarily be regarded as a desirable attribute—it is simply the result of one design philosophy. Using a stiff power supply is another approach, as exemplified by PCR. Because of this design, the PCR800 has very low IHF dynamic headroom—no more than a fraction of 1 dB. On the other hand, it can provide more of its continuous rated power under the extreme line-voltage variations found in many real-world operating situations than would be the case with conventional soft power-supply amplifier designs.

Measurements

The Soundcraftsmen PCR800 delivered 211 watts per channel into 8-ohm loads at mid-frequencies and an almost equally high 205 watts per channel at the frequency extremes of 20 Hz and 20 kHz for its rated THD of 0.05%. At rated output, THD measured 0.01% at mid-frequencies, 0.038% at 20 Hz, and 0.04% at 20 kHz. Figure 5 is a plot of THD versus power output (per channel) for the key frequencies of 20 Hz, 1 kHz and 20 kHz. I also measured the amplifier's power output capability at lower impedance loads: With 4-ohm loads, the PCR800 delivered 305 watts per channel at mid-frequencies and more than 275 watts per channel over the entire audio frequency range for its rated THD of 0.05%. Even when 2-ohm loads were connect-



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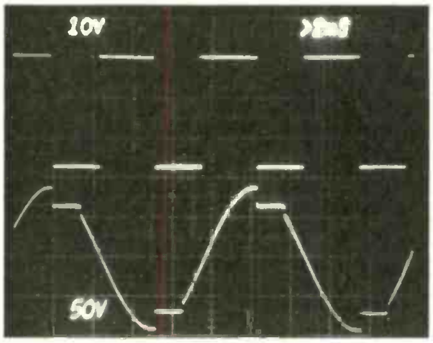

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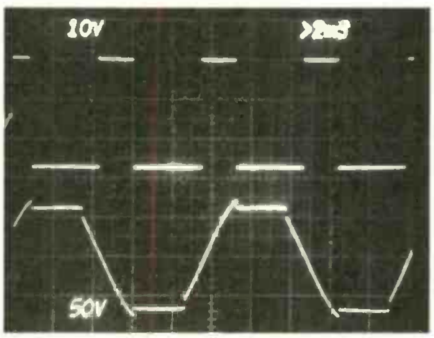

C

Fig. 3—'Scope photos of voltage waveform appearing at power transformer secondary show how conduction angle of SCRs increases from light load (A) through medium (B) to heavy load (C).

Soundcraftsmen says little about how the PCR800 *sounds*. That's a pity, because besides stable power, it delivers clean and accurate sound.

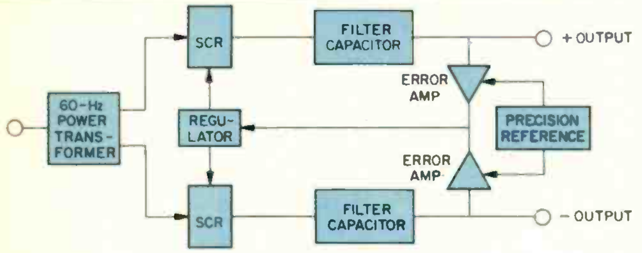

Fig. 4—In the PCR system, a precision-referenced feedback signal regulates the output of silicon-controlled rectifiers, used in place of the ordinary diode rectifier in Fig. 2.

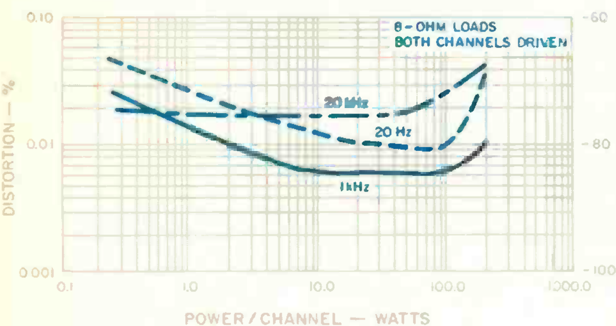

Fig. 5—Power output vs. THD.

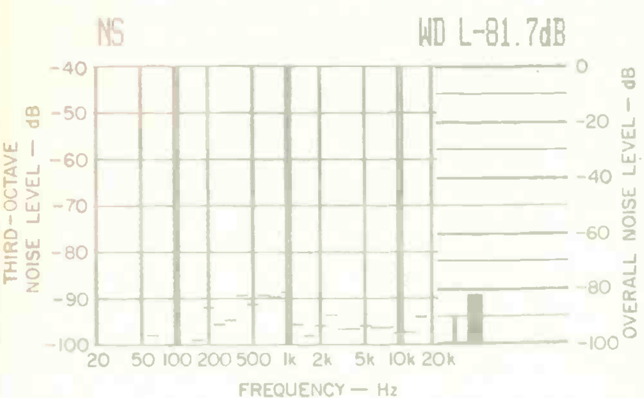

Fig. 6—Noise analysis referenced to 1-watt output, plus A-weighted noise measurement.

ed to this amplifier, it managed to deliver better than 230 watts per channel at mid-frequencies and just over 200 watts per channel over the entire audio frequency range. The SMPTE-IM distortion at rated output measured 0.023%, while CCIF (twin-tone) IM measured 0.005%. The IHF IM at rated power was lower than 0.03% (the limit of my test equipment's ability to read this specification). Frequency response was flat within 1.0 dB from 6 Hz to 100 kHz and within 3 dB from 3 Hz to 200 kHz. As I would have guessed, based upon this stiff power-supply design philosophy, IHF dynamic headroom was practically nil, measuring a mere 0.21 dB.

Input sensitivity referenced to 1 watt measured exactly 100 mV, which corresponds to 1.4 V for rated power output (into 8-ohm loads). A-weighted signal-to-noise ratio with reference to 1 watt was 81.7 dB (as shown in the noise analysis plot of Fig. 6). Adding 23.1 dB to this measurement (the dB ratio between 1 watt and 205 watts) results in an S/N figure of 104.8 dB, essentially identical to the 105 dB claimed by the manufacturer. Damping factor was very high, with a reading of around 200, referred to 8 ohms, using a 50-Hz test signal. Slew factor was better than 5, while slew rate measured around 45 V/μS.

Use and Listening Tests

It's rather a pity that Soundcraftsmen's literature on the PCR800 says very little about how it *sounds*, because, besides packing a lot of stable power into a very small package, it delivers clean, accurate sound that is as good as any I have heard from an amplifier in this power class. I can't say for sure whether elimination of any and all current-limiting circuits within the signal path is responsible for the clarity and transparency of sound I heard when listening to some of my favorite CDs, but it certainly isn't doing any harm. Prompted by Soundcraftsmen's chief engineer, I bravely short-circuited the output terminals of one channel while playing full blast, all the while monitoring the B+ and B− supply voltages inside the amp. Of course, all semblance of musical sounds from the shorted channel ceased at once, and then, smoothly and with no apparent panic, the supply voltages dropped neatly down towards zero. There was no actual shutdown of the amplifier, nor did fuses blow or output transistors go up in smoke. When I freed the amp of its short, the voltage swiftly rose again (the SCRs having now been turned on to deliver a greater percentage of the power transformer's available a.c. voltage swings to the filter capacitors), and undistorted sound returned, none the worse for the experience!

It's one thing to develop a good-sounding amplifier that remains accurate when no unusual demands are made on it and power-line voltage is exactly what it should be. It's another thing to achieve this in a powerful amplifier which is suited to the real world, where loudspeakers have dips in their impedance curves, utility companies provide out-of-tolerance line voltages, and users may subject their equipment to all sorts of thermal and short-circuit indignities. To have achieved this in an amplifier as compact as the PCR800 is truly remarkable; to sell that amplifier at $1.10 per watt (75¢ if you use 4-ohm loads) is nothing short of miraculous! *Leonard Feldman*

3

YAMAHA CD-X1 COMPACT DISC PLAYER

Manufacturer's Specifications
Frequency Response: 5 Hz to 20 kHz, ±0.5 dB.
S/N Ratio: Unweighted, 95 dB; A-weighted, 100 dB.
Dynamic Range: Greater than 95 dB.
Channel Separation: Greater than 90 dB at 1 kHz.
Noise Plus Harmonic Distortion: Less than 0.005% at 1 kHz, 0 dB.
Output Level: 2.0 V for 0 dB.
Number of Programmable Selections: 23.
Power Consumption: 20 watts.
Dimensions: 13⅜ in. (34 cm) W × 3⅝ in. (9.2 cm) H × 11⅜ in. (28.9 cm) D.
Weight: 7 lbs., 15 oz. (3.6 kg).
Price: $499.00.
Company Address: 6660 Orangethorpe Ave., Buena Park, Cal. 90620.
For literature, circle No. 92

Yamaha's second-generation CD player is a good example of what can be done to bring the miracle of laser-read digital sound to a broader audience, for its large-scale integrated (LSI) circuitry has had an impact on product cost. The CD-X1, with a suggested price less than half that of Yamaha's first CD model, is a feature-laden player whose sonic performance rivals or perhaps even exceeds that of the earlier, much bulkier unit. The CD-X1 is, in fact, the lightest (home) CD player I have encountered to date, tipping the scale at just under 8 pounds.

According to Yamaha, the substantial reduction in size and weight (not to mention price) was made possible by the development of two LSIs which are used for all of the necessary signal processing, servo-controlled tracking, and digital filtering. Yes, for those of you who feel that you can tell the difference, Yamaha has elected to go the digital filtering route in this player. They have doubled the effective sampling rate (from 44.1 to 88.2 kHz) and were therefore able to use a simpler low-pass filter to reduce phase distortion. According to the owner's manual, only a seventh-order LC filter is used in the post-D/A circuitry. The CD-X1 also uses a three-beam laser pickup for excellent tracking.

As for convenience features, they are remarkable, considering the price of the unit. Discs are loaded into a motorized tray, and the user can select auto play (which starts the disc playing as soon as the door is closed), timer-activated play, or a mode that permits playback of a single selection at a time—all in addition to the normal play mode. Up to 23 selections can be programmed to play in normal sequence, but the unit does not allow completely random-access programming. In other words, you can ask the CD-X1 to play tracks 1, 5, 9, 11 and 12 but you cannot request that the playing sequence be out of numerical order. Fast-forward and fast-reverse audible music search is possible, and while this feature is operating, audible output level is reduced by 20 dB. An A-to-B repeat function allows you to repeat-play an entire disc or certain phrases within a single selection.

Control Panel Layout

The power switch is located beneath the disc drawer at the left of the unit. Although there is a separate "Open/Close" button to the right of the drawer, I quickly discovered that a slight tap on the front of the opened drawer also causes it to close. The three-position "Play Mode" switch, with settings identified as "Auto," "Norm" and "Single," is below the drawer touch button. A multi-function display of playback information, to the right of these buttons, shows elapsed or remaining time, track number, and playback status (which illuminates during normal playback, flashes during pause, and is off in stop mode). Other playback display indicators are "Repeat" (which lights when any repeat mode has been selected), A-B repeat, and "Memory" (which lights during memory playback or when entering selections during programming of the unit). "Play/Pause" and "Stop" buttons are just to the right of the display.

Remaining touch buttons are located along the lower right section of the front panel. They include "Repeat On/Off," "Repeat A-B," and the "Store," "Cancel" and "Check/RT" buttons associated with memory programming. The final four buttons relate to the CD-X1's "Music Search" feature.

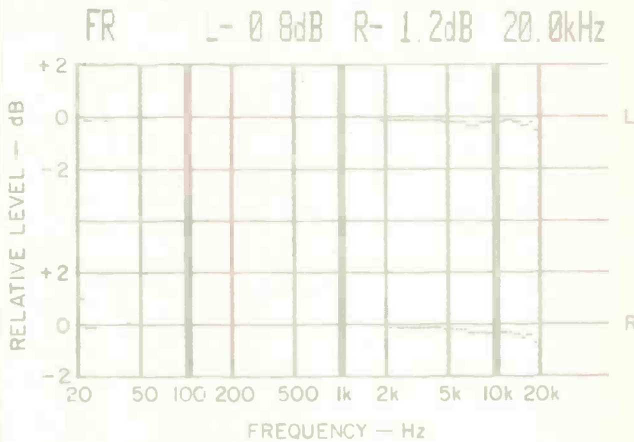

Fig. 1—Frequency response, left (top) and right channels.

