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versus Beta and vice versa. That's because each format has its respective strengths.

While VHS decks play longer, which saves tape costs; Beta cassettes are smaller and more portable, making possible home video equipment such as the integrated NEC Video Camera/Recorder BetaMovie.

THE NEC BM-11EU BETAMOVIE. *NEC put it all together with an integrated Color Video Camera/Video Cassette Recorder that only weighs 5.5 lbs. including its battery.*

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JUNE 1984 VOL. 68, NO. 6

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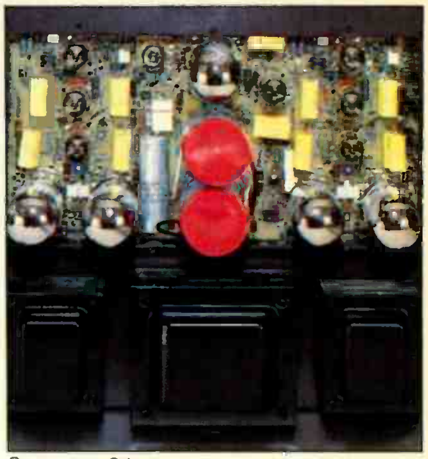

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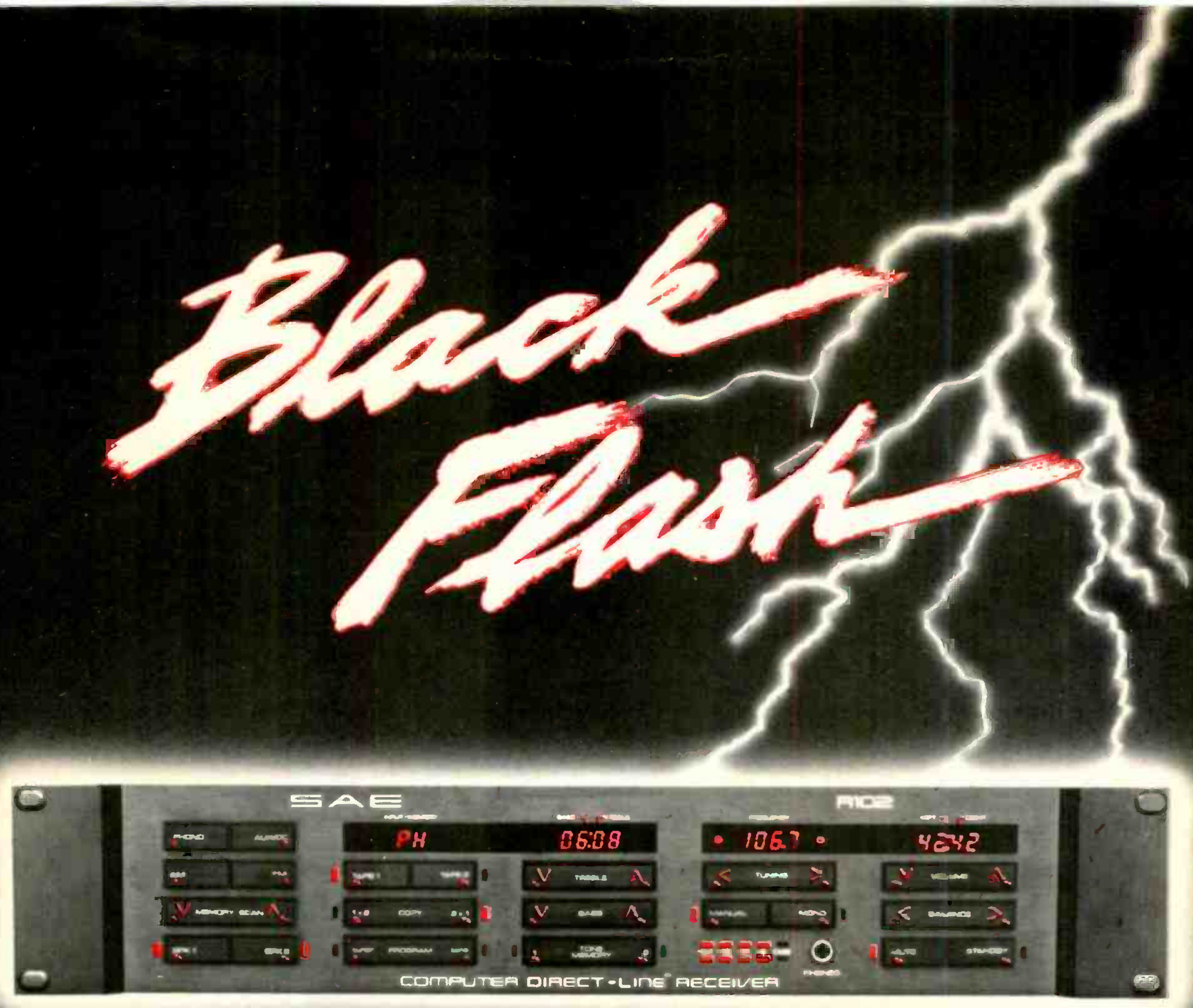

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TAPE GUIDE

HERMAN BURSTEIN

Playback Equalization

Q. My cassette deck has a four-position equalization switch: 70 µS for Type II and IV tapes, 120 µS for Types I and III. What is the difference between these settings? What frequencies do 70 and 120 µS use equally? And what is the equation for converting microseconds to Hz?—Ray Segura, Jefferson, La.

A. With 120-µS equalization (used only for Type I ferric oxide tapes), playback bass boost starts (up 3 dB) at 1,326 Hz; with 70-µS equalization (used for all other tape types), it's up 3 dB at 2,274 Hz.

To convert turnover frequency in microseconds to Hz, divide 159,155 by the number of microseconds. Thus, for 70 µS, we have: 159,155 divided by 70, or 2,274 Hz. To convert turnover frequency in Hz to microseconds, divide 159,155 by the frequency. For 2,274 Hz, we thus have: 159,155 divided by 2,274, or 70 µS.

Tape Saturation

Q. I have a problem when recording with Dolby C but not with Dolby B. When I record live material from radio or phono records, the music always saturates the tape; the result is scratchy and blurred sound. I keep the recording level at the point suggested by the instruction book and have also tried lowering the level. Should live material be recorded with Dolby B instead of Dolby C? Any help would be appreciated.—Douglas Brenner, Douglaston, N.Y.

A. First, let me point out that "live" material, as you call it (truly live material would be the music source itself, not a radio station or phono record), tends to contain sharp transients which challenge the capability of the tape system with respect to tape saturation.

I suspect that something is wrong with the calibration of your Dolby C circuitry in recording, so you are not getting correct tracking (match between recording and playback levels) for the tape you are using. If anything, Dolby C has been devised to provide even greater headroom (protection against tape saturation) than Dolby B. This is achieved by reducing the treble emphasis at the upper end of the audio range in recording. As you may recall, the Dolby system variably emphasizes treble in recording, with low sound levels getting more emphasis than high sound levels, and in complementary fashion it variably de-emphasizes treble in playback to restore flat response. For all this to work properly, there has to be a match between recording and playback levels.

If Dolby B works better than Dolby C, this provides further evidence that something is wrong with the Dolby C circuitry in your deck. You should have your deck checked by a competent technician; take along one or more of the cassettes you plan to use so that adjustments can be made on the basis of these tapes.

Dubbing, Dolby, and dbx

Q. I have to dub about 20 cassettes encoded with Dolby B NR which were made on a deck with incorrect azimuth adjustment. I couldn't play a friend's tapes, nor could he play mine because of my deck. I have a new deck which provides Dolby B, Dolby C, and dbx noise reduction. I want all my newly dubbed tapes encoded with dbx. I'll be dubbing from the deck that was originally used to record the Dolby B tapes. Will I have any trouble dubbing the old tapes and encoding them with dbx? Do I decode the Dolby B tapes as if I were listening to them? Do I have to be overly concerned with level adjustments on the new deck? And how do I set the bias switch on the old deck? I use chrome tapes.—John Flanagan, Fall River, Mass.

A. When playing the original tapes on the source (old) deck, do so in the Dolby B mode, which will give you a correctly equalized and quiet source signal. When you make your dbx-encoded dubbings on the new deck, you do not have to be concerned with level (sensitivity) adjustment, as is the case with Dolby. When playing your original tapes on the source deck, the equalization switch should be in the 70-µS mode—the mode for all but ferric tapes. Bias selection is not involved when *playing* tapes; bias is used only in recording.

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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AUDIOCLINIC

JOSEPH GIOVANELLI

Compliance

Q. What does "compliance" of a cartridge mean?—Ron Webb, Tempe, Ariz.

A. Cartridge compliance refers to the ease with which its stylus can be displaced. The higher the compliance, the more readily the stylus can move in response to the undulations of the record groove, and the less work the grooves must do to move the stylus.

Phonograph Muting

Q. I have an automatic turntable. When I press the "Stop" button, its tonearm lifts. My right channel becomes silent—just as it is supposed to. My left speaker becomes silent just after it lifts. What causes this problem? How can I resolve it?—Peter Dea, Brooklyn, N.Y.

A. Your problem results from difficulties with the muting circuit associated with the left channel of your turntable. The audio is supposed to be shorted out just before the tonearm lifts. If it does not, you will hear the arm being lifted from the surface of the disc.

A number of factors can produce this condition. One is that the contacts which actually perform the shorting may be oxidized; this oxide may be removed by a suitable contact cleaner. These contacts could also be bent, or the cam which controls their positions might be worn. In either of these latter instances, the cam will not press the contacts together with sufficient pressure to create a short. You must examine the contacts, and bend the appropriate one ever so slightly toward the other. This work is best performed with needle-nose pliers.

If the equipment is still in warranty, do not attempt a repair; take advantage of your warranty.