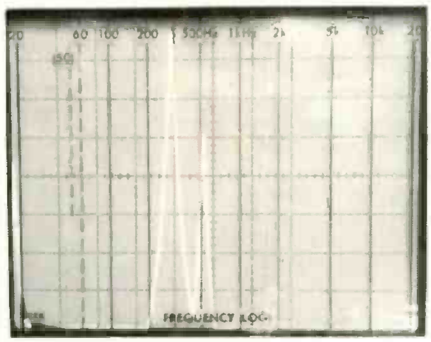

Fig. 2—Spectrum analysis, 0 Hz to 50 kHz, showing 20-kHz tone (tall spike) and spurious beat tone at 24.1 kHz (smaller spike), only 26 dB lower.

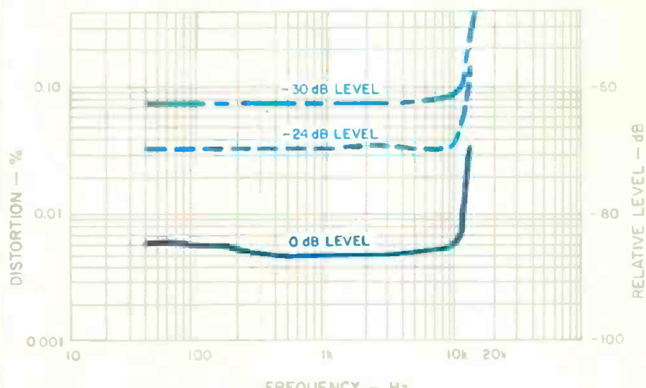

Fig. 3—THD vs. frequency at three recorded levels.

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**34 EPA EST. MPG. 46 EPA EST. HWY. 1984 EPA estimate for our STD Hatchback. Use EST. MPG for comparisons. Your actual mileage will probably be less.

The performance of the feature-laden CD-X1 rivals or exceeds that of the previous Yamaha model, at less than half the price.

Two are used for fast-forward or fast-reverse searching. The audible search is fairly slow for the first 3 S, but it speeds up if you keep your finger on either button for a longer period of time. Depressing the remaining two buttons, labelled "+" and "−," will advance (or reverse) the pickup to the next (or previous) track. No provision is made for accessing music by index numbers, but in view of the fact that the player offers audible fast searching, I do not regard this as a major omission. I do rather wish that the unit had an output-level control (2.0 V for 0 dB is a bit much compared with such other typical program sources as tuners or tape decks), but since lower pricing was an important objective of Yamaha, I think, overall, the designers managed to incorporate the most essential and useful features, leaving out those which most of us can certainly live without.

Measurements

Figure 1 shows a plot of frequency response for both left and right channels of this CD player. As in previous reports, the vertical scale has been expanded to 2 dB per division. At 20 kHz, response was down by 0.8 dB for the left channel and 1.2 dB for the right.

Harmonic distortion at mid-frequencies, for maximum recorded level, measured only 0.0045%, rising to 0.006% at 10 kHz. Above that frequency, I encountered a by-now familiar sudden rise in apparent THD. Using a simple distortion analyzer, the readings jumped to a high 0.4% at 20 kHz. Investigating the phenomenon with my spectrum analyzer, I quickly discovered that the high reading was not actually harmonic distortion, but rather a "beat" frequency appearing at 24.1 kHz, outside the range of human hearing. In Fig. 2, a linear sweep from 0 Hz to 50 kHz was used (5 kHz per division). The tall spike is the desired 20-kHz output signal; just to its right, about 4 kHz higher in frequency, is the spurious beat component which was responsible for the higher distortion reading. Figure 3 presents plots of distortion versus frequency for 0-dB recorded level as well as for −24 and −30 dB levels. The expected relationships (higher distortion at lower output levels) hold true here, as in previously tested CD players.

Output linearity was accurate to within 0.2 dB from 0-dB output down to −60 dB, and within 0.6 dB from −60 to −80 dB. Stereo channel separation is plotted for left and right channels in the graph of Fig. 4. I measured separations of approximately 88 dB at mid-frequencies and between 82 and 84 dB at the high-frequency end of the spectrum.

SMPTE-IM distortion measured 0.0018% at 0-dB recording level, increasing to 0.012% at −20 dB. CCIF (twin-tone) IM, using 19- and 20-kHz signals of equal amplitude corresponding to a sum signal at 0-dB level, measured 0.002%, while the same signals, reproduced at a −10 dB equivalent level, produced a CCIF-IM figure of 0.0044%. Signal-to-noise analysis was conducted with and without an A-weighting network. Unweighted S/N measured 91.6 dB (as displayed in Fig. 5A), and weighted S/N was 99.4 dB (Fig. 5B).

Reproduction of a 1-kHz, digitally generated square-wave test signal, shown in Fig. 6, was typical of that encountered with CD players which utilize digital filtering plus gentler multi-pole, analog post-D/A filters. The same held true for reproduction of the digitally generated unit-pulse test signal,

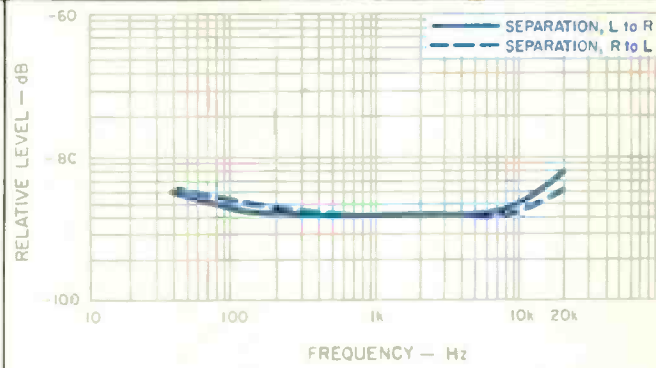
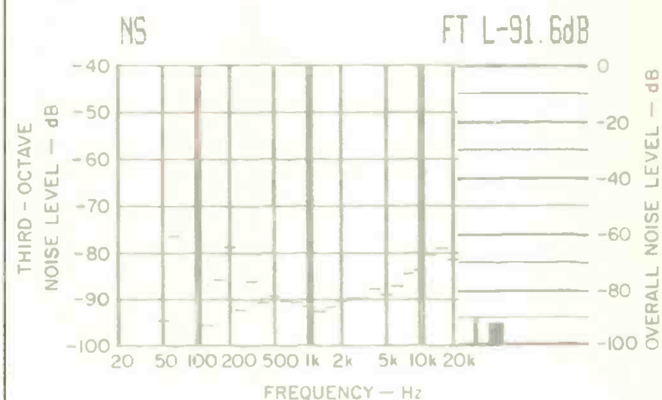


Fig. 4—Separation vs. frequency.



A

B

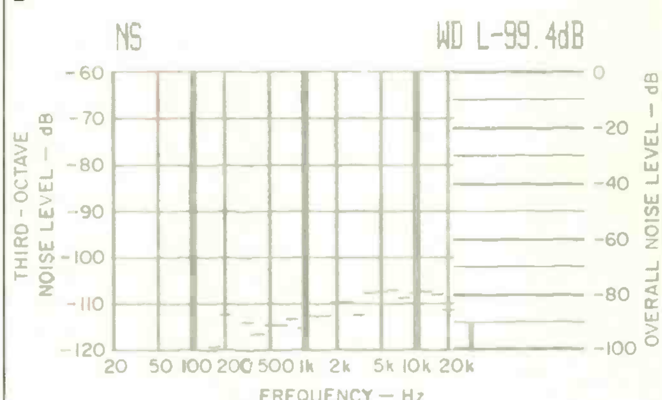


Fig. 5—S/N analysis, both unweighted (A) and A-weighted (B).

The CD-X1 is one of the few players I've tested that can track the test record's entire "obstacle course."

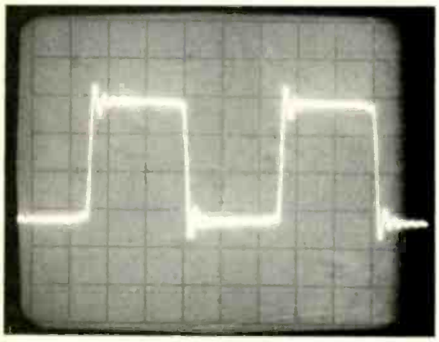


Fig. 6—Reproduction of 1-kHz square wave.

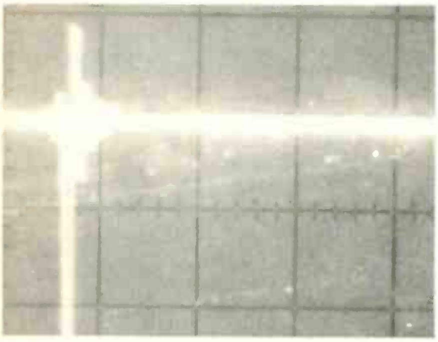


Fig. 7—Single-pulse test.

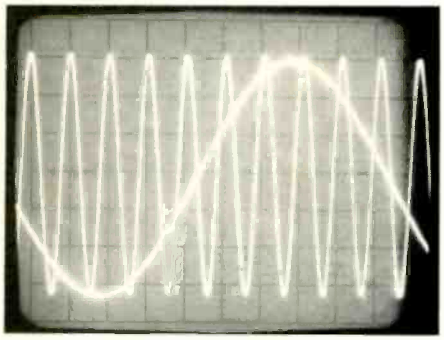


Fig. 8—Phase linearity test, 200-Hz and 2-kHz signals.

shown in the 'scope photo of Fig. 7. The usual slight phase displacement between a left-channel, 200-Hz test signal and a right-channel, 2-kHz test signal is evident in the 'scope photo of Fig. 8. Had phase linearity been perfect, positive crossing of the zero axis would have occurred at the same time for both signal frequencies.

I conducted my usual tracking and error-correction tests using the specially prepared Philips test disc, which contains a wedge of opaque material, several black dots of specified diameters and a semi-transparent simulated fingerprint smudge. The Yamaha CD-X1 was among the few CD players I have tested which successfully completed this "obstacle course" without ever muting or mistracking. This means its laser tracking system, in combination with the built-in error-correction circuitry, was able to "overlook" disc "scratches" having a linear thickness of 900 microns, "dust" particles of 800-micron diameter, and a rather nasty "smudge" occupying nearly an inch of linear distance near the outer diameter of the test disc. It took a rather heavy pounding of my fist to the top of the unit to make the laser pickup mistrack because of externally induced vibration, and I was also able to tap the sides of the CD-X1 reasonably hard without upsetting its tracking servo and laser pickup. Small and light though this CD player may be, it rivals the more ruggedly built, heavier units as far as stability of the tracking mechanism is concerned.

Use and Listening Tests

Testing this player gave me an opportunity to try out a couple of new Telarc CDs. One was the CD version of a digitally mastered LP, *Malcom Frager Plays Chopin* (on a Bösendorfer Imperial Concert Grand piano, Telarc CD-80040). I had been overwhelmed by the rich sound of that instrument when I first heard it more than a year ago on the LP. Now that I've heard the CD version, I can tell you that anyone who prefers the LP is, in my opinion, simply being an obstinate die-hard. With the surface noise gone, and the dynamic range even further expanded than it was in the admittedly excellent LP, that Bösendorfer was *in my listening room!* I like listening to good music with my eyes closed, but I literally had to open them every few minutes to remind myself that I was not in the same room with Frager and his magnificent instrument.

Does that mean this lightweight player from Yamaha is superior to my reference CD player? Not at all! I played the Frager disc, as well as a marvelous live recording of Lionel Hampton (part of a jazz sampler CD released for demonstration purposes by Sony), on my "older" CD player, and they sounded great. It's as I've been saying right along: Given good software, nearly all the CD players I've tested produce musically accurate sound, with little of the harshness or brightness which engendered complaints from listeners about earlier discs.

None of this is meant to detract from the many merits of the Yamaha CD-X1. That it produced such magnificent music—at the price it costs and with the features it has—makes it an outstanding CD player that will undoubtedly attract a large audience which has been waiting for a lower-priced unit that doesn't sacrifice performance, reliability and convenience features. *Leonard Feldman*

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CONRAD-JOHNSON PV-5 PREAMP

Company Address: 1474 Pathfinder La., McLean, Va. 22101.
For literature, circle No. 93

The choice between tube and transistor preamps is increasingly hard to make. In the past, transistors offered extended frequency response and amplitude linearity, but usually lacked the natural and upper-midrange detail, life, and sweetness of their tube counterparts. Tube preamps, however, often sounded warm. They lacked the extended highs and deep, tight bass of the better transistor units, and sometimes lacked their speed in handling bass and lower-midrange transients.

During the last two years, transistor units have begun to acquire many of the merits of tube units, and vice versa. The best preamps of both types now differ more in nuance than in predictable strengths and weaknesses.

The conrad-johnson PV-5, however, makes a good case for the continued superiority of the best tube units. It is remarkably linear in frequency response and is extended in the lows and the highs. It has excellent detail regardless of whether the music has the fine harmonic structure of a soft chamber group or the complex imaging and dynamics of a full orchestra. At the same time, it has the superb midrange traditional with the best tube preamps.

If this sounds like high praise, it should. The conrad-johnson PV-5 does not quite equal the company's top-of-the-line Premier Three, but it comes close. The differences are subtle: The PV-5 has less ability to resolve fine harmonic detail and also has a slightly less sweet and natural upper four octaves.

The PV-5 may lack the upper octave transient detail of the Audio Research SP-10, or the superior high-frequency extension of the Audio Research SP-8, but many listeners are likely to prefer the warmth of its lower midrange and its ability to give musical life to the many records and Compact Discs with slightly hard treble and upper midrange.

The PV-5 is not perfectly neutral (no piece of audio equipment is), but it approaches the state of the art. I have used it with a wide variety of top-ranking components, including the conrad-johnson Premier Four and the Audio Research D-160B amps and the Quad ESL-63, Thiel CS3, and Fuselier 3+3

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Our S-X1030 25 watt* receiver is another Sansui achiever with many of the great features of our S-X1050 unit.

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*S-X1050—35 watts, 0.02% THD; S-X1030—25 watts, 0.05% THD. Minimum RMS, both channels driven into 8 ohms, from 20-20 kHz.

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Transistor and tube preamps are acquiring each other's virtues, but the PV-5 makes a case for tube superiority.

speakers. In each case, the PV-5 emerged as remarkably uncolored, even in comparison with preamps costing twice its price.

This lack of coloration is particularly clear on phono sources. The PV-5 brings the best out of the best records. Imaging is stable and natural. There is good center-fill and depth, but the sound still extends slightly to the left and right of each speaker.

The PV-5 approaches the Premier Three and SP-10 in showing just how much detail is hidden in direct-to-disc recordings. Not only is it relatively uncolored, it is remarkably quiet for a tube unit. This may result from its twin triode configuration, its regulated d.c. filament supply, from the choice of tubes, or simply from good execution of design. Nevertheless, it is possible to use many of the higher output moving coils like the EMT, Koetsu, and Alpha-1 without a pre-preamplifier. This will involve some sacrifice of dynamics and timbre, but it is still an achievement that some tube preamps are too noisy to allow.

The PV-5 is also a convenient preamp to use. It is a "basic" preamp and lacks tone controls and the convenience of a built-in, high-gain stage for moving coils, but it has a full range of input options, including the controls to use two tape decks. It provides a mode control with a choice of mono, stereo reverse, left, and right—something sadly missing on some high-end preamps. The rest of its controls have a good "feel" and allow for easy adjustment of gain and balance without having to keep the controls at extremes or fuss with very small movements.

In summary, the PV-5 comes close to being a $3,000 to $4,000 preamp at a price of $1,485. If you are committed to tubes, Audio Research and Counterpoint offer strong competition in this price range, and I would still recommend that you audition top-ranking units such as the Audio Research SP-10 or conrad-johnson Premier Three. If you prefer the transistor competition, I suggest auditioning the Krells, Thresholds, or Levinsons. Money still buys more than a brand name and a faceplate. In any case, the PV-5 is undoubtedly one of the best preamps around. *Anthony H. Cordesman*

TDK
Portrait of a Company In Fast Forward

Nothing about the products of a manufacturing company is ever really accidental. To the contrary, anything a firm designs and builds is, metaphorically speaking, a mirror of sorts and reflects the image of the company that created it. While the products TDK Corporation is best known for, magnetic audio and video recording tape, are specifically designed for near-perfect reproduction of sounds and images, even before the magnetic impulses that translate to words, musical tones and pictures are imprinted on TDK tape, each cassette can be said to contain a wealth of thought and energy. This is because each is endowed with the collective intelligence and philosophy of the many dedicated people responsible for the creation of TDK products.

Portrait of a Company in Fast Forward

The Deception of Little Things

There is something deceptively simple about an audio cassette. Perhaps it is the minute size, or the fact that parts constructed to such critical tolerances are housed in an enclosure which the user can safely handle as casually as he or she can a pack of chewing gum. Look a bit deeper, however, and it is easy to see why, before TDK introduced the first high fidelity cassette in 1968, audio experts were virtually unanimous in doubting that genuine high fidelity performance could be attained from this medium, originally intended for use in dictation.

Looking closely at a TDK cassette, however, can take one only part way down the road to understanding it. More information is necessary, including facts relating to the company's history, its key executives and corporate philosophy as well as technical data. For this reason, TDK Corporation, the world's leading producer of magnetic tape, is taking the occasion of the medium's 50th anniversary to present readers of AUDIO magazine with a company portrait. It is sincerely hoped that the understanding it conveys will enhance the enjoyment you derive from TDK products.

Yasuo Imaoka: The Father of Avilyn

Much of the credit for the technical leadership that TDK has achieved belongs to Dr. Yasuo Imaoka, Executive Director and General Manager of Research and Development. Dr. Imaoka is known in the electronics industry as "the Father of Avilyn," the magnetic material composing the particles that are the heart of TDK recording tape.

"We are continually interested in upgrading," Dr. Imaoka declares. "This means producing new products which satisfy the needs of the consumer and which assist in upgrading overall industry standards. Our research and development efforts are directed to finding ways of overcoming the limitations of existing materials and translating the results into products that can be manufactured on a commercial scale."

"A position of leadership demands that we lead in all areas," asserts this internationally-known authority on magnetics. To this end, he points out, TDK devoted about one half the company's R&D budget of $49.8 million in the last fiscal year to magnetic recording media.

Some Facts About TDK

TDK (the initials stand for Tokyo Denki Kagaku Kogyo) was founded in 1935, the year following the invention of magnetic recording tape. The company's founders, Dr. Yogoro Kato and Dr. Takeo Takei, were scientists striving to commercially harness what was then a revolutionary magnetic material called ferrite.

Because ferrite powder can be sintered into a variety of shapes, it proved an ideal core material for radio transformers, but the radio industry was only the first to benefit from TDK's expertise in ferrite technology. It wasn't long before the material was widely utilized among consumer electronics manufacturers. Today the products that contain ferrite, of which TDK is the world's largest producer, include countless audio and video recording heads, speaker magnets, transformers, bar antennas and more. In fact, the firm now fabricates some 75 per cent of all rotary transformers used in the video cylinder heads for video cassette recorders.

TDK's role in the development of magnetic tape is of parallel importance. The firm unveiled its first recording tape in 1952 and, in 1966, introduced the cassette format to Japan. Two years later, TDK won worldwide recognition by developing the first audio cassette to achieve true high fidelity performance. Designated SD, this groundbreaking formulation is the ancestor of today's TDK cassettes, singled out by nearly 60 per cent of the world's leading audio cassette deck manufacturers as their reference standard normal bias, high bias and metal tapes.

TDK Corporation is now a multinational corporation with stock traded on exchanges throughout the world, including the New York Stock Exchange. In addition to manufacturing in several Japanese facilities, the company now operates two plants in the U.S. The TDK factory in Peachtree City, Georgia, concentrates on videotape production while audio cassettes for the American market are assembled and loaded in a facility in Irvine, California.

In the fiscal year ending November 30, 1983, TDK's sales of magnetic recording tape reached $755.3 million, accounting for just over 50 per cent of the company's total sales of a billion and a half dollars. These are substantial numbers, and numbers are crucial in any business. Top executives at TDK, however, prefer to view the company as a microcosm of the world itself—and the primary ingredient of our world, of course, remains its people.

TDK HX-S:

The tape for Audio's Digital Age

The people, the philosophy, the procedures that fuel growth at TDK are also prime contributors to each technological advance at the company. In audio tape, TDK's most recent giant step forward is a formulation known as HX-S. This is the first metal particle formulation designed expressly to record in the Type II (high bias, 70 microsecond) position. HX-S is a remarkable tape which fills a special niche in the marketplace by providing audiophiles a formulation keyed to the special demands of digital recording. Moreover, it allows recordists to avail themselves of the advantages of metal tape whether or not their decks are equipped with a bias position designed for conventional metal formulations.

Until now, the chief problem in recording from digital source material has been the inability of the tape to store the enormous levels of high frequency energy. TDK HX-S eliminates this problem; it excels in its retention of highs and offers a maximum output level (MOL) in this frequency range that is unmatched by other cassette formulations. In addition, its sensitivity in other parts of the frequency spectrum exceeds or matches the best high bias formulations.

The unmatched MOL and exceptional high-end response of HX-S cassettes allow them effortlessly to handle the wide dynamic range and substantial treble energy of Compact Discs and digitally recorded material. Specificially, HX-S can record a 4 dB higher signal level at 10 kHz than the best of Type II cassettes (such as TDK's own SA). High frequency overload and saturation cease to be a problem. And as a bonus, there is also a 2 dB improvement in midrange energy storage.

Available now in 60 and 90-minute lengths, TDK HX-S is backed by a full lifetime warranty.

The Importance of Avilyn

Super Avilyn's high-density storage capabilities and excellent reproduction characteristics are largely responsible for the advanced state of audio and video recording technology today. TDK announced the discovery of Avilyn in November, 1973. An amalgam of two highly combustible substances, gamma ferrite and metal cobalt particles, Avilyn proved ideal as an alternative to the expensive and scarce chromium dioxide formulation; this indicated, as has since been proven, that it would set precedents in audio recording. Video recording was seen as an other important application of the substance.

Shortly after Avilyn's introduction, TDK engineers combined cobalt hydroxide in lieu of metal cobalt with its ferrite base to produce an improved material known as Super Avilyn.

The Super Avilyn formulation first appeared in a standard audio cassette in 1975. Known simply as SA, this became the world's first non-chrome high bias audio cassette. In 1981, TDK produced a dual-layer audio tape called SA-X, which became its flagship high bias tape, and in 1982 the firm introduced a special Avilyn formulation, the first to be incorporated in a normal bias cassette. This achieved higher density and higher coercivity in the normal bias position.

EHG HiFi and HD-Pro:

TDK Upgrades its video tapes to meet a changing market

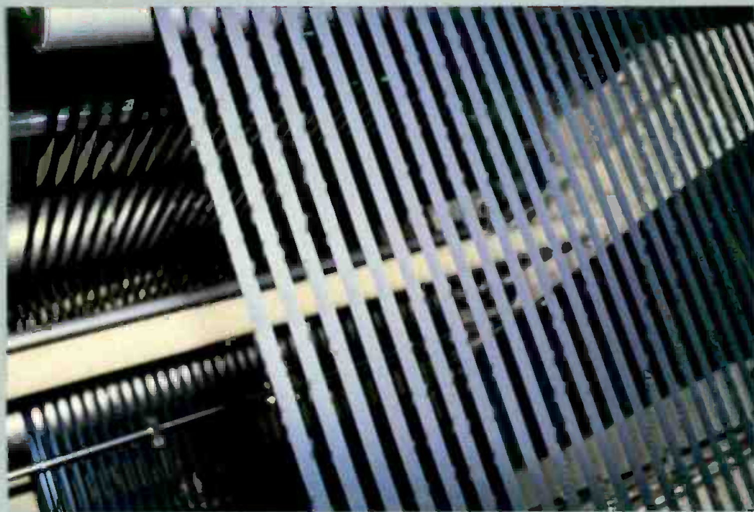
Back in the early 1970's, TDK stepped beyond the existing formulations that existed in audio tape at that time—most notably the chromium dioxide particle—to produce Avilyn, a magnetic particle consisting of cobalt ions adsorbed (coated) on finely-milled, needle-shaped, gamma ferric oxide particles. These early developments in fine particle technology laid the groundwork for breakthroughs in today's new wave of high fidelity VCRs. The first of these breakthrough formulations, dubbed TDK EHG Hi-Fi, benefits the videophile who wants to be certain that lifelike video images are coupled with high quality stereo sound. The second breakthrough tape, HD-Pro, is the closest thing the connoisseur

The Tape Production Triangle

There are three essential elements of tape manufacturing that can be seen as an equilateral triangle. One need only envision the magnetic materials as the triangle's base with one side consisting of shell and component parts and the other the manufacturing processes by which these parts are combined to become a unified whole. During production, members of the TDK family constantly strive for improved techniques. In addition, the newest in automated machinery assists these TDK employees in the quest for perfection.