Keeping Your Analog Phonograph

Q. A few months ago, I purchased a very good analog playback setup. Now I constantly read and hear about the digital "attack" on analog recording techniques and I get angry. Did I waste my money when I bought good record playback gear?—Ed Miglino, Deer Park, N.Y.

A. I do not believe you have wasted your money. The phonograph record, as you have come to know and love it, will be with us for years. There are so many phonographs that their presence becomes a marketing force too great to ignore.

The quality built into today's phonograph systems is very high, and they will last for a long time. This means there will continue to be a demand for records to play on these systems.

Many recordings will never be reissued on Compact Discs. If you plan to collect these, the only way this can be done is to buy the present-day phonograph record.

The 78-rpm disc has not been made for many years, yet manufacturers are still responding to a demand for good equipment on which to play them. This, then, is just one more guarantee that you will have lots of discs to play on your new phonograph. Not only will you have new discs to play, but you will have those which you now own. Given a good cartridge and stylus—kept in good condition—you will be able to enjoy your collection for years!

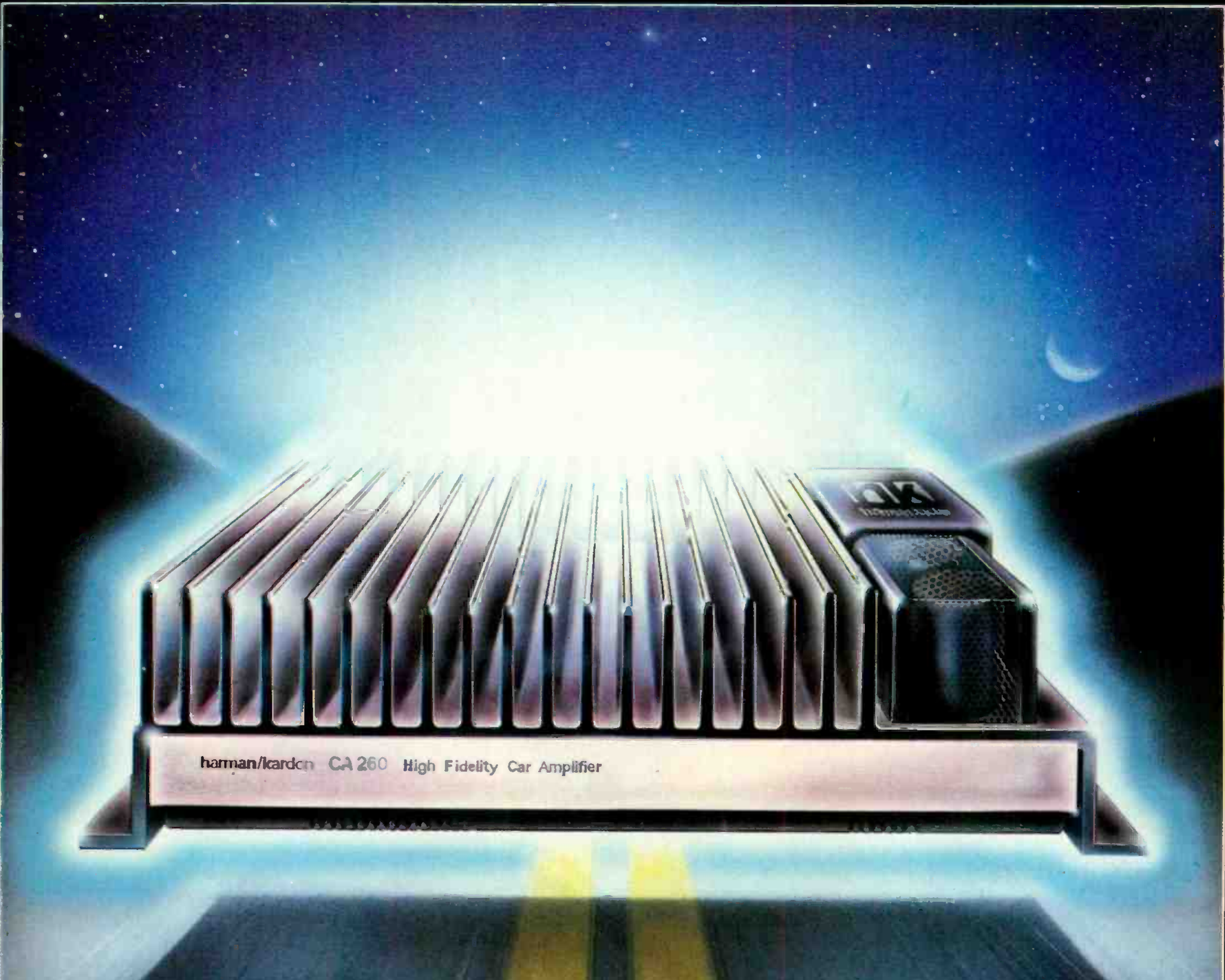
Changing Internal Speaker Wire

Q. I see ads for various heavy-gauge speaker wires. I understand how lower wire resistance can help improve the performance of a sound system. I don't understand how it can help when the wiring inside the speaker enclosure remains the same. Is it necessary or desirable to install heavier gauge wire inside the enclosure when using heavy-gauge interconnecting cable?—Al Shelton, Arleta, Cal.

A. The effects, if any, of a change of wire will be in proportion to the wire's length. There is, therefore, more chance of improving the sound by changing the 20 feet or so of wire between the amplifier and the speaker cabinet than by changing the 2 or 3 feet of wire inside the enclosure. Also, the external wire is far easier to change. Some speaker manufacturers are now using heavy, premium cables inside their enclosures. That's simple to do in manufacture, but taking a speaker apart in order to rewire it is, at best, an awkward process, and there is unlikely to be enough improvement in the sound to warrant all that work.

If you have a problem or question about audio, write to Mr. Joseph Giovanelli at AUDIO Magazine, 1515 Broadway, New York, N.Y. 10036. All letters are answered. Please enclose a stamped, self-addressed envelope.

HARMAN KARDON'S
STATE-OF-THE-MIND TECHNOLOGY TAKES TO THE ROAD



With the introduction of the CA260 high fidelity car amplifier, Harman Kardon blazes new trails. The commitment to sonic superiority that's synonymous with Harman Kardon home audio equipment is now ready for those who demand the same quality on the road.

At Harman Kardon, we believed that there was a need for quality car audio components for the discerning listener... A car amplifier that would outperform any car amplifier on the market. Harman Kardon's thirty years of audio expertise is unleashed with the CA260.

The unrivaled design technologies that are embodied in the CA260 include: High instantaneous Current Capability, Low Negative Feedback, Ultrawidebandwidth and Discrete Components. The CA260 goes beyond industry standards to set new ones.

Incorporated in the Harman Kardon CA260 is 30 amps of High instantaneous Current Capability to provide 60 Watts of power into 4 Ohms, 90 Watts into 2 Ohms, and 180 Watts bridged mono into 4 Ohms. Two 10,000 µF capacitors provide full power even at 20Hz.

The CA260 is rugged and reliable enough to perform under any environmental and automotive conditions. It has been designed to overcome extreme humidity, varying voltages in the car's electrical system, mechanical vibrations, intense temperatures and engine noise.

The CA260 is the debut of a line of superior and fundamentally advanced car stereo products from Harman Kardon.

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INTRODUCING THE 325e.
BMW AFFIRMS ITS DOMINANCE IN THE CATEGORY IT CREATED.

Many years ago, into a world forced to choose between the sports car and the passenger sedan, BMW introduced an innovation that proved prophetic. A way of merging the two into a whole greater than the sum of its parts.

Car and Driver, taking note of the achievement, wrote that "BMWs have reigned as the definitive sports sedan for nearly twenty years now. The world's car companies perennially take them apart to see what makes them tick."

Now there's a new candidate for such dissection—an effort that will prove exhilarating for driving enthusiasts and chastening for a world of late entrants into the sports sedan genre.

It's called the BMW 325e.

HIGH TECHNOLOGY DEDICATED TO HEIGHTENING YOUR PULSE RATE.

The 325e is a $20,970† paragon of high performance. And central to its prodigious performance is a power plant unique to BMW: the technologically ingenious 2.7-liter, 6-cylinder 'Eta' engine. It develops high torque at low to medium range engine speeds, thus offering you exceptional response as you move through the gears. This response is enhanced by a newly refined version of BMW's Digital Motor Electronics. A microprocessing system that uses data based on engine and driving conditions to calibrate the electronic fuel injection and ignition instantly and precisely. The system is so efficient and unerring it also manages the BMW engine that powers the current Formula One Grand Prix Championship car.

In the 325e the result is an aggressively smooth engine that delivers soul-stirring performance with a remarkable EPA-estimated [23] mpg, 36 highway.*

But as Road & Track states and BMW engineers concur, "the concept of performance encompasses a good deal more than the various aspects of acceleration."

It encompasses, for example, excellence in deceleration as well. For that reason the 325e has been equipped with disc brakes for all four wheels. And they're vented in front, where most braking stress occurs, to increase their fade resistance.

The 325e also has a newly engineered sport suspension that's fully independent, with anti-roll bars at the front and rear for flatter, confidence-inspiring handling and a crisp, yet supple ride.

A NEW INTERIOR ARCHITECTURE.

Inside the BMW 325e there are no sacrifices required in the name of high performance. The ergonomically engineered driver's domain includes totally new BMW sport seats that can be molded to your needs with a myriad of orthopedic adjustments.

While in front of you the instrument panel incorporates the second generation of BMW's onboard computer. It handles such chores as warning you when the outside temperature nears freezing and providing anti-theft protection. You can activate it by pressing the turn signal so it won't distract you from driving.

Other informative BMW innovations include a Service Indicator that determines your individual driving style and recommends when routine services are due. And an Active Check Control that monitors vital engine functions to offer early warning in the event of a malfunction.

THE SPORTS SEDAN OTHER CARS PROFESS TO BE.

The 325e exudes the same attentiveness to detail and quality that characterizes all BMWs and elicited this from Motor Trend: "doors close with a nice solid clunk, gear changes are crisp as cold celery and the steering as precise as a dial indicator."

In sum, it expands the prerequisites for all those cars seeking credibility as high-performance sports sedans. Every nuance of its performance has been finely honed and heightened to elevate driving from a mere pastime into a passion.

THE ULTIMATE DRIVING MACHINE.

†Manufacturer's suggested retail price. Actual prices established by dealers. Taxes, freight, optional equipment and any other dealer charges are extra. Price is subject to change without notice. *Fuel efficiency figures are for comparison only. Your actual mileage may vary, depending on speed, weather and trip length. Actual highway mileage will most likely be lower. © 1984 BMW of North America, Inc. The BMW trademark and logo are registered. European Delivery can be arranged through your authorized U.S. BMW dealer.

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EDWARD TATNALL CANBY

TIME WATCHES ON

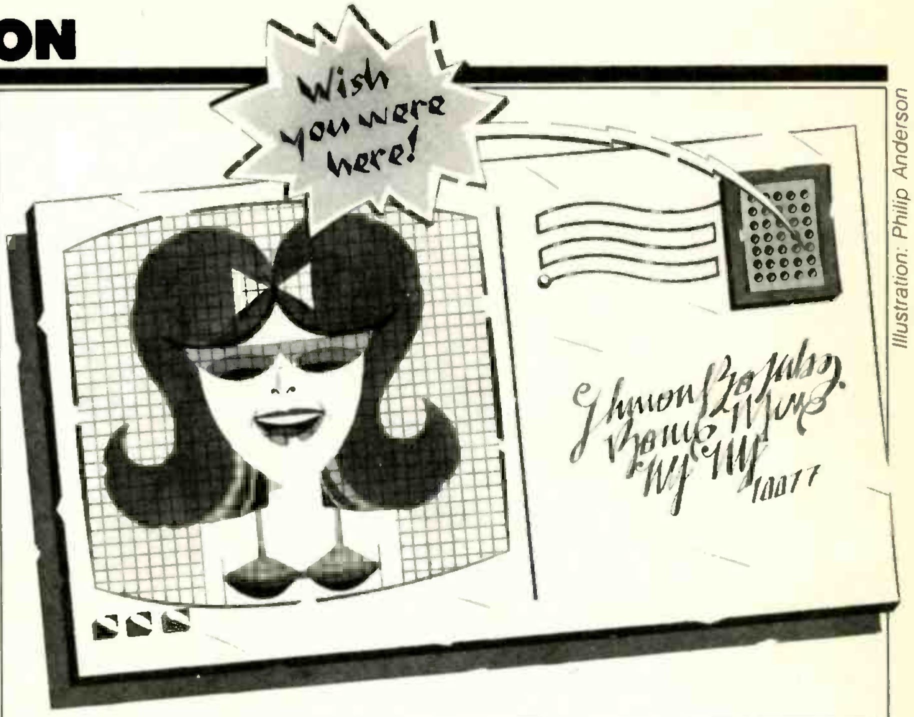

Illustration: Philip Anderson

I'm feeling like the cat on a hot tin roof. Only a year-plus ago, I was writing about the Three Phases of the then much-touted marriage of video and audio, or TV and hi-fi if you wish, and now we are already heading straight into Phase Three, the real revolution. Things are indeed heating up and I'll have to move fast if I want to indulge in speculation as to what may be in store for us—before it goes and *happens*, in the electronic flesh, not merely my imagination.

Phase Three, of course, is liberation from the tube, towards other and radically different methods of producing an electronic moving picture in color. The direction in which this will take us is familiar enough. Those potent triplets, miniaturization, ultra-low power drain (from long lasting batteries) and astronomically increased versatility, are already with us now in a hundred ways.

When I look at my small, cheap, stick-on watch, or clock, bought two years ago for around seven bucks (and now selling for maybe less than three), I see future video. All this time, that little round timepiece, cream plastic with one small window showing the LCD numbers, has been flashing away, back and forth, alternating between the date and the exact time, neatly keeping track of all the months and their different numbers of days, including February—though this is by no means all the thing can do. Stick a pointed tool into its two little guide holes and you can get the usual, a stopwatch counting seconds, the time by itself minus date, and so on. You can guess that, this last February, I waited with the traditional bated breath to see what it would do with Leap Year. Alas, it wasn't that brainy. Not programmed for Leap Year. I had to move it forward a day, which took about a half-hour since it involved my usual random pushings of the two control elements, through those little holes, until I could once more figure out what their functions were. (The directions, I found, were for me worse than meaningless. Better just to experiment.)

I think it is a constructive analogy also to take note of my Lorus quartz wristwatch. This, too, has been running for ages—well, a year—on its original battery, and it keeps the usual astonishingly accurate time, but that is not my point. Unlike the little stick-on watch (which is stuck onto a tray on my kitchen table where its LCD numbers can catch the light at the right angle for legibility), the Lorus is a composite. The main action is still mechanical. The hands go 'round, including the step-by-step second hand—which once again returns to the exact function that produced that name some centuries ago. (It is fascinating to watch my pre-revolutionary grandfather clock's second hand keep in precise time with the second hand on my Lorus.) The date action is also mechanical, if battery driven, and therefore much less sophisticated than the cheaper LCD system. Its months are all the same, 31 days, because anything more complex than this would be mechanically monstrous and enough to kill the battery before its time. So every few months I have to go through the mechanical reset rigamarole.

Is that significant! This composite stage is where we also have been for years in just about every aspect of our hi-fi and recording fields, as well as the same in the entire video field.

Why, then, did I choose a wristwatch with old-fashioned hands that go 'round, instead of the more versatile number type? It was a thing I debated for a long time, as my earlier all-mechanical watch pestered me with the usual annoyances—it not only stopped when unwound but also stopped when wound up fully; it gained two minutes, then five minutes a day, and there was no adjustment, nor could I remember to remember when I had last reset it. Its hands slipped loose and when put back in place caught against each other, converting the hour hand into a minute hand. Frankly, I never had a watch in my entire life that didn't pull a few of these annoying stunts on me, including an expensive Swiss pocket watch I got when I was 15.

The reason I like hands on my watch is simple. *I read them at least twice as fast* as I can read and translate numbers into time. And this is a very potent thought for all sorts of communications, digital or no.

What we must understand is that time, like most other vital parameters in electronics, is not by nature digital—it doesn't come in digits. When we digitize it, we are translating, just as we translate a basic or natural audio signal into a set of discrete quanta. Every time you look at a digital clock, you must reconvert, D/A, back to the simple flow of time itself. Like all our new digital processes, this one is extremely rapid, to the point where you are mostly unaware of it. And yet when you see 3:52:30 and then say out loud, "It's seven and a half minutes before four," you have performed a major translit-

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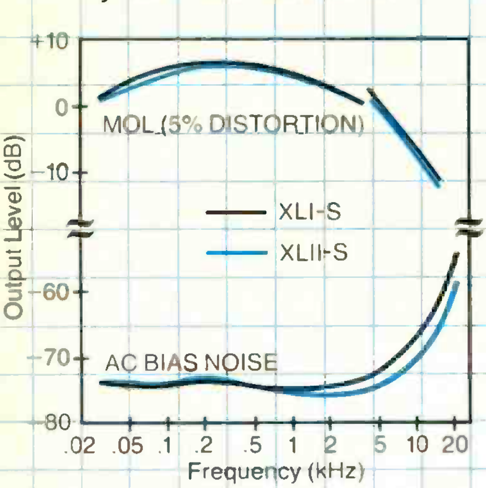
Maxell introduces the new XL-S audio cassettes; a series of ferric oxide tapes which deliver a level of performance that can capture the sound nuances found on Compact Discs more faithfully than other ferric oxide cassettes on the market.

There are a number of areas where this achievement is apparent.

GREATER DYNAMIC RANGE.

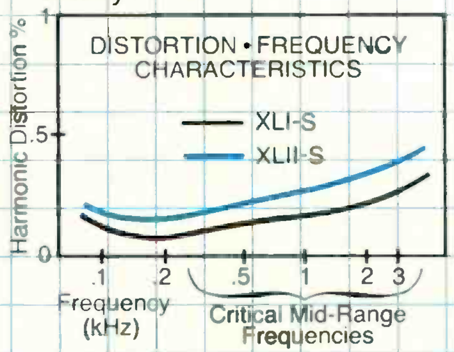
Through a new formulation of our magnetic particles, we were able to reduce the perceived residual AC bias noise level by 1 dB in the critical 2 kHz to 10 kHz mid-frequency range. And simultaneously increase sensitivity and maximum output levels by as much as 2 dB.



As a result, the dynamic range of each tape has been significantly expanded. So you get a better signal to noise ratio and a fuller impact of the dynamic transients exclusively inherent to digital CD recordings.

LOWER DISTORTION.

The newly formulated particles also contribute considerably to XL-S's low output fluctuation, as well as its virtual distortion-free reproduction, especially in the critical mid-range frequencies. This, in turn, accounts for our XL-S tape's enhanced sound clarity.

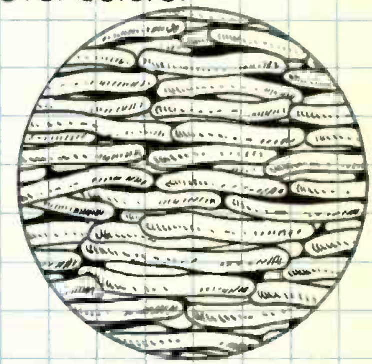


IMPROVED MAGNETIC PARTICLES.

Our refined particle crystallization process is the basis for all of these accomplishments. Maxell engineers are now able to produce a more compact needle-shaped Epitaxial magnetic particle of extremely high uniformity.

This allows us to create a greater ratio of total surface area to unit weight of magnetic particles.