There is a phrase that has become a byword on the TDK production line; it is "total productivity maintenance." In keeping with this admirable philosophy, workers set out to learn as much as possible about the machines they monitor, attempting to understand what makes them malfunction when they do and establishing routines for preventive maintenance. Through such efforts, the overall operating efficiency of production machinery—and ultimately the entire plant—is upgraded.

Naturally, quality assurance is a key consideration at each stage of production—from materials manufacture and product design through preproduction and manufacturing. The process includes



environmental testing, endurance and shelf life tests.

Visitors to TDK's Chikumagawa plant, the company's largest and the facility producing the audio tape pancakes to be sent on to the Irvine factory for slitting and loading into cassette shells, are fascinated by row upon row of audio cassette decks. These, along with a battery of VCR's, run round the clock for testing purposes. Such usage imposes undue strain on this hardware, and an average of 100 new machines per month are required at Chikumagawa.

In addition to their quality assurance functions, the audio and video decks at the plant serve as emblems of TDK's concern with hardware development. The company works hand in hand with the leading deck suppliers to keep current with developments in tape-related hardware, and information relating to product evaluation is exchanged on a regular basis.

video tapist can get to ¼-inch resolution in half-inch format—a tape which is ideal for live camera recordings, dubbing, special effects work and other pro or semi-pro applications.

Critical Performance

Both EHG Hi-Fi and HD-Pro share certain technical similarities which enable each to offer visually better results than their competition. TDK accomplished this by further refining Super Avlilyn particles so that they are noticeably shorter, thinner and more uniform than particles used in other tapes. This means the tape particles can be packed together more densely to produce better sound and video. In HD-Pro's case, the particles are so fine that they can be packed together 12 times more densely than TDK's own Standard tape. Designed to meet the needs of today's unerringly precise VCRs, TDK's EHG Hi-Fi delivers exceptional picture quality and dynamic sound—even after hundreds of plays. Signal-to-noise ratio is up 4.5 dB in luminance and 5 dB in chrominance over TDK's Standard video tape. This means razor-sharp definition, extra bright colors and extra detailing and shading even in black and white. EHG Hi-Fi also offers cleaner, more natural sound with improved frequency response and sensitivity up 1 dB over Standard TDK tape.

The second tape, HD-Pro, is without question the highest definition half-inch video tape on the market, boasting unequalled freedom from dropouts. And if you don't believe us, testing experts at Asahi Camera in Japan agreed, placing TDK well above its competition in this respect.

Digital Audio Recording

A good video tape has wide and remarkably uniform response over a Megahertz bandwidth, low noise relative to the signal recordable and reasonable freedom from dropouts (random losses of signal as a result, usually, of physical imperfections in the tape coating). Digital recording on video tape doesn't care about bandwidth and low noise, but is profoundly disturbed by dropouts. Dropouts in digital audio are heard, and if sufficient in duration can sound as violent as the deepest sort of record scratch. The digital world has learned, as did Asahi Camera's tape tesers, that not all video tapes are equal.

Digital usability has become a by-product of TDK's meticulous attention to physical integrity and the uniformity of the cassettes coming off its line. Both HD-Pro and EGH Hi-Fi reflect this careful attention to quality and detail. Remember, however, that these tapes are still the best video tapes you can buy, with features such as a precision-made "SQ" shell mechanism built to tolerance 2.5 times industry standards, a high conductivity back coating, and ultrasmooth base film, contributing to the smoothest running performers on the market.

So whether you are a videophile whose needs are met by TDK's EHG Hi-Fi or a master "pro" recordist who demands the sophisticated HD-Pro you'll welcome the benefits of these recent developments. Just visit your favorite retailer and pick out a few to try on your own VCR.

TDK: Some Historical Highlights

1935—TDK is established to begin production of ferrite cores.
1951—Ceramic capacitor production begins.
1952—Magnetic tape production commences.
1960—Barium ferrite magnetic material is introduced.
1966—Cassette tape introduced to Japan.
1968—SD, the world's first hi-fi audio cassette formulation, debuts.
1973—Avilyn unveiled.
1975—SA Super Avilyn audio cassette introduced.
1979—Metal audio cassette tape debuts.
1984—HX-S audio cassette, world's first high bias metal formulation, unveiled.

Future Perfect

While it is gratifying for members of the TDK family to look back on a proud history spanning nearly half a century, it is the primary responsibility of the firm's top executives to look ahead. Continuing leadership in electronics is the goal at TDK, and to achieve it a full 3.5 per cent of the company's revenues are earmarked for research and development. The money is being invested in five R&D departments scattered throughout the firm's production facilities and to a new Magnetic Tape Technical Center located near the Chikumagawa plant.

"Many of TDK's products, including tapes, heads and other components are connected with recording technology," concludes Yutaka Otoshi, TDK's President and a company veteran of 47 years. "The next generation of recording media will be optical, and TDK has already produced prototypes of both DRAW (direct read after writing) and erasable-recordable optical discs. In the months and years to come, we will be considering using our skills to develop a number of advanced products related to this technology, but each and every one of these would have to be unique and reflect the full measure of TDK's creativity."

The TDK Professional Reference Series

Represents the highest level of achievement in recording tape technology. Each tape sets a standard for sonic excellence. That's why they're the choice of the most discriminating audiophiles. (Includes MA-R and HX-S.)

The TDK Reference Standard Series

Provides outstanding premium quality for a wide variety of recording needs. Each cassette is a product of TDK's advanced tape technology, and offers maximum reliability, performance and value.

All TDK audio cassettes come with a Lifetime Warranty, backed by almost 50 years of magnetic media technology and experience.

TDK's diverse product line also includes an impressive group of tape-related accessories, designed and built with the same stringent standards that have made TDK the world leader in magnetic tape technology.

MA-R is generally recognized as the Type IV industry standard and is used by most major deck manufacturers to set their metal bias position. MA-R's metal particle formulation has extremely high coercivity and remanence for superior high frequency MOL and low distortion. Its unique TDK engineered Reference Standard Mechanism features a precision die-cast metal alloy frame affording the highest possible accuracy in tape travel and performance. MA-R is the optimum energy-packed performance tape designed to maintain excellence over long periods of time.

Available in 60 and 90 minute lengths.

SA reigns as the finest high-bias position reference tape, used by numerous deck manufacturers in high-bias calibration. SA provides a feeling of presence and realism with its extended flat frequency response, high MOL and greater recording headroom, which contribute to better balance, placement, and definition in stereo reproduction. SA features the Laboratory Standard Mechanism for smooth tape transport and trouble-free operation.

Available in 60 and 90 minute lengths.

MA features the same metal particle formulation as our famous MA-R cassette which sets the Type IV standard for most deck manufacturers. Program sources over the entire audible frequency range, including peaks and high speed transients, can be faithfully stored and clearly reproduced, thanks to MA's superior headroom, frequency response and sensitivity. MA is encased in TDK's Laboratory Standard Mechanism which assures long term reliability and sonic performance.

Available in 60 and 90 minute lengths.

CLEVELAND'S CLASSIC CHRISTOPH

Christoph von Dohnanyi

Schubert: "Unfinished" Symphony; Beethoven: Symphony No. 8. The Cleveland Orchestra, Christoph von Dohnanyi.
Telarc CD-80091.

Christoph von Dohnanyi is the new conductor and music director of the Cleveland Orchestra, replacing Lorin Maazel, who made a number of memorable recordings for Telarc.

Mr. Dohnanyi has gained quite a reputation for his performances with the major European orchestras. As he is more oriented to the classical tradition of Beethoven and Brahms, Telarc decided their first recordings with him should reflect that philosophy.

Thus we have this pairing of the Schubert Eighth ("Unfinished") Symphony and the Beethoven Eighth Symphony. A felicitous coupling, this, and with a total playing time of 52:11, a good CD value.

Telarc's president and recording engineer, Jack Renner, told me this recording was made in Severence Hall in Cleveland because of the unavailability of the Masonic Auditorium, a venue much favored by Jack for its superior recording acoustics. He feels Severence Hall can be a shade too reverberant for some scores. With these two works, then, he was compelled to use his spaced array of three Schoeps omni microphones a bit closer to the orchestra. Consequently, the high strings are a little bright-sounding compared to most Telarc recordings.

Nonetheless, Jack has struck a good balance between the hall acoustics and orchestral definition. All orchestral choirs are well delineated and have a nice textural richness. The imaging and sound field are excellent, with an almost three-dimensional presentation.

Mr. Dohnanyi's performance of the "Unfinished" is well paced and quite eloquent; he is obviously a master in his control of the inner balances of the orchestra. The Beethoven Eighth receives one of the most spirited, ebullient performances I've heard for some time, and the Clevelanders respond to his direction with a bravura display of their virtuosity. An auspicious recording debut for Mr. Dohnanyi on the Telarc label.

As an aside, Christoph is the grandson of Ernst von Dohnanyi, famous composer and pianist, whose most familiar work is his witty and delightful "Variations on a Nursery Song." In 1960, I had the pleasure of recording him playing some of his works and some Beethoven pieces for Everest Records. He was over 80 at the time, but gave a strong and persuasive performance. Unfortunately, several days after the recording sessions, Mr. Dohnanyi passed away. *Bert Whyte*

John Williams: Star Wars Trilogy. The Utah Symphony Orchestra, Varujan Kojian.
Varese Sarabande VCD 47201.

For those who have a chip on their shoulder and don't like the CD format, this *Star Wars Trilogy* recording could well be the catalyst to change their minds.

Irrespective of CD, this is one of the best recordings of its type I have ever heard. It would certainly make a great impression on LP, but given the advantages of pure digital recording, the sound here is simply overwhelming. It has great clarity and high definition, and all the great variety of percussion instruments John Williams has incorporated into the scores are heard with breathtaking fidelity. The tympani and bass drums have an impact and acoustic output that is startling. The great fanfares from trumpets, trombones, tubas and French horns have a clean, brazen brilliance and projection which generate a lot of excitement. The hall acoustics are splendid—just the right amount of reverberation and warm, spacious ambience. The orchestra is beautifully balanced for this perspective.

I was surprised to find out that the recording engineer who did such an

John Williams

Dutoit and London's engineers have given us a splendid recording, revealing every strand of Ravel's complex orchestration.

outstanding job was Bruce Leek. Heretofore, Bruce had been familiar for the fine cutting of master lacquers he does for Telarc. On the strength of this recording, he should devote more time to this new pursuit. Bruce used four Schoeps CMC3U microphones, with Mark II capsules, in a spaced array in front of the orchestra, plus a few AKG 414s and Neumann KM-86s as discreet sweeteners. Multi-mike to a degree, but done with restraint and intelligence. These were fed into a console and mixed directly to a two-channel Soundstream digital recorder.

The Utah Symphony Orchestra, conducted by Varujan Kojian, was recorded in their new Symphony Hall, which obviously is blessed with acoustics particularly suitable for large-scale recording. They played the brilliantly orchestrated "Star Wars," "The Empire Strikes Back" and "Return of the Jedi" suites with great panache, with Maestro Kojian showing obvious respect for John Williams' scores.

Those who rightfully abhor the edgy, strident, high strings on many CDs will appreciate the exceptionally smooth, clean string tone on this recording.

I suppose many people will dismiss these pieces as mere musical trifles which accompanied galactic horse operas. Be that as it may, no one can deny the skill of the colorful orchestrations, nor the excitement they generate in a recording of this really outstanding quality. *Bert Whyte*

Ravel: Piano Concertos & Orchestral Works. L'Orchestre Symphonique de Montreal, Charles Dutoit; Pascal Roge, piano.
London 410 230-2 LH.

The Ravel piano concertos are among the most colorfully scored in all of piano literature. This splendid recording, another of demonstration quality from Charles Dutoit and the Montreal Symphony Orchestra and the London engineers, reveals every strand of the complex orchestration.

Pascal Roge affords a very dynamic, high-tension performance of the concertos, and he is expressively lyrical when the score demands this quality. The piano sound is very clean, with realistic transient attack. It is beautifully balanced, slightly forward of the orchestra in the lovely, warm acoustics of St. Eustache Church. This church has become one of the premier recording venues for the London engineers, and records carrying the St. Eustache imprimatur are a virtual guarantee of superior sound.