As a result, our XL-S tapes now have the ability to record more information per unit area than ever before.



PACKING DENSITY OF UNIFORM PARTICLES.

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.

For technical specifications on the XL-S series, write to: Audiophile File, Maxell Corp. of America, 60 Oxford Drive, Moonachie, New Jersey 07074.

IT'S WORTH IT.

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Time, like most other vital parameters in electronics, is not by nature digital; it doesn't come in digits.

eration. That is very different from our much-vaunted redundancy, the need for excess and overlapping information. This is a conversion, and a fairly complex one at that. It wastes time. And energy of the human sort.

On the other hand, once you are trained up to it, the moving-hand system of indicating time is far more direct, and inherently quicker. It is a one-step process, visual position directly into your choice of verbal expression, if any. No digitalization in between. I am definitely *conscious* of that difference as I look alternatively at a set of time numbers and at a set of hands. Indeed, I observe that often enough *I do not verbalize the time at all.* I know what I need to know without the intervention of words. I am late, period! *I know it so fast* that there is no time or need for words.

We have committed ourselves to numbers for communication far beyond any earlier period. The numbers are easy to produce—that's why. But are they easy to read? Another story and, as A & P says, we had better mind our Ps and Qs in this respect. Numbers are stylish and so we have gone further into them than we should. True, we can learn to read numbers faster, and we do. We can, I suppose, learn to use them without consciously speaking their names in our heads. But the "position in space" readout is *always* going to be simpler, much more direct to the brain, and therefore more vitally useful. Colors in space, too. Why else our familiar red, yellow and green? Position and color—instantaneous, uncomplicated perceptions—have been recognized for centuries as the quickest way to affect intelligence when speed is vital, as in all railroad signals, not to mention signals at sea, weather information, traffic signs and so on. The old radios took traditional note of this as the surest of principles. Numbers—but positioned out in space on the radio dial. Television was the first to depart, but there were only 13 channels to begin with. And at least they remained in numerical order, which is a subspecies of spatial position though one stage removed already.

Phase Three in the getting together of audio hi-fi and video TV is going to get us into this kind of thinking with a vengeance—if we take the time to think. We'd better. We are going to have an incredible spread of new miniaturizations, of low power drains, of versatility through microchips you can hardly see. The Lorus watch, above, might roughly be compared to our presently remarkable developments in tubed miniature TV. The tube is still there, and in most TV cameras too. But it is already foreshadowing in size the natural products of the coming tubeless age. The intermediate composite, astonishingly ingenious, beautifully designed and built (in Japan, of course), is already markedly ahead of its time (our present time), whether pocket TV or tiny video camera. And already foreshadowing the new usefulnesses of products yet to come, already incorporating some of them.

In the Lorus watch, it's crystal accuracy and a power supply to last a year-plus, even with an old-fashioned mechanical movement, pared to minimal size and weight. In video, it's miniaturization and portability—big things to come and the wave of the future—but still the old tube, similarly pared down to minimize its tubeness.

Curious that, at the present stage of technology, the video composite format takes some odd twists. There is the new camera with a main picture receptor that—at last—is *not* a tube; but oddly, its finder, the tiny little B/W screen that now inevitably serves that function, remains a mini-TV tube. That means high voltage and the usual high drain, relatively speaking. Also the slow warm-up, so familiar through decades of every sort of tube. Even though the main camera in this composite is instantaneously ready to go.

Needless to say, the large run of video products are not yet of this progressive and experimental sort. We are still in Phase Two, decidedly, the integration of existing forms of video with our existing forms of hi-fi audio. That's another story and an exciting one, but this cat, as I say, is on a hot tin roof and I can't wait. I keep thinking of all sorts of radical, crazy things the new video and its new audio might do—the most immediate, as should be clear to anyone following the video news, being the return to home movies, a somewhat dead popular art in recent years in the old and silent film medium. (Sound film for consumer use has never managed

Position and color have been recognized for centuries as the quickest way to affect intelligence when speed is vital.

to get far off the ground and for good reasons.) But now, in Phase Three video terms, and audio terms, home movies are going to come back.

Not really yet. The composite era is working hard in that direction, even so, trying to achieve home-style moving pictures with small cameras that really aren't small when you come down to it, dragging or carrying along VCRs too, plus long cables or packs full of batteries, plus even a monitor playback—excellent idea but even more cumbersome as of now. And the whole thing both complicated and hugely costly. But in Phase Three, in all its glory, we'll have it! Plus more of the same. And other changes so startling that one can go way off the beam imagining them.

And just to show you—one of my own recent zany ideas. As a non-engineer, I made a minor mistake when I thought I understood one of the new ways of video playback, using the LCD. This system is practically with us now and no dream product: The LCD-type video screen. The LCD is all over the place, including my stick-on watch and my elderly (already) calculator. No emitted light like the LED. Reflected light. That's how my LCDs work. You have to hold them in an outside light at just the right angle.

And flat! Look at the newest Canon card calculator, so thin you can bend the thing like a playing card. A reflected color picture like *that*? Wow!

Just like in the old comics, a 1,000-watt light went on in my head. How about a *video postcard*?

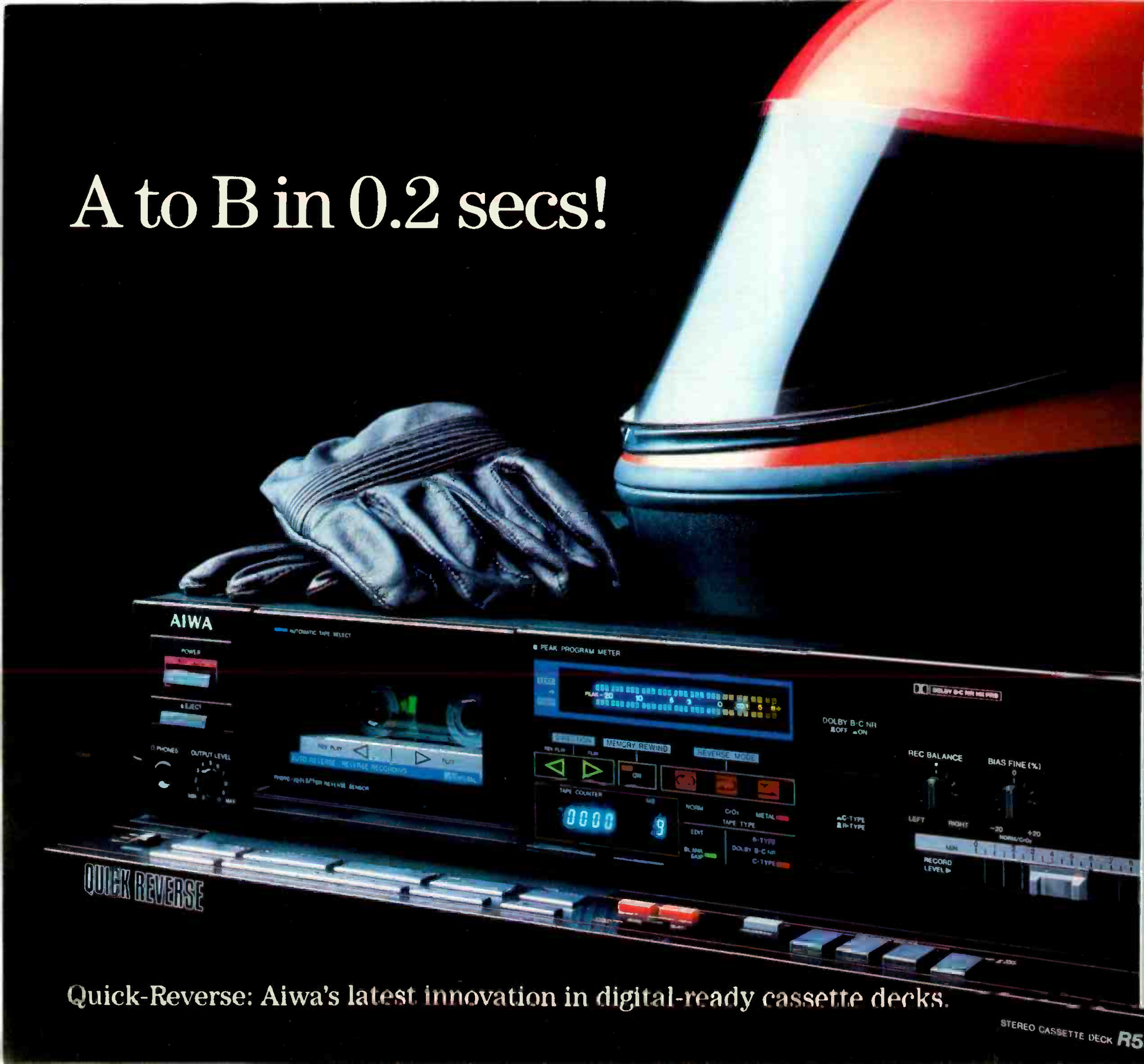
Undaunted by engineering problems, I worked it out in a few minutes. Flat, slim TV screen, postcard size, portable. Like a postcard, you put its LCD surface under a bright light for viewing. But this would be a *movie* postcard, receiving a TV signal (somehow. . .). Sound too. Quarter-inch receiver, flat, along with the video, and maybe a half-inch speaker under the surface, up where the postmark usually lands. Boy, am I a quick designer. I just ignored the complications.

Then Hitachi let me on to some further truth. As I now soberly understand, the LCD video screen will not emit light but will *reflect* light, coming from in front. Millions, maybe, of open-and-close color blinds, switchable on and off. When electronically off, they blend with the background. On, and you see a tiny spot of dark color. Do I have it right? If so, it sounds terrific to me. You could do anything with that.

Okay, then, let's make it an illuminated postcard, still flat and thin but with built-in lighting. White LEDs? Something fluorescent? Anyhow, a nice, flat battery inside, à la Polaroid. No mere technical problems are going to faze me, you see.