Dutoit, as usual, elicits a well-played, very sonorous accompaniment from his ever-improving Montreal Symphony Orchestra. The overall sound is very clean and highly detailed. The scoring of the low-level opening of the "Concerto for Left Hand," which in most recordings is amorphous and murky, is clearly revealed here with this high-definition sound. Of course, the noiseless CD recording never intrudes in quiet passages such as this.

Three short orchestral works by Ravel fill out this good-value CD, providing over 59 minutes of music. *Bert Whyte*

Respighi: Pines of Rome, Feste Romane, Fountains of Rome. L'Orchestre Symphonique de Montreal, Charles Dutoit.
London 410 145-2 LH.

Here is another winner from Charles Dutoit and the Montreal Symphony Orchestra. The ever-familiar "Pines of Rome," "Fountains of Rome" and "Feste Romane" add up to a CD containing 60 minutes of spectacular sound.

As usual, the London engineers and St. Eustache Church acoustics work their wonders. The huge brass sounds are almost palpable in their projection, and percussion is clean and thunderous. Some extremely high-pitched high strings in the beginning of the "Pines of Rome" are scored to be played with great vehemence and intensity, so don't confuse them for an anomaly of digital recording or poor mike technique.

Dutoit's readings of the "Pines" and "Fountains" are first-rate and very expressive, and he fully exploits their great dynamic range. His "Feste Romane" is headstrong, tumultuous, even frenetic in the "tarantella" section, but he displays much tenderness in the lyrical sections. Mark this as one of the best-sounding CD recordings thus far. *Bert Whyte*

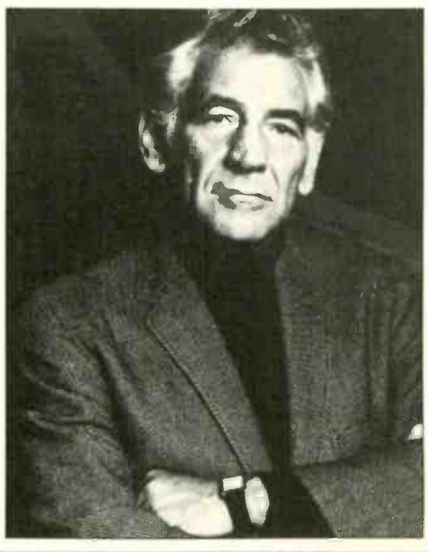
Brahms: Symphony No. 1. The Vienna Philharmonic, Leonard Bernstein.
Deutsche Grammophon 410 081-2.

Here is the sort of Compact Disc recording that makes you gnash your teeth in frustration.

Leonard Bernstein is at the top of his form, with an impassioned, dramatic and very compelling performance of the Brahms First Symphony. He elicits wondrous playing from the Vienna Philharmonic Orchestra. The great, noble french-horn motif, which appears shortly after the opening of the fourth movement, is intoned most vividly and soars effortlessly into the spacious acoustics of the recording hall. The broad, hymn-like chorale that follows the repeat of the horn motif is richly sonorous.

So, why the gnashing of teeth? Same old DGG story of multi-miking excesses. Yes, every single strand of the orchestration is heard, but with all sorts of exaggerated instrumental spotlighting and the ever-present grating edginess of the higher strings. I reported

Leonard Bernstein



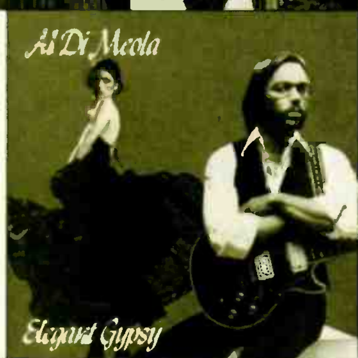
THIS MONTH'S BIG EVENTS ON CBS COMPACT DISCS.

AUGUST

3

4

8



11

17

JUST RELEASED!

ADAM ANT "Strip"
JANE OLIVOR "Stay The Night"
MATTHEW WILDER
"I Don't Speak The Language"
JANIS JOPLIN "Pearl"
LIONA BOYD Live In Tokyo
MOZART: Three Piano Conc., K.107
Perahia; English Chamber Orch.

18

Enjoy today's revolution in sound with CBS Compact Discs. Our rapidly-growing catalog features over 150 titles by superstar artists in all categories of music. Ask for a free copy wherever Compact Discs are sold.

COMPACT disc DIGITAL AUDIO

Massive sonority and detailed, revealing sound highlight Mehta's powerful, well-paced, dramatically seething *Ein Heldenleben*.

some time ago that DGG was aware of many complaints about these aspects of their sound quality and was going to take remedial action in the form of simpler, more natural-sounding microphone techniques. To date, no sign of this, and thus much great music-making on DGG recordings continues to be marred by this kind of sound.

Bert Whyte

Richard Strauss: Ein Heldenleben. The New York Philharmonic, Zubin Mehta.
CBS MK 37756.

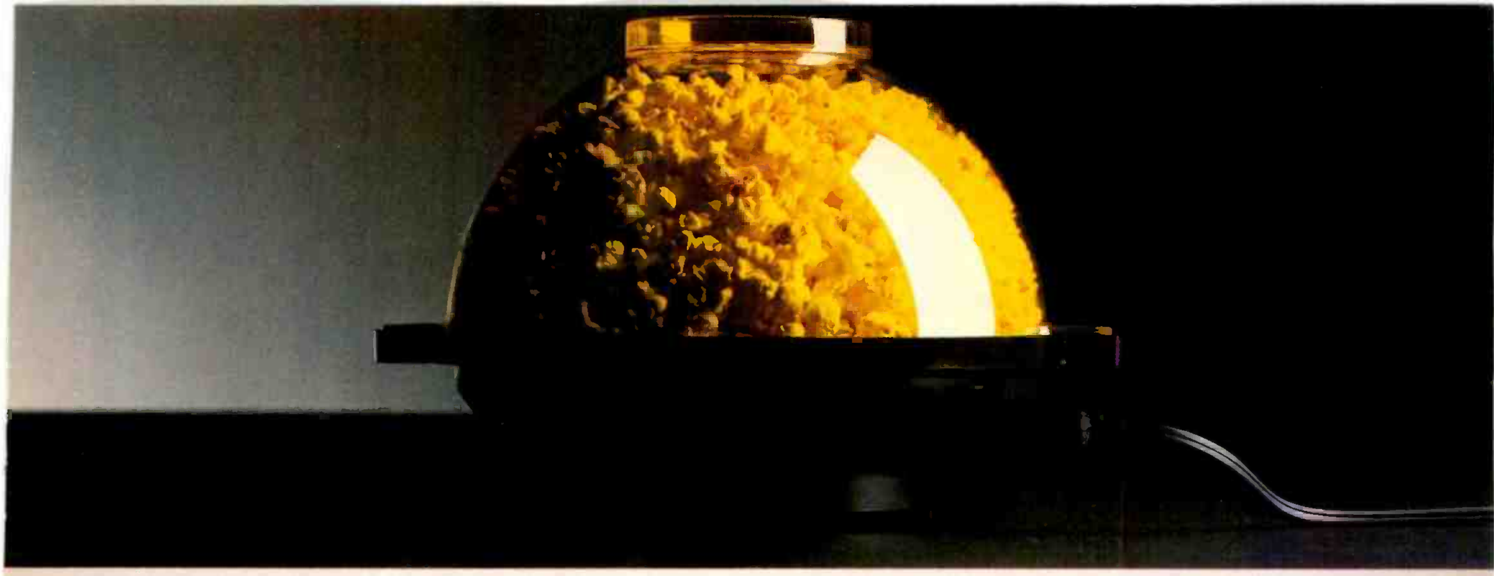
Zubin Mehta and the New York Philharmonic are in good form in what is certainly Richard Strauss' most monumental tone poem. Mehta provides a powerful, well-paced performance that may not be as insightful as that of von Karajan, but it has an exciting, propulsive energy. The battle scene is particularly well done, highly dramatic, seething with tension. Notable, too, is the splendid playing of the New York Philharmonic.

The multi-miked sound has massive sonority; the opening chords on the contrabassi are just wonderful. Unfortunately, there is spotlighting of some instruments and an edginess to the high strings, although not as pronounced as in other CBS recordings. The important solo violin part is beautifully performed by concertmaster Glen Dicterow, and it is cleanly recorded. Particularly notable is the sound in the dense, complex scoring in the battle scene. This is the most highly detailed, most revealing sound I have ever heard in this difficult section. Here again, the digital recording, with its lack of noise, is of great aid in the delineation of the pianissimo sections, especially during the long solo violin part. It goes without saying that the great dynamic contrasts in *Ein Heldenleben* benefit greatly from the CD's availability of 90 dB of dynamic range.

Bert Whyte

Mozart: Violin Concertos Nos. 3 & 5. The St. Paul Chamber Orchestra, Pinchas Zukerman.
CBS MK 37290.

Pinchas Zukerman is one of the most highly regarded of the younger violin virtuosos. In this recording, he assumes the role of conductor as well. In both cases, his performance is excel-



PERHAPS THE ONLY PIECE OF HOME ENTERTAINMENT EQUIPMENT THAT CAN'T BE CONTROLLED BY THE SX-V90 RECEIVER.

One look at the diagram to the right should convince you that the SX-V90 audio receiver isn't merely an audio receiver.

In fact, it might just be the most revolutionary piece of equipment in the entire home entertainment revolution.

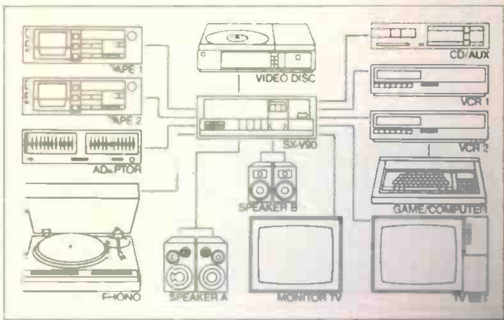
Because it serves as a control center for more pieces of audio and video equipment than any other competitive product of its type.

Through the SX-V90, you can channel two VCRs (of any format), one TV monitor, one regular TV, one video disc, one compact disc, two cassette decks, two turntables, and one video game or one computer.

But not only does the SX-V90 have the best connections in the business, it also has ingenuity. Because as well as reproducing video sourced signals (such as MTV), it creates simulated-stereo imaging from any mono signal (such as regular TV).

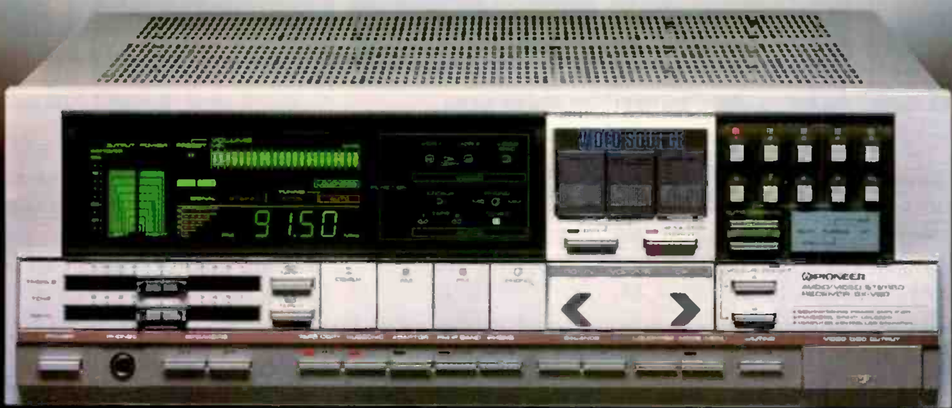
In short, it turns your television into a stereo.

As for the quality of the stereo, with its advanced DDD tuner technology, and 125 watts of power per channel minimum (at 8 ohms, from 20-20,000 Hz with no more than 0.005% THD), the SX-V90 ranks at the top of audio receivers.



Which is a very important point.

Because there's no sense in investing in a control center, only to have it sound like it has a built-in popcorn popper.



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Because the music matters.

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The Kroumata Percussion Ensemble plays the Swedish pieces brilliantly, and the CD shines where the LP never could.


The Kroumata Percussion Ensemble

lent, a finely wrought, sensitive and expressive traversal of these two great violin concertos composed by Mozart when he was 19. The playing of the St. Paul Chamber Orchestra is very good indeed and clearly illustrates why this is one of the premier chamber orchestras in this country.