So down with old-fashioned, silent, still postcards and also color prints. Maybe the Polaroid battery could itself fluoresce, behind the LCD screen? And hey, how about a paper-thin mini-videocassette to play inside my new color cards? There I go again.

A to B in 0.2 secs!



Quick-Reverse: Aiwa's latest innovation in digital-ready cassette decks.

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Auto-reverse was a great idea. Quick-Reverse is a better one. It not only changes tape sides, it does something even more miraculous. It eliminates interruption between sides!

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IVAN BERGER

SOMETHING TO COUNT ON

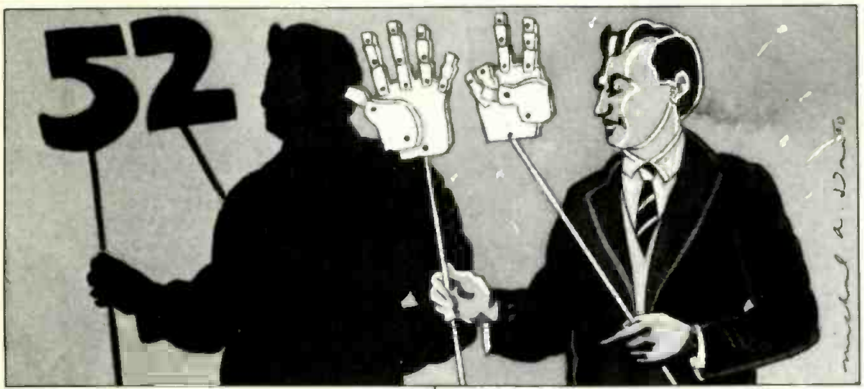


Illustration: Michael A. Donato

Finger Fun

Ken Pohlmann's "Digital Domain" columns have been talking about binary, decimal, and unitary number systems. The human hand can be used to illustrate all three.

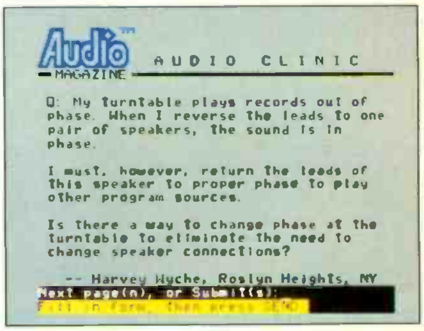
When we count on our fingers in the normal way, we're using the unitary system, letting one digit stand for each item counted. That limits our count to 10, unless we take our shoes off.

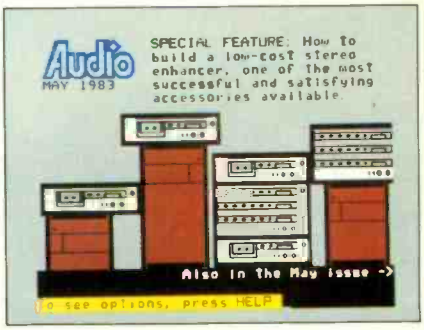
The decimal system takes that figure, 10, as its base. Using both hands and feet and a combined decimal/unitary system, we can count up to 110, letting the fingers stand for unitary digits while the toes stand for unitary multiples of 10. Three toes and two fingers symbolize "32," and so on.

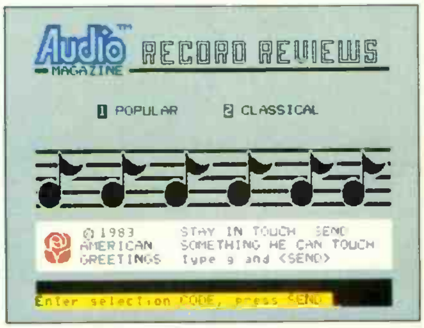
But using binary, we can count up to 1,023 on our hands, letting each finger stand for a different power of two. Both thumbs and the least-significant pinky, for example, would then stand for 00001 10001, or decimal 49.

Audio on Video

Audio showed up on 200 New Jersey TV screens last year as part of a CBS experiment in videotex programming. Viewers saw information on the current issue's contents, and abbreviated versions of our Q & A columns and record reviews. For those who didn't get to see it, here's what we look like on TV. Film at eleven.







Shed an Oxide, Shed a Tear

Polygram has been reissuing a lot of jazz on CD lately, but some of these releases have not been of the artists' most popular recordings. According to *Billboard*, Polygram's Barry Feldman has been picking more for sound considerations than for initial popularity. That's not just a tribute to CD's superior sound, either: Feldman is quoted as saying, "Unfortunately, the [master] tapes from a lot of the great old jazz albums are falling apart."

That points out another advantage of digital sound: Archival stability. Some media (such as CD) should last just about forever. And even if they don't, digital's error-correction capability should make it possible to make perfect duplicates from tapes which are starting to lose their perfection, giving the old masters a new lease on life.

On the other hand, today's digital master tapes are on nonstandard formats (as far as I know, there are no standard ones), for which few recorders exist. Some day, these tapes might become unplayable—not through deterioration but because the equipment to play them has been scrapped. I hope that, when a studio standard does come into existence, these masters will be dubbed to the new format.

Right/Wrong EQ

My February item on "Prerecorded Progress" pointed out, correctly, that some recording companies, such as A&M and Sine Qua Non, were using chrome cassettes without the Type II recognition notch, so decks with automatic playback-EQ selection would play them with 120-µS equalization. But I was incorrect in assuming that this was a mistake. According to Mark Fishman, Editor of the Boston Audio Society's publication *The BAS Speaker*, these tapes "are *intended* for playback at 120-µS equalization." Musical Heritage Society, he adds, offers chrome tapes for 120-µS playback (marked "Compatible Chrome—CrO_2 tape—120 µsec EQ") and for 70-µS play (marked "Superchrome—CrO_2 tape—70 µsec EQ"). The latter tapes, he points out, have the notch. BASF has since confirmed this.

Unannounced dbx transmissions had listeners phoning in about the unusually clean sound.

dbx Digital

The dbx 700 digital audio processor, which uses a nonstandard encoding format (see "Behind the Scenes," Jan. 1983), is beginning to make a little news in broadcasting. RKO Radio used the system last October, in a coast-to-coast broadcast of the Little River Band from the Universal Amphitheater in Los Angeles. The sound was relayed to New York in digital form, then decoded and sent in analog form to RKO affiliates around the country. In March, public-radio station WGBH Boston began using the system to send Boston Symphony concerts direct from Symphony Hall to their transmitter site in Milton, Mass. According to the station, their unannounced initial tests of the system had critical Boston-area listeners calling in to comment about the unusually clean sound.

Dubble Trouble

While cassettes can't match the dynamic range of Compact Discs, I do find that the best tapes I have are those dubbed from CD (mainly using Dolby C NR). And I still don't sympathize with those who want to tax tapes on the basis of lost record sales—most of my dubbing is to copy, for the car, records I already own, or occasionally copy, for friends, records long out of print.

On the other hand, I do approve the suit just filed in Tokyo by 20 members of the Japan Phonograph Record Association. The aim was to get an injunction against the shops that both rent music tapes and provide high-speed, coin-operated dubbing machines. For under a dollar, according to a story in *Electronics*, you can copy an LP or its equivalent in only three minutes. That *is* an invitation to a rip-off.

When was the last time this many publications agreed on anything?

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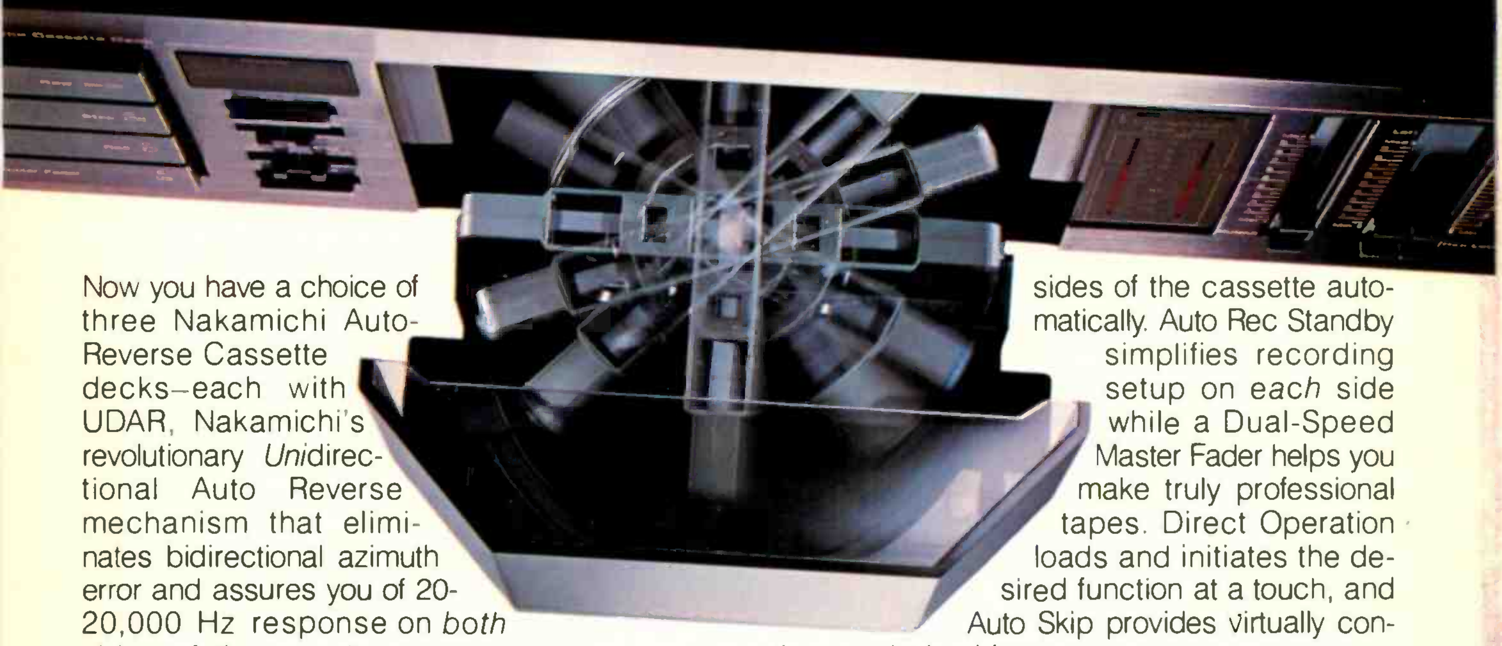