Unfortunately, the sound quality here negates all the performance values. The violin/orchestral balance is nicely handled in both concertos, even though they were recorded in different halls. However, once again, upper strings are thin and wiry. Mr. Zukerman's violin does not seem to have much resonance, to the point of sounding like some of the harmonic structure is missing. The fairly close-up perspective also emphasizes what can only be described as a glassy tone. It is hard to understand these sonic anomalies, because apparently the main microphone complement was the excellent and normally quite smooth AKG 414EB and C-12. Perhaps it is equalization or the electronics of the input console. I am sure the anti-digital types will point an accusing finger at the digital recorders. The Mitsubishi, Sony, and 3M recorders were used, and it has been rather well documented that excellent digital recordings can be made on all of these machines.

Bert Whyte

Music of Cage, Cowell, Lundquist, and Taira. The Kroumata Percussion Ensemble.
BIS CD-232, $18.98. (Available through Qualitone Imports, 39-28 Crescent St., Long Island City, N.Y. 11101.)

BIS is a very important Swedish label whose catalog must number somewhere around 200. Much of the music is indigenous to Sweden, and the performers are largely unknown in this country. To those of us who have witnessed the passing of the entrepreneurial spirit in American classical-recording production, the success of this small label stands out as something to be admired.

The Swedish Kroumata Percussion Ensemble plays these works brilliantly, and the CD shines where the LP never could. Quiet passages are just that, and loud sounds emerge out of utter silence the way they are supposed to.

This music will certainly not be to everyone's taste, but if you are interested in hearing the full dynamic range that can be contained on a CD, then get this one.

John M. Eargle

"A Feast of Sonic Splendors..."

— Hans Fantel, Ovation

TELARC DIGITAL

TELARC CD-80090, DG-10090

TELARC CD-80091, DG-10091

TELARC CD-80092
(2 LP set available Fall '84)

TELARC CD-80094, DG-10094

TELARC CD-80099

- First in a series of history-making recordings with The Cleveland Orchestra's new Maestro, Christoph von Dohnányi. "...first-class interpretations ...presented in glowing color and impressive vitality..." *(Washington Post)*
- Brahms' most personal vocal expression from the acknowledged choral master of our time. 70 minutes...complete on one CD.
- A *new* test for your stereo rig that's out of this world! The opening moments of *Star Tracks* should be approached with caution.
- Just in time, the famous "Olympic Fanfare", British Band Classics and seven stirring marches, including the *Stars and Stripes*.

All Telarc Compact Discs & Records are produced from Digital Masters

CD designates Telarc Digital Compact Discs • DG designates Telarc Digital Records

Distributed in Canada by Audio Market Sales, Milton, Ontario

Enter No. 37 on Reader Service Card

Telarc's recording of "Resurrection" is sonically stunning, certainly the best ever of Mahler's symphony.

Ravel: Bolero, La Valse, Pavane, Daphnis et Chloé. Orchestre de Paris, Daniel Barenboim.
Deutsche Grammophon 400 061-2.

Barenboim furnishes idiomatic performances of these Ravel chestnuts, embellished with good playing from the Orchestre de Paris. The multi-microphone recording sonically crosses every "t" and dots every "i." Unfortunately, this makes the music rather bereft of any sense of atmosphere, and the by-now-infamous DGG upper string sound is as wiry and strident as ever.

Bert Whyte

Mahler: Symphony No. 2, "Resurrection." The St. Louis Symphony & Chorus, Leonard Slatkin; Kathleen Battle, soprano; Maureen Forrester, contralto.
Telarc CD-80081 & CD-80082, two-disc set.

Jack Renner, Telarc's recording engineer, has made many splendid recordings, but surely this new one of Mahler's Second Symphony is his crowning achievement. Sonically, the recording is simply stunning, certainly the best ever of this symphony and a formidable musical achievement as well.

Leonard Slatkin's performance may not be on the inspirational level of a Bruno Walter or Otto Klemperer, but it is a very fine, heartfelt and deeply expressive reading—obviously a labor of love. His St. Louis Symphony Orchestra and Chorus give him playing of very high order, both in precision of ensemble and in richness of tonal resources. Soprano Kathleen Battle and famed contralto Maureen Forrester sing like angels in their important parts.

In this work of violently contrasting dynamics, Slatkin, aided by Jack Renner's engineering, explores the outer regions of dynamic expression. This is what digital recording is all about, what 90 dB of dynamic range means. In the gigantic finale, just after the distant off-stage horn and trumpet fanfares have completely decayed, the chorus enters at an ultra-pianissimo level. Their sound is at the threshold of hearing, just above the noise floor of your listening room. Set your volume control at this point, and you better have a big amplifier and bulletproof speakers on hand. The orchestral/choral sound levels become higher and ever higher, culminating in a stupendous outpouring of full orchestra with massive brass fanfares, full-throated chorus, orchestral bells and organ. It is positively cataclysmic, leaving you limp and emotionally spent!

Jack Renner achieves an ideal balance between hall reverberation and orchestral detail. I could go on and on about this *Resurrection*, but only by listening to this masterpiece will you understand the splendor of the sound. For Mahlerites, it is simply a must.

Bert Whyte

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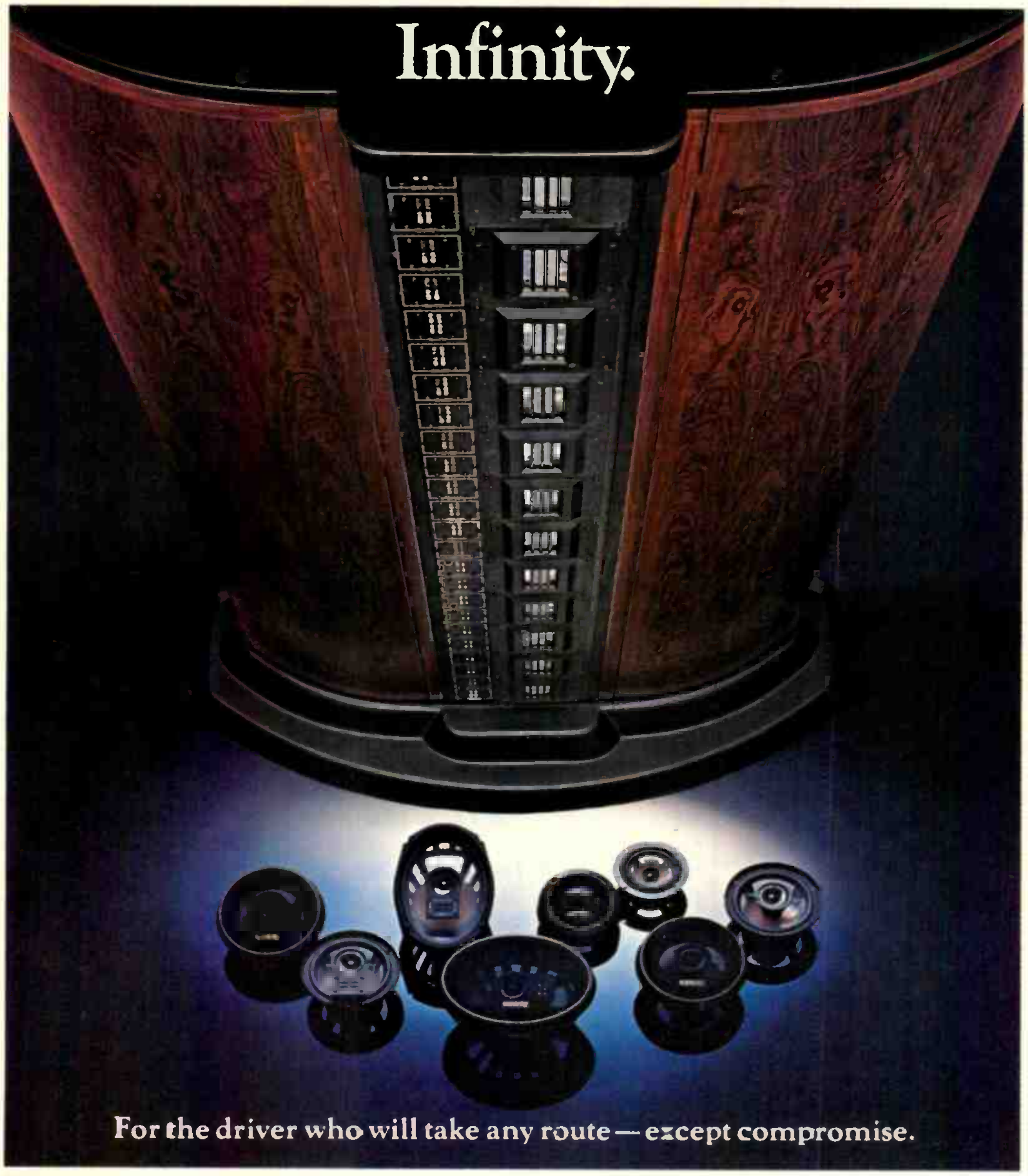

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Enter No. 41 on Reader Service Card

MICHAEL TEARSON
JON & SALLY TIVEN

OVER THE WALL

David Gilmour *Roger Waters*

The Pros and Cons of Hitch Hiking: Roger Waters
Columbia FC 39290.

Sound: C+ Performance: B

About Face: David Gilmour
Columbia FC 39296.

Sound: C+ Performance: B+

By all appearances (or lack thereof) Pink Floyd seems to have officially disbanded. Two of the three remaining members have released solo projects barely a month apart.

Roger Waters' album is a direct descendant of Pink Floyd's magnum opus, that double album, *The Wall*. To emphasize the point, Waters uses *Wall*-style lettering on the album's cover. His coproducer, Michael Kamen, helped arrange the orchestra for *The Wall*. Musical themes recur, too, notably the melodies from "Mother" and "Outside the Wall."

Pros and Cons is definitely a conceptual piece, as each side is a musical whole, one song blending seamlessly into the next, the individuals subordinate to the whole. It is also a journal in real time. Each song bears two titles, the actual song title and a time. The album is timed sequentially, in approximate real time, from 4:30 to 5:11 a.m.

What it is about, on the surface anyway, is traveling by car—be it by driving or hitching. It is a bleak tableau, but we must expect that from Roger Waters, who's written nearly all of Pink Floyd's material from *Dark Side of the Moon* on. He has embedded in the record sound effects and spoken bits by "The Actors," again using the Zuccarelli Labs holophonics process first introduced on last year's Pink Floyd album, *The Final Cut*. And again, this process adds depth and strength to the voices and effects. The recording has a lustrous richness and smoothness very much in the Floyd tradition of audio excellence. For those of us who for years have perceived Roger Waters as Pink Floyd, the new album is additional proof.

Guitarist David Gilmour has made a far more conventional album of songs not necessarily bound by a concept. And a sprightly collection it is.

The support players perform with class, great spirit and, when the occasion demands, high energy never required of Gilmour in Floyd. Bob Ezrin is coproducer with Gilmour, and his contribution is invaluable. With past credits including Alice Cooper's best work and Peter Gabriel's first solo album—not to mention *The Wall*—Ezrin is a prime exponent of what I call Grand Gesture music: Stuff with big, sweeping cinematic scope. Gilmour effectively reaches for that here, on pieces like the mournful "Out of the Blue" and the wryly named instrumental, "Let's Get Metaphysical." He is equally effective on high-energy rockers, such as "Blue Light" and "All Lovers Are Deranged." "Murder," set in delicate 6/8 time, seems to have been inspired by the anger unleashed in the aftermath of John Lennon's assassination. The two were friends, and the story fits. Perhaps that rage explains the otherwise inexplicable tempo shift just over a minute before the song's end, an uncomfortable shift that frustrates, just like the feelings Gilmour is addressing here. Another delicate song, "Cruise," is a riddle: Is it a love song or a protest song about a guided missile? I should note here that two songs, "All Lovers Are Deranged" and the wistful "Love on the Air," are collaborations of Peter Townshend lyrics and Gilmour music.

David Gilmour's frustration within the grand boundaries of Pink Floyd has been something of an open secret for years. This is, after all, his second solo album, coming about five years after the first. Additionally, David is out touring to support the release. A man's got to do his work. *About Face* (apt name, that, and on several levels) is one excellent album. I can feel David Gilmour's pride in it. *Michael Tearson*

Lament: Ultravox
Chrysalis FV 41459, $8.98.

Sound: B− Performance: B−

Ultravox was one of the first self-contained synthpop bands—not that they have any exclusive rights to the territory, but, if nothing else, they *were* original. The band has forged a sound both unique and immediately recognizable, and in doing so many other bands (notably Duran Duran and Flock of Seagulls) have followed Ultravox's lead and taken a step further: Sold records in America. However, Ultravox has yet to find its way to mass adulation and is still a cultish unit.