IVAN BERGER

CD ON THE ROAD

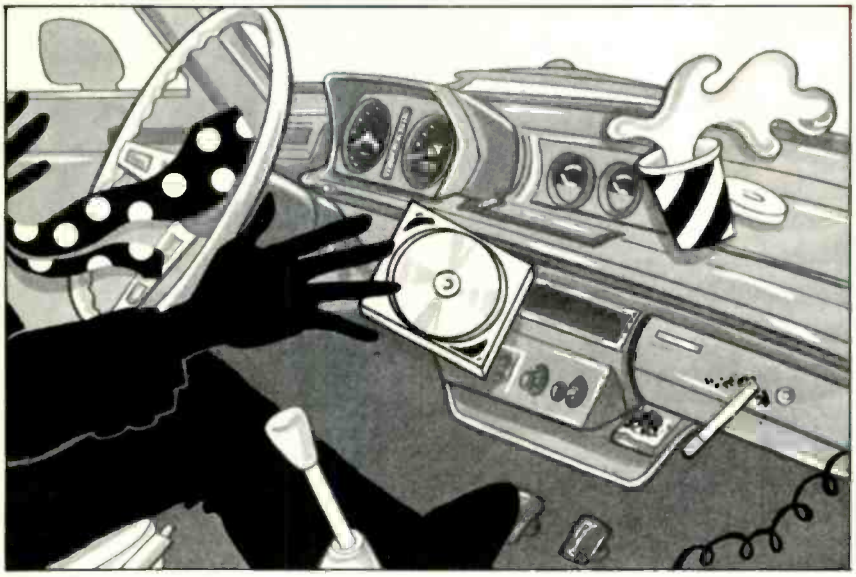


Illustration: Donna Corvi

CD on the Road

There's little question that we'll have the option of equipping our cars to play Compact Discs, probably about the beginning of '85. What I'm beginning to wonder about, though, is whether we'll want to.

The chief advantage, to me, of a car CD player is the ability to play records from my home collection directly, without having to tape them first. On the other hand, CDs will only form a small part of my collection for some years to come (I have a few thousand recordings, in various formats, about as many as all the titles that are out yet on CD). A CD player in my car would only be able to play those few recordings; a tape player can play anything in my collection that I take the time to tape. The best tapes I have now, in fact, are those I've dubbed from Compact Discs. The other main CD advantage, wide dynamic range, is less of an advantage in the car, where the noise floor is 20 to 30 dB higher.

Now for the disadvantages: You can't open today's "jewel-box" CD package with one hand, which you would have to do while driving. And I don't want to subject my expensive CDs to the car's environment, where they're likely to be warped (or, I hear, delaminated) by heat, scratched by the omnipresent grit, and more likely to be stolen. Considering that I can tape several CDs for the cost of replacing one of them, I think I'll stick with tape as my main mobile music souce.

That doesn't mean I won't try CD in my car as soon as it's available. Practical considerations may moderate my enthusiasms, but they cannot completely kill them.

Equalizer Inequalities

Equalizers are not all alike, nor are similar equalizers necessarily labelled similarly. For example, Kenwood has a three-band "equalizer," while AudioMobile's three-band unit is a "preamp." Which is correct? You can make a good case either way. Many home preamps, for example, have three-band tone controls (bass, mid, treble), but most home equalizers have five bands or more. Yet, having the three-band AudioMobile unit in my car, I can see just how useful an equalizer it is, especially as its high and low bands cover the frequency extremes (50 Hz and 10 kHz), rather than duplicating the wider range of bass and treble tone controls. In former days, I had a Clarion system with a five-band equalizer and no tone controls. (Plugging in the EQ disabled those controls, to keep users from blowing out their speakers by turning bass and treble up full on both the tone controls and the EQ.) I found it took more of my attention to get the sound I wanted with the five-band EQ than with my present three-band whatever and tone controls. (On the other hand, the speakers I then had were far from being as flat as the ones I now have.)

Then there's the question of how much an equalizer's controls should boost or cut. Most have a range of ±12 dB, with a few (AudioMobile, Craig, Monolithic and Zapco) offering more, Linear Power offering slightly less (±9 dB) and Proton offering a switchable choice (±12 or ±18 dB).

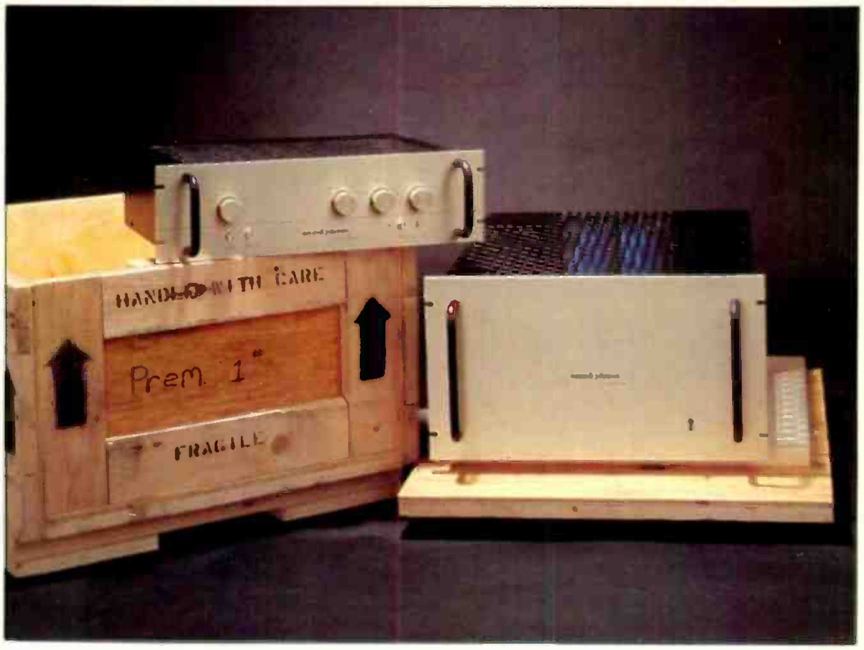
The narrower a control's range, the easier it is to adjust precisely. But I discovered that the Proton's control slope was steeper in its 18-dB range, effectively narrowing the band of frequencies controlled.

So wide-range controls have an indirect benefit, but I'm not so sure about their direct ones. Assuming decent speakers, decently installed, the system's response should never need a boost or cut of 12 dB or more—and extreme boosts can blow speakers, or at least push amps nearer their distortion points. The odds are, too, that an equalizer's bands won't be at the precise points needed to neutralize system defects without causing problems elsewhere. The only time I ever use one of my AudioMobile's controls to its full 15-dB capacity is when I need to cut high-frequency garbage in my source material. Then, I sometimes use full cut on the 10-kHz band; the rest of the time, I use so little of that range that precise control is difficult.

If I were designing a car equalizer for use with good systems, it would have either three bands (spaced about like AudioMobile's now—50 Hz, 2 kHz, 10 kHz) or possibly four (the extra one splitting the midrange). The control ranges would be limited to about ±8 dB for all but the uppermost band—that one would be asymmetrical, something like +6, −15. Filter steepness (Q) and perhaps center frequency would be selectable, but the switches would be screwdriver types, used for setting up the system but untouched during normal operation.

BERT WHYTE

PREMIER PERFORMERS



In the December 1983 issue, I discussed tube amplification technology—past and present. I reported on some of the lower priced tube equipment, and promised that down the line I would cover high-end tube equipment—specifically, conrad-johnson's Premier One amplifier and Premier Three preamplifier. These units are generally considered as being at the "cutting edge" of tube amplification design.

As I pointed out in my previous column on tubes, these conrad-johnson units are particularly prized by the underground audio press and their readers. I wondered what these people found so attractive about tube equipment. I know a number of individuals who are devotees of the technology, and asked them to express their opinions on why they favor tube sound. Their answers were pretty much as I had expected. They talked of the "smoothness" of the sound, the absence of "graininess" and "overbright, tizzy" top end. The sound had an "open, airy, and transparent" quality. They liked the "imaging," "stage width," "sense of depth" and "ambience preservation." Above all, they stressed that these qualities added up to what was reverently described as "musicality." These people contend that even with the most sophisticated and expensive solid-state preamps and amps, this vaunted "musicality" is missing.

Acting on a hunch, I asked these tube aficionados what they thought of digital sound, and most especially the Compact Disc. Almost to a man, they turned out to be vociferously anti-digital! I asked them if it had occurred to them that the negative qualities they had ascribed to solid-state equipment over the years was somewhat akin to what they disliked about digital sound. Well, we won't get into that can of worms! Suffice to say, some people like vanilla, and some like chocolate. A number of my friends knew I was gently needling them, and I would never summarily dismiss their notions about "musicality" as mere self-delusion.

The conrad-johnson Premier One is a *big* amplifier. It measures an imposing 19 in. W × 10 in. H × 21 in. D and, at 135 pounds, is one of the heaviest amplifiers—tube or solid-state—extant. A large part of this weight is due to the massive power and audio transformers. The main power supply provides more than 4,000 µF at 550 V. After the input condenser, the power supply is separated for each channel to reduce stereophonic cross-coupling. A cascode triode pair of 5751 tubes is employed at the input as a voltage amplifier. As described by Bill Conrad and Lou Johnson, "This high-gain, phase-linear single stage is direct coupled to a cathode-coupled, differential phase inverter made up of paralleled sections of high-current triodes (6FQ7) to provide balanced low-impedance drive to the push-pull output stage. The output stage utilizes paralleled 6550 tubes, a total of six per channel." The arrangement features ultralinear operation at high power levels, while reducing the source impedance of the stage. Thus, the amplifier is capable of the high current necessary to handle high-amplitude transients.

Power output of the Premier One is rated as 200 watts per channel rms at 4, 8, or 16 ohms from 30 Hz to 15 kHz, with no more than 1% total harmonic or intermodulation distortion. Two hundred watts is a high output for a tube amplifier, and for many years, the only tube amp with that kind of power was the 200-watt McIntosh. George Piros, the disc cutter for the late Bob Fine, used a Mac to drive the special Miller cutter head when the superb Mercury Olympian Series recordings were made.

It is interesting to note that conrad-johnson uses domestically manufactured tubes (including the 6550 output tubes) in the Premier One. Many owners of tube equipment are always looking for esoteric Russian or other foreign tubes which purportedly are better than American tubes. The folks at conrad-johnson say they have extensively researched the performance of U.S. versus foreign tubes, and, for their purposes, the American tubes are superior. In fact, they state that substituting foreign tubes in the Premier One will significantly degrade its performance. The company also points out that their tubes have been tempered by a controlled burn-in procedure, permitting extended performance of up to two years without sonic degradation.

A nice feature of the Premier One is its output-tube bias-adjustment system. The amplifier is connected to a loudspeaker, the preamplifier to the amplifier with the volume control fully off, and no signal is applied to the amplifier. Through the perforated metal cover of the Premier One, screwdriver-adjustable controls (one for each output tube) are turned clockwise until an associated red LED is illuminated. Next, the controls are turned counter-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The conrad-johnson Premier One and Three do, indeed, present a broad sound stage and a great sense of depth.

clockwise until the LED is just extinguished. After a 30-minute warming period, the procedure is repeated and that is all there is to do. With this biasing system, it is not necessary to buy output tubes in matched pairs. In use, the Premier One generates quite a bit of heat, but not as much as some Class-A amplifiers; it operates in Class AB.

Considering that this Premier One is a tube amp, its rated hum and noise figure is extraordinarily low, 100 dB below full power output. That is right in line with noise figures of top-quality transistor amplifiers. Frequency response of the Premier One is rated within ±0.5 dB from 20 Hz to 20 kHz. This unit costs $4,350.

The conrad-johnson Premier Three is the Premier One's companion preamplifier. It measures 19 in. W × 5¼ in. H × 12¼ in. D. The unit has an attractive gold finish and solid-metal control knobs for volume, balance, and mode and input selection. Pushbuttons control on/off, muting, and tape monitor. There are two tape monitor functions and two main outputs. The rear panel has inputs for phono, AUX, tuner, and tape record in and out. Two switched and two unswitched a.c. receptacles are provided. Herewith is conrad-johnson's description of the Premier Three preamplifier circuit:

"The Premier Three phono stage consists of two stages of cascode triode pairs. This provides sufficient open-loop gain to achieve optimum feedback ratios even at bass frequencies. The second stage is direct coupled to a cathode follower which drives the feedback loop as well as the output. Phono equalization is accomplished by RC networks in the feedback loop. A generalized anode follower configuration on the second cascode stage tailors the circuit's open loop response to maintain a constant feedback ratio across the audio spectrum.

"The line amplifier stage uses two triode amplifiers, separated by a cathode follower which maintains open-loop phase linearity at high frequencies. The second amplifier stage is direct coupled to a cathode follower to achieve low output impedance.

"Plate voltages are supplied by a separate circuit for each channel. Special voltage regulators effectively isolate the two channels as well as eliminate line voltage fluctuations. The regulators achieve an extremely low impedance supply for the audio stages.

"Filaments are operated at a regulated d.c. voltage to eliminate coupling of subsonic line voltage disturbances to the audio signal."

Phono input is the industry standard 47 kilohms and 100 pF. RIAA equalization is within 0.25 dB from 20 Hz to 20 kHz. Phono overload is in excess of 500 mV at 1 kHz. Phono gain is 40 dB, and phono hum and noise is 72 dB below 10 mV.

The phono input is for moving-magnet cartridges, but I am a bit surprised that no moving-coil phono input was provided on a preamplifier of this price ($2,850) and sophistication.

As in the Premier One, the Premier Three's tube complement (two 12AX7s, five 5751s, and two 5965s) has undergone the special burn-in procedure for extended life. And here, too, conrad-johnson does not recommend the use of foreign tubes.

The high-level gain for the Premier Three is 28 dB, and maximum output is 25 V. Response bandpass is 2 Hz to more than 100 kHz. High-level hum and noise is 84 dB below 2.5-V output. Total harmonic and intermodulation distortion are specified as less than 0.05%.

I hooked the Premier Three into the Premier One and added a Sota Star Sapphire vacuum turntable with Sumiko's The Arm and a new Grado Signature Eight phono cartridge. I also used Technics, Kyocera and Sony CD players, the Sony PCM-F1 digital processor, and my Ampex 440C open-reel recorder. In other words, I had plenty of top-quality input sources. I used a number of speakers, ranging from Quad ES-63s and B & W 801s, to IMF Monitor Sevens and the new Duntech PCL-3 planar wall loudspeakers.

Did I perceive the same qualities of performance as the "tube freaks"? It is best to remember I had not listened to a tube preamplifier/amplifier combination for many years, especially units with this degree of sophistication and quality. I was very pleasantly surprised by many of the things I heard, less so with some other things. The conrad-johnson Premier Three and Premier One did, indeed, present a broad sound stage, a great sense of depth, and more retrieval of hall ambience (with selected recordings). There was an airiness, a transparency, and a more evanescent quality to the sound, especially notable with strings and woodwinds. The smoothness tube lovers prefer was certainly evident. Transient response from piano, percussion, and guitar was fast and clean but not with the super-fast attack of amplifiers like the Levinson, Krell, and Citation XX. Bass response was better than is traditionally expected of tube amplifiers. It was clean and extended, but the lower damping factor meant less control and a thickening in the lowest frequencies. However, it was not tubby and should be fine except with speakers which produce a really lumpy low end. Vocal and choral work fared very well, with a fine sense of presence and no blurring.

With digital vinyl, CDs and digital tape, did the tube equipment produce sound any different than solid-state units do? Not appreciably. In some of the shriller CDs, the sound did seem to smooth out somewhat. Did all the nice things I heard add up to this much-abused term, musicality? Can musicality equate with accuracy? Is it more of a euphonic coloration (a phrase beloved by the little magazines) than a superior reproduction of sound? Perhaps it is like a well-known and expensive phono cartridge, of which auditioners say, "If it doesn't sound like music, than that is how music *ought* to sound."

In several months of use, I found the conrad-johnson Premier One and Premier Three very reliable, and all controls were very smooth and positive in operation. These components reproduce recorded music with all the parameters so beloved by the tube cultists. Their sound falls extremely easy on the ear.

(*Note:* In my April and May columns, I inadvertently caused some confusion as to the location of two companies. Duntech loudspeakers are imported by W & W Audio, 4821 McAlpine Farm Rd., Charlotte, N.C. 28226. Components developed by Win Labs are available through Tru-Sonics Marketing, 7320 Hollister Ave., Goleta, Cal. 93117.—*B.W.*)

KEN POHLMANN

ALMOST FREE SAMPLES

I'm back again for a third installment, encouraged by positive comments from people who are enthused about digital audio and anxious to learn more. Surprisingly, a lot of you have confessed that you still haven't heard true digital reproduction; I strongly encourage you to visit a good stereo shop and take a listen, because I think you'll like it. Meanwhile I hope these columns pique your curiosity, sustain your interest, and develop your understanding of digital audio. Thus, I'm forging ahead with more theory and explanation; stick with it and soon you'll be a bonafide digital audio expert.

So far we've discussed numbers, information, civilization, reality, and motorcycles. Our next topic relates to all of these, as well as everything else in the universe. First, some observations: Digital information can exist only in pieces, as discrete values, as numbers. And that is a vastly different approach than with analog, in which one continuous, infinitely indivisible value is recorded. At first glance, you might think you're getting less for your money with digital—a finite number of fixed values as opposed to an infinitely changing one. In actuality, digital is often the better deal because we can more precisely manipulate discrete values and thus get more and more accurate information from the recorded data. That, more or less, is why digital computers are taking over the world.

Illustration: Michael A. Donato

With analog recording, we merely rolled tape or cut a groove, but with digital we must choose numbers. The first question we are faced with is: How many numbers do we want? In other words, how often do we record a data point? That is, how fast do we sample? And the idea of sampling is bound with the idea that relates to everything in the universe—and that is time. It is important for us because what we are dealing with is time sampling. This is the essence of what makes digital tick.

Speaking of ticking, and time, let's try a clock analogy to illustrate how a digital music system might differ from an analog system. Time seems to flow continuously (more on that later), and the hands of an analog clock sweep across the circle of hours, covering each part of time. A digital readout clock also tells time but with a discretely valued display; in other words, it displays a sampled time. It's the same with music. Music varies continuously in time and may be recorded and reproduced either in continuous analog form or time-sampled digital form. Just as both clocks each tell the same time, both types of recordings each play the same music.

Intuitively, a nagging question presents itself at this point in time. If a digital system samples discretely, what happens in between samples? Haven't we lost the information going on between samples? The answer, intuitively surprising, is no; given correct conditions, no information is lost. The samples contain the same information as the conditioned, unsampled signal. To illustrate this, let's try another analogy.