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"THE COMPETITION IS GOOD. WE HAD TO BE BETTER."*

Lee A. Iacocca

Reckoning is a nervy and strong album which draws me into it as an active participant.


R.E.M.

To an extent, the band has stagnated. They've become so incredibly adept at the production side of their music that they can synthetically soup up any mediocre song into an incredible-sounding extravaganza. This is the failing of *Lament*, which is more of a sonic statement than a musical one. Their "Soundtrack for the Apocalypse" musical signature makes for a richly colored tableau, but it lacks the fire to distinguish itself. Midge Ure is a talented singer/songwriter, but he was more effective in Rich Kids, where he had an equally talented foil (Glen Matlock) off whom to bounce his ideas.

Ultravox has painted itself into a corner. What they should do is get Alan Parsons to produce so that they can become New Music's Pink Floyd. A little bit of focus and the members of Ultravox could be the new psychedelic kings of background music. As is, they're just a bit too tedious to emerge from their well-woven sonic tapestries.

Jon & Sally Tiven

Reckoning: R.E.M.
IRS SP-70004, $8.98.

Sound: D Performance: B+

The resounding critical acclaim and middling popular success of *Murmur*, R.E.M.'s 1983 album debut, begs the question of just what it is that makes a band the darling of critics but not the sweetheart of the masses.

The R.E.M. sound appears to be an '80s update of the '60s airflow sound, as epitomized by The Byrds' "Eight Miles High." But it is made denser, with jangling guitars and impenetrable lyrics which sound as if they would mean a lot if you could only make them out. When you *can* get through to the words, you find fascinating ellipses of flashing image that suggest far more than they say. Plus, the album graphics make nothing simple; the rectangle of album credits on the inner sleeve is scrawled in no real order, and, naturally, there is no lyric sheet provided.

It all adds up to a band that critics can applaud for making them feel literate. And I must point up that I am not immune, for, as regular *Audio* readers might recall, I reviewed *Murmur* and *Chronic Town* most favorably in these pages. And I like *Reckoning* a lot, too. I don't see it as album-of-the-year material, but it is nervy and strong. R.E.M. still makes nothing easy, but I find that this draws me into their albums as an active participant.

The band's confidence has grown perceptively from *Murmur* to *Reckoning*. Now you can hear the words much of the time, especially on the tender ballad "Camera," the folky "Don't Go Back to Rockville," and the bitchy "Pretty Persuasion." The words still don't make a lot of surface sense, but they succeed in evoking the emotions as clearly as needed. At other times, the lyrics can be maddeningly dense. The chorus of "Harborcoat" is the peak of density, when each of the four band members sings a different part simultaneously.

The instruments, especially the guitars, give real texture to the sound. The obscurity of the lyrics is by design and intent, not by accident. This alone will probably be enough to keep R.E.M. from ever gracing the cover of *People* or from selling in the millions, but it also makes them a group which truly challenges the listener to take part, something few groups really try to do—for that route is more difficult and dangerous. I doubt R.E.M. would have it any other way.

Michael Tearson

Keep Your Hands Off My Power Supply: Slade
Epic FZ 39336.

Sound: B+ Performance: A−

Slade was the brightest hope of the British Glamrock Brigade of 1972, but being stuck on a duff label quashed its hopes for American success. Now that fashion is back in fashion, Slade resembles more the proletariat rock band than the glitzy group of clowns it formerly was (Dave Hill even hides his grin behind a beard), and its music is streamlined, metallic bash. But there's no hiding the uncompromising talent that the Noddy Holder/Jim Lea songwriting team always wore on its sleeve, and *Keep Your Hands Off My Power Supply* (on a new record label) could well be the album that brings Slade the Stateside chart position it has always missed.

It doesn't hurt that "Cum on Feel the Noise" (as performed by headbangers Quiet Riot) sold a couple of million discs last year, making a new (and younger) audience at least partially aware of Slade. But this record is as relentless as any Slade album in memory. Side one, in particular, is simply stacked with the goods. Every song is


Slade

Costello's albums sound more like product and less like art. He is currently in what is known as a "bad phase."

a killer, and could be a hit for any one of a zillion Anglophilic rockers looking for a chart entry (hear that, Joan Jett?), but Slade's versions are powerful and believable. Jim Lea's production brings out the full force of Noddy's mighty pipes, and seems tailored for the metal marketplace.

Those unfamiliar with the group's style should expect the heaviest pop band in the world and/or the most tuneful metal outfit ever heard. And Slade has a sense of humor. Greatness such as this can lie undiscovered only so long. *Jon & Sally Tiven*


Elvis Costello

Goodbye Cruel World: Elvis Costello
Columbia FC 39429.

Sound: C+ Performance: B–

Elvis Costello's very nature lends itself well to change; it seems that each of his records strives for a different sound. The only strands of continuity are his voice and songs; Costello's arrangements, genre and musical style change drastically from album to album. Until now, that is. *Goodbye Cruel World* seems very much like a reprise of his last album, and, although it's slightly better, it may be E.C. is in a rut. His songs appear more formulated than inspired, his pseudo-R&B more contrived than enthused. He even resorts to a would-be duet with Daryl Hall (of you-know-who & Oates), but his guest star is barely audible.

This is not to denigrate Costello's innate talent, but he is currently in what is generally known as a "bad phase." The albums he offers sound more like product and less like art, and the reason for this may be that Elvis has yet to be a viable force in the American record market. It's almost time for him to have a couple of hits (just one would be nice) or else turn into last year's news. Even though Costello's closest counterpart, Bob Dylan, does not sell mega-units, he had a few hits in the mid-'60s that established him as more than just another great songwriter. Elvis is thought of by the masses of record buyers as (a) that little punk, (b) the funny-looking Buddy Holly imitator who writes songs for Linda Rondstadt, or (c) the snotty little Englishman who had the bad taste to make racist remarks about Ray Charles.

Given records like this, and his Ray Charles remarks, Elvis may be getting exactly what he deserves. You can't expect people with intelligence and memories to forgive everything. Or maybe he should make a rock 'n' roll record. *Jon & Sally Tiven*

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EDWARD TATNALL CANBY

SILENCES AND SIZZLES

Richard Toensing

Richard Toensing: New Music for Piano and Organ. Peter Takács, piano; David Shuler, organ; John Galm, percussion.
Owl 27, $8.98. (Owl Recording, P.O. Box 4536, Boulder, Colo. 80306.)

Records like this one, it seems to me, should be of great interest to audio listeners. Why? On many fronts, only one of which is pure, musical content. Let's begin simply: This is the quietest LP surface I have yet to hear—at least on side one, the piano-solo variations. In the numerous quiet parts of the music, there is no sound, no turning-of-the-table; it is as though the turntable had stopped. One could call it the CD effect—but on LP. Is this significant, out of a very small and highly music-oriented record label? Contemporary music, at that! (On side two, the natural ambience of a church, like the sea in the proverbial conch shell, is the noise that we hear behind the organ and percussion.)

Hi-fi? This isn't digital, it seems, but it is extraordinary sound even so. My own home system still can take Tchaikovsky and Brahms and Stravinsky, but it broke up, helplessly, under these sonic lashings of incredibly sizzling cymbals, violently percussive drums, the positive screech of high-powered, high-register organ notes, drilling holes in your ears. A hi-fi "test" record? But yes! Uniquely so. (And the piano, too, strains everything you have.) Also, a remarkable, if perilous, balance between a battery of percussion instruments and a battery of organ sounds—just two men, controlling a huge "orchestra" of effect, done with, shall I say, cruel finesse from the recording viewpoint! A recording to command respect, given the incredible high-power sonic material.

And the music. *Is it music*? Who cares? Music is merely a word, used to cover a lot of sound and new sounds all the time. Edgard Varèse, way back, had the right impartial term for this kind of stuff: "Organized sound." That fits Mozart, too. In any case, Richard Toensing is a super-high-voltage contemporary composer whose musical language is pile-driver-strong and laser-sharp. By no coincidence, he happens to be a university prof in charge of an electronic lab in the music department, though these recorded works are "live," produced by conventional musico-mechanical means.

Does he live in the same world as ours in audio? Of course! So Carver puts out a 201/201-watt stereo amp in a little box a few inches on a side, and Toensing puts out an ear-tingling piece for vast organ and whole battery of percussion produced by only two sets of powered arms and feet. You see the drift of my thinking. The *music itself*, on this disc, goes right along with everything else that is of this modern age. Can you afford to be bored by it? Not if you have any curiosity as to what's going on in audio these days.

Side one, piano, is more for the musicians among us, though at the beginning—such is piano progress!—I thought I was hearing a taped synthetic reverb. It is densely built around a hearable sequence of a dozen *extremely* dissonant chords, a sort of chaconne variation form. Side two is for the hi-fi enthusiasts among us—such a novel use of the big, modern pipe organ as a source of short, violent, percussive blasts and peeps and honks, surrounded by long, quiet sustained tones. To their credit, a number of organists have taken up this music for public performance. It'll shock, all right, but what interesting sounds!

When the percussion is added (the last piece) the impact is magical. A potent ending. But when it is all over, note that on side one, via reverberating piano strings, Toensing used a device that Schumann used almost 150 years ago. And by combining percussion and organ he echoes a well-known work by Saint-Saëns, that Organ Symphony that everybody plays. Good composer—of organized sound—this man Toensing.

Zoltán Kodály: Missa Brevis, Te Deum. Budapest Symphony, Árpád Joó; Hungarian Radio Chorus, soloists. **Sefel SEFD 5011,** digital, $15.98.

This is another in the deluxe, super-series of Hungarian-based recordings (Sony digital, Sony-plus-Soundstream processing) that comes out of Canada's golden boom town, Calgary, Alberta. (A recent *National Geographic* mentions this label as part of Calgary's great surge of culture.) Boom town or no, the music is all-Hungarian, both in composition and performance. Maestro Joó, an earnest young man with brown hair and a black, tailored beard, is Hungarian by birth but studied in this country. And, by no coincidence, he is

Zoltan Kodály

Kodaly's "Missa Brevis" is on the most enormous scale and goes on and on and on, chorus, four soloists and vast orchestra.

the maestro of the Calgary Philharmonic. Shades of Texas!

Big, fat, long music for large orchestra and chorus here, ever so definitely post-Romantic, though of relatively recent composition, post-WW II. Hungary's two famed musical leaders, Bartók and Kodály, are actually very different: Bartók, the inward-turning, reticent, shy personality with the force of a hurricane inside—and in so much of his music; Kodály, a more benign, peaceful, outgoing personality whose music is much revered but far more easygoing than anything by Bartók. You'll enjoy it, until maybe its sheer length and verbosity bore you. It did that to me.

"Missa Brevis"—"short Mass"? I had to laugh. It is on the most enormous scale and goes on and on and on, chorus, four soloists, vast orchestra, like the Beethoven Ninth but 10 times looser. All very friendly and direct, if mildly modern. The similar-sounding "Te Deum" lasts a mere 20 minutes. I have one by Henry Purcell of England that lasts maybe three minutes—but says plenty.

Árpád Joó, by the way, is a first-rate, young conductor, in this and in his numerous Bartók recordings for Sefel. If he can make the Calgary performers operate as well as these Hungarians, you'd better plan your next music festival expedition for Alberta, Canada.

Løgumkloster. Peter Langberg, klokkespil and orgel; Kirsten Kolling Langberg, orgel.
Paula #6. (Available from Editions Orphée, P.O. Box 364, Prudential Center Boston, Mass. 02199.)

We've suddenly been receiving a batch of Danish imports, all in virgin Danish dress; this was the first I tried.

The first side is the *klokkespil*, not unrelated to the German glockenspiel, actually an outdoor carillon of bells, as depicted on the cover. This is a weird one, set on its own mod tower, a sort of squat Eiffel shape with halfway balcony and a hideously hanging staircase in space spiralling up to it—nobody would get *me* up those stairs. The music is, well, carillon music. I found it unusual but dull on the whole. That labored, heavyweight approximation of "real" indoor musical harmonies, replete with varied clunks and clanks and overlapping bell-type overtones which, of course, clash with the intended harmonies like crazy. Never did like carillons much. If you do, try.

The second side features organ music, played by both performers, two hands, two feet and four hands, four feet. The old music isn't much; the organ is not suited to it and the performance is not very knowledgeable. Skip it. The recent music by Gade (Danish, of course) and Langlais, is better of its kind, but it isn't for everybody. Lovely Danish-English in the notes. "He godt a campagnologist diploma"—a bell-ringer's degree.