Let's suppose we mount a movie camera on the handlebars of a motorcycle and go for a spin, up and downhill, over smooth pavement and some not so smooth, and then we head back and process the film. When we audition our piece of avant-garde cinema, we discover that the discrete frames of film successfully come together to reproduce our ride, uphill and down; it looks great. But when we come to some bumpy pavement, our picture is blurred, and we ascertain that the quick movements were too fast for each frame to capture the change. We draw the following conclusions: If we increased the film speed, using more frames per second, we would be able to capture quicker changes. And if we complained to City Hall and had the bad pavement smoothed, then there would be no blur even at slower frame speeds, and our movie would perfectly reproduce our motorcycle ride (except our hair wouldn't be blowing in the wind). We settle on a compromise; we have the roads fixed so no one feels the bumps, and then we use a film speed adjusted for a clean picture.

Just as the discrete frames of a movie create moving pictures, the samples of a digital audio recording create time-varying music; there is little conceptual difference between the visual and aural systems. In a digital audio system, we must smooth out the bumps in the incoming signal; specifically, it is low-pass filtered at 20 kHz. When this above-audibility filtering is accomplished, we can successfully sample the signal such that there is *no* loss of information between the sampled signal at the output and the smoothed signal at the input. It is *not* an approximation; it is exact. When the input is smoothed, we can compute *all* the intervening values without error and thus re-create the original wave-

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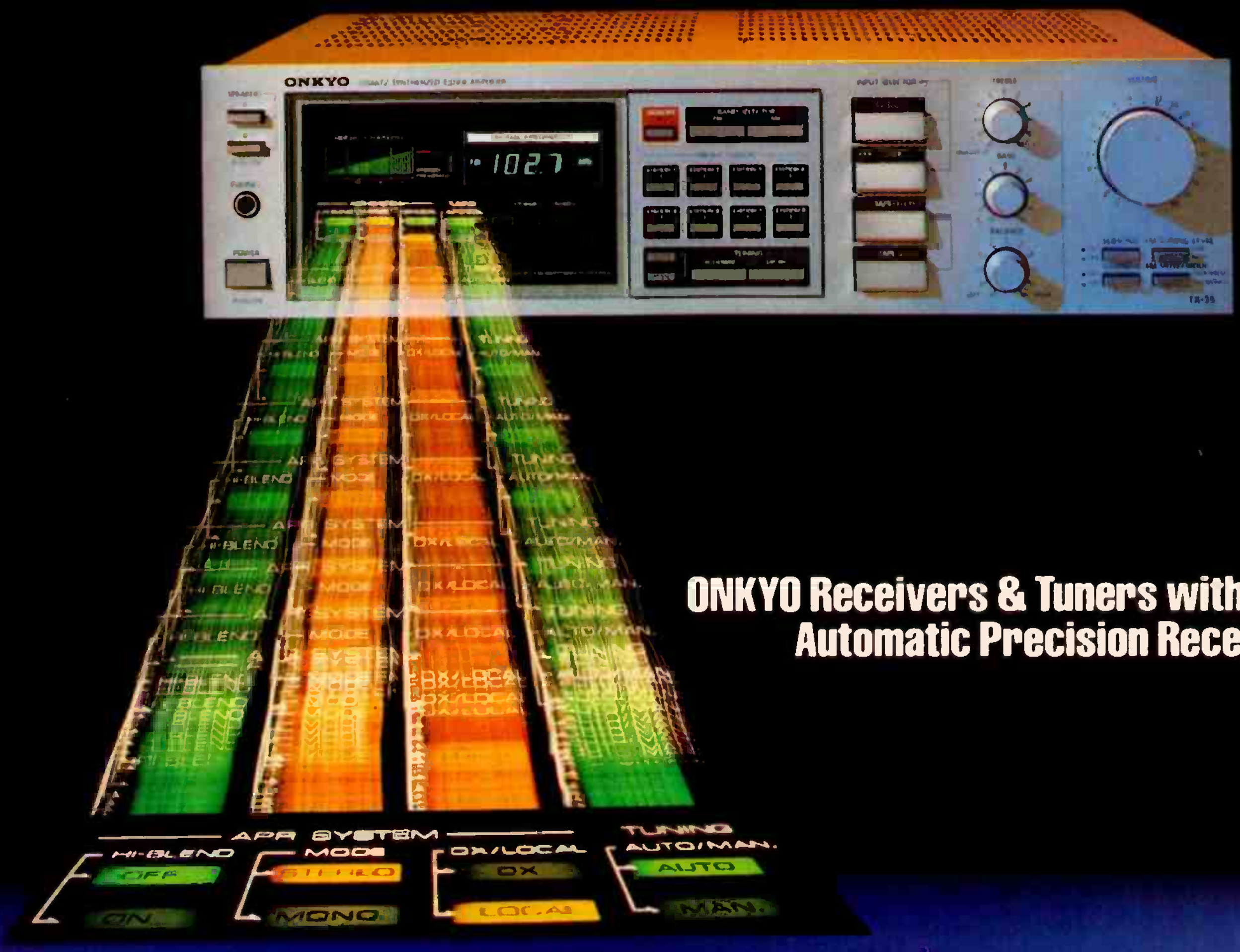

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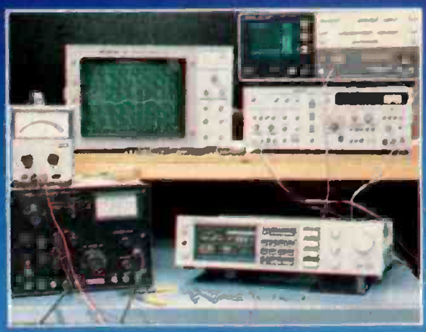

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Just as discrete frames of a movie create moving pictures, samples of a digital audio recording create time-varying music.

form smoothed at the outer limit of audibility. And fortunately, the sampling rate required to achieve this is well within our technology. The Nyquist sampling theorem shows that we must sample at a rate twice the highest throughput frequency to achieve lossless reproduction. Thus, for an input signal extending from 0 Hz to 20 kHz, we must sample at twice the highest frequency, or 40 kHz. And that is essentially what manufacturers have adopted, with a guardband to make life easier on their hardware engineers; they need a little leeway because the analog filters used cannot cut off as suddenly as the sampling theorem would like. Thus, a few thousand hertz are allowed for the filter to sufficiently attenuate the signal. An alternative approach to these so-called brick-wall filters is the oversampling technique, in which the sampling rate is effectively extended to permit less drastic filtering. Regardless of the hardware design, the Nyquist theorem must be observed, and sampling must occur at least at twice the highest signal frequency. Compact Disc players, for example, sample at 44.1 kHz. Thus, 44,100 times a second, a CD player outputs a value. With stereo, that's 88,200 times per second. And over the course of an hour, that's about 3.2 million samples. For a Compact Disc costing $15, this means you're paying about 0.0005¢ per sample—almost free. At any rate, the point is clear: A smoothed signal may be sampled, stored in discrete values, desampled, and reproduced without any loss.

Of course, this discussion doesn't close the book on sampling. Later, we will discuss exactly why we have to have a low-pass filter at the input of a digital music system (and at the output, too), what happens if we don't, and why some digital systems choose sampling methods which require rates in the megahertz range. And time sampling is only half the battle; a digital system must also be able to determine the actual numerical values it will use at sample time to represent the original waveform's amplitude; we'll byte into that question next month.

Oh, I almost forgot! I mentioned that time *seems* to be continuous. However, some physicists have recently suggested that, like energy and matter, time also might come in discrete packets. Just as this magazine consists of a finite number of atoms, the time it takes you to read the magazine might consist of a finite number of time particles called "Nows." Specifically, the indivisible period of time might be 1×10^{-42} seconds (that's a 1 preceded by 41 zeros and a decimal point). The theory is that no time interval can be shorter than this, because the energy required to make the division would be so great that a black hole would be created and the event would be swallowed up. If any of you out there are experimenting in your basements with *very* fast sampling rates, please be careful.

POLK'S SDA SPEAKERS

Designed-In Stereo

MATTHEW POLK

When made commonly available in the 1950s, stereo revolutionized the quality of reproduced sound. Originally conceived before the turn of the century, stereo reproduction was not made practical until the invention of a stereo disc recording and playback system at Bell Labs during the early 1930s. Due to the economic effects of the Depression and the turmoil of World War II, stereo was not introduced to the general public until the 1950s. In the interim, many fundamental works on acoustics and sound reproduction were written, but from a strictly monaural point of view. A framework of monaural theory was created, within which sound-reproducing equipment, mainly transducers, was designed and its performance judged. Stereo, in no small measure, owed its success to its superficial compatibility with existing monaural equipment and the fact that engineers could apply familiar monaural concepts to the design of equipment for stereo. The first stereo systems offered were, in fact, two separate and complete mono systems linked by a common volume control and fed by a "new" stereo disc player. The concept of stereo as "dual mono" reproduction continues to this day, especially as regards the design of loudspeakers. In addition, criteria for measuring the performance of the equipment also remain unchanged from the days of monaural reproduction.

Matthew Polk is Chairman of the Board and Vice President/Engineering of Polk Audio, Baltimore, Md.

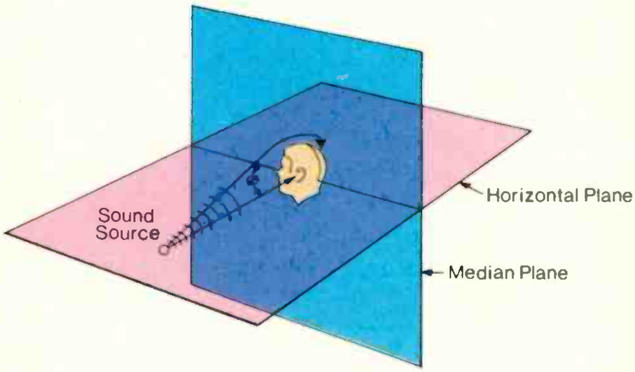