Audio? Perfectly adequate, nothing spectacular.


BEATLES

If it weren't for the work of two Army Signal Corpsmen, Mullin and Orr, we might still be recording on steel wire.

MAGNETIC RECORDING

Continued from page 33

just about everything, from field use by military commanders and journalists to high-fidelity broadcast use. At the same time, the U.S. and Allied commands made do with wire recorders.

We might still be recording on wire if it weren't for the work of two Army Signal Corpsmen, John T. Mullin and John Herbert Orr. The fall of 1945 found Mullin in occupied Germany, part of a team looking for anything of electronic interest left behind by the defeated German army. One day, while he was checking out an antenna site north of Frankfurt, he met a British officer on a similar mission.

"Have you heard the tape recorder they have down at Radio Frankfurt?" the officer asked. Mullin had heard German tape recorders before—lots of them, abandoned in the field by retreating troops and correspondents—and he had been unimpressed by their sound quality.

Still, it was a glorious day for a drive, the afternoon was still young and Mullin had nothing else scheduled, so he set off for Bad Nauheim, where Radio Frankfurt actually was located. The station was being operated by the American Armed Forces Radio Service, but the technicians were predominantly German. When the officer in charge learned what he wanted, Mullin recalls, "He summoned an assistant, who clicked his heels and ran back into a room and came out with a roll of tape and put it on the machine. That's when I really flipped, because I had never heard anything like that. To my knowledge, there had never been anything like that in recording before. You couldn't tell whether it was live or playback; there was no background noise. I was thrilled."

So thrilled was Mullin that, after he had rounded up the two working Magnetophons required by the Signal Corps, he managed to find two more for himself. These he disassembled into parts small enough to be shipped home to his mother. "My biggest problem was getting the case into a mailbag. You couldn't send anything that wouldn't fit in a mailbag, and, of course, the case had to enclose everything else." Nonetheless, he did it, mailing back 35 packages in all, including some recording tape. After his discharge and return home, Mullin began reassembling his machines.

Meanwhile, another Signal Corpsman, Major John Herbert Orr, had been assigned the task of getting BASF's tape manufacturing plant at Wald Mittelbach back in operation as quickly as possible. There, he worked with Dr. Karl Pflaumer, a chemist who was responsible for the oxides BASF had been using to coat tapes all during the war, and the two developed a close personal relationship.

Toward the end of his tour of duty, Orr was involved in an automobile accident which put him in the base hospital. While recuperating there, as he told it later, he was attended by an Irish nurse who helped him pass the time. In appreciation, he was later to name the company he established to manufacture tape in the U.S. after her—Irish Tape. When Orr finally was discharged from the hospital and headed homeward, Dr. Pflaumer gave him a going-away present, a brown paper bag. Inside the bag was the iron-oxide formulation BASF had been using to make its tape. Back home, Orr bought himself an abandoned prisoner-of-war camp on the outskirts of his home town of Opelika, Ala., and turned it into a tape factory.

The regular meeting of the San Francisco chapter of the Institute of Radio Engineers was scheduled for May 16, 1946, at the NBC studios. The featured speaker was John T. Mullin, who would talk about and demonstrate the two tape recorders he'd been using to do studio sound recording for several months. Among those jammed into the studio audience was Harold Lindsay, who would later join a small company named Ampex (which had been making precision motors for the Navy). Lindsay told Ampex founder Alexander M. Poniatoff what he had seen. Sometime later, Murdo MacKenzie, Technical Director of Bing Crosby Enterprises, also heard about the Magnetophon and asked Mullin to repeat the demonstration for him.

MacKenzie realized at once that Mullin's tape recorders were the solution to a serious problem: "The Bing Crosby Show" was the only major network radio program not broadcast live.

Mullin's tape recorders were the solutions to a serious problem, editing the Crosby Radio Show down to the proper time.

Crosby preferred to record his show in advance, using 16-inch transcription discs for the purpose. To edit out fluffs and to cut programs (which frequently ran overtime) down to size, Crosby's engineers dubbed from one disc to another, with a resulting loss in sound quality with each transfer. Since some transfers were made three or four times, the final version didn't always sound very good.

At the end of the demonstration, MacKenzie asked Mullin to bring his machines back two months later to record and edit the first show of the season, a kind of dry run. It went so well that the network (ABC) dubbed Mullin's edited tape onto transcriptions for broadcast, and he undertook the job of taping shows for the rest of the season. Meanwhile, Ampex's Lindsay had taken careful measurements of Mullin's Magnetophons, and Ampex engineers were busy designing their own recorder, based on them. Mullin's machines stayed in use until Program 27, when the first Ampex recorders showed up and 3M's Scotch recording tape arrived to replace Mullin's original German-made tape.

"All I had was the original 50 rolls of tape I'd brought with me from Germany," Mullin recalls. "I didn't dare throw anything away when I edited, because I didn't know where I could get any more. So after every show, I'd go through and take the tape apart, splicing all the little bits together so that I could use them over again." By the time the first American-made tape arrived, he continues, there were more splices than tape in the original rolls.

BASF's early tapes had used magnetite, a black powder of ferric-ferrous oxide. By the end of 1936, magnetite had given way to gamma ferric oxide, a brownish powder, which formed the basis for virtually all American recording tapes from the introduction of Scotch 111, by 3M, in the late 1940s until the introduction of chromium dioxide in 1969. Unlike the 1980s, when hardly a week seems to go by without the announcement of some dramatic improvement in tape and particle technology, the 1950s and 1960s were stable times, an era when Scotch 111 could remain the standard to which all other tapes were compared for a full 20 years.

Photo Captions and Credits

Page 27, Telegraphone by American Telegraphone, Springfield, Mass., from the author's collection.

Pages 28 & 29, clockwise from top, Poulsen Telegraphone with steel wire on reels (photo by C. G. Nijsen, Philips International, in "—And the Music Went Round and Round . . ., Part 2," *JAES*, April 1984); Dailygraph c. 1920 and Telegraphone from the collection of Prof. Harold Layer, San Francisco State Univ.; transmitting equipment at the Sayville, N.Y. station; Valdemar Poulsen, inventor of the Telegraphone, and Charles D. Rood with neighborhood children, c. 1906. Props: Lamp, Guinevere Antiques, N.Y.C.; desk set, Niccolini Antiques, N.Y.C.

Pages 30 & 31, counterclockwise from top, AEG Magnetophon in J. Herbert Orr's collection (photo by Donna Foster Roizen); a sample of BASF's first trial of tape production in 1932 (photo from BASF); Lorentz-Stille steel tape recorder, c. 1933, now on display in Swiss Broadcasting's Basel studio, holds 3,000 meters of steel tape for 30 minutes playing time at 1½ meters/second, viewer is C. G. Nijsen (photo from Nijsen/*JAES*); AEG "portable" Magnetophon which weighed over 100 pounds and included recording module, amp, speaker, and mike (photo from BASF), and page from the manual for the K4 Magnetophon, c. 1940 (photo from BASF).

Page 32, from top, the London Symphony Orchestra, led by Sir Thomas Beecham, on Nov. 19, 1936, played the first concert ever to be recorded on tape (photo from BASF); Bing Crosby first used tape in 1947 as the basis for syndication of his radio program; Charles E. Apgar unravelled the high-speed radio code transmissions from Sayville, N.Y.; the Emperor Franz Josef was very interested in Poulsen's Telegraphone at the Paris Exposition of 1900, and John Mullin with Murdo MacKenzie, who was Bing Crosby's technical producer. Props: Mood Indigo, N.Y.C.

Part II of "History of Magnetic Recording" will appear in the September issue.

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Integrated 2-way 6" / Dome Tweeter (Adapted for bi-amp)

Power Handling Capacity	100 Watts RMS
Frequency Response	45-25000 Hz
Woofer Type	6" Dia. 3" Aluminum voice coil
Tweeter Type	Soft dome, Aluminum voice coil
Ferrofluid Cooling/Damping	Yes
Impedance	4 ohms
Sensitivity 1W/1M	91 db
Magnetic Structure Weight	2.3 lbs./1.05 Kgs.
Dimensions	160mm/6¼" Dia. 67mm/2⅝" Depth
Mounting Depth	53mm/2⅛"
Net Weight	2.85 lbs./1.3 Kgs.
Front Grill	Integral metal grill

INTEGRA-2
Integrated 2-way 8" / Dome Tweeter (Adapted for bi-amp)

Power Handling Capacity	120 Watts RMS
Frequency Response	35-25000 Hz
Woofer Type	8" Dia. 3" Aluminum voice coil
Tweeter Type	Soft dome, Aluminum voice coil
Ferrofluid Cooling/Damping	Yes
Impedance	4 ohms
Sensitivity 1W/1M	92 db
Magnetic Structure Weight	2.3 lbs./1.05 Kgs.
Dimensions	220mm/8⅝" Dia. 75mm/3" Depth
Mounting Depth	57mm/2¼"
Net Weight	3.3 lbs./1.5 Kgs.
Front Grill	Integral metal grill

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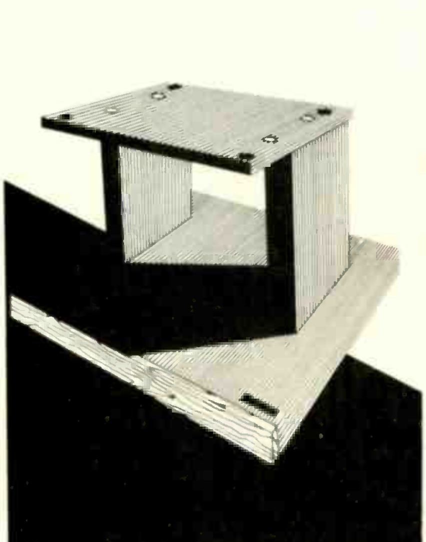

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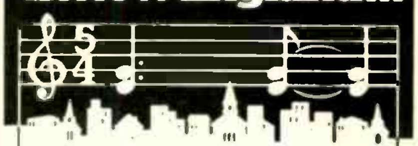

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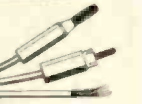

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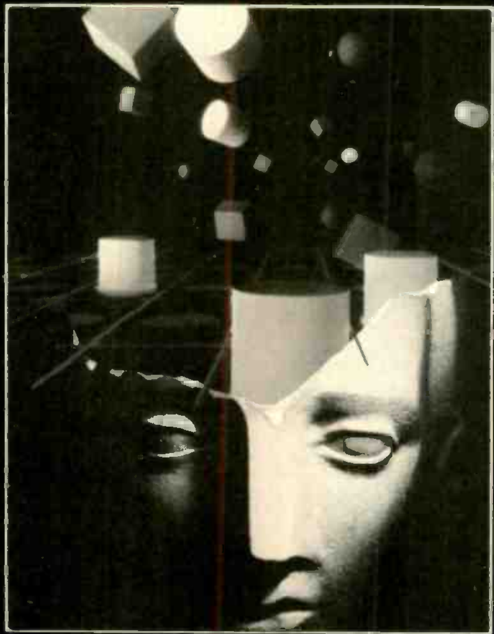

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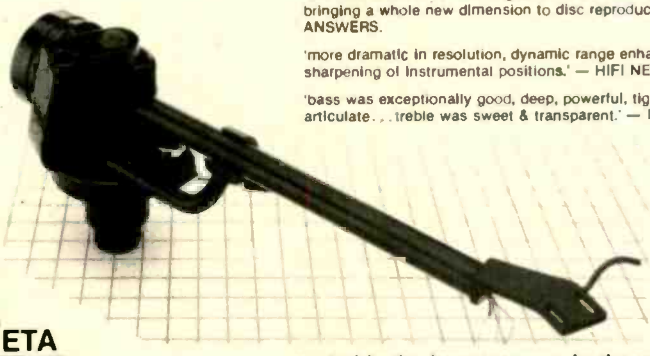

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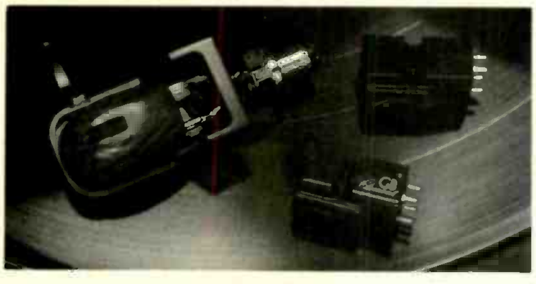

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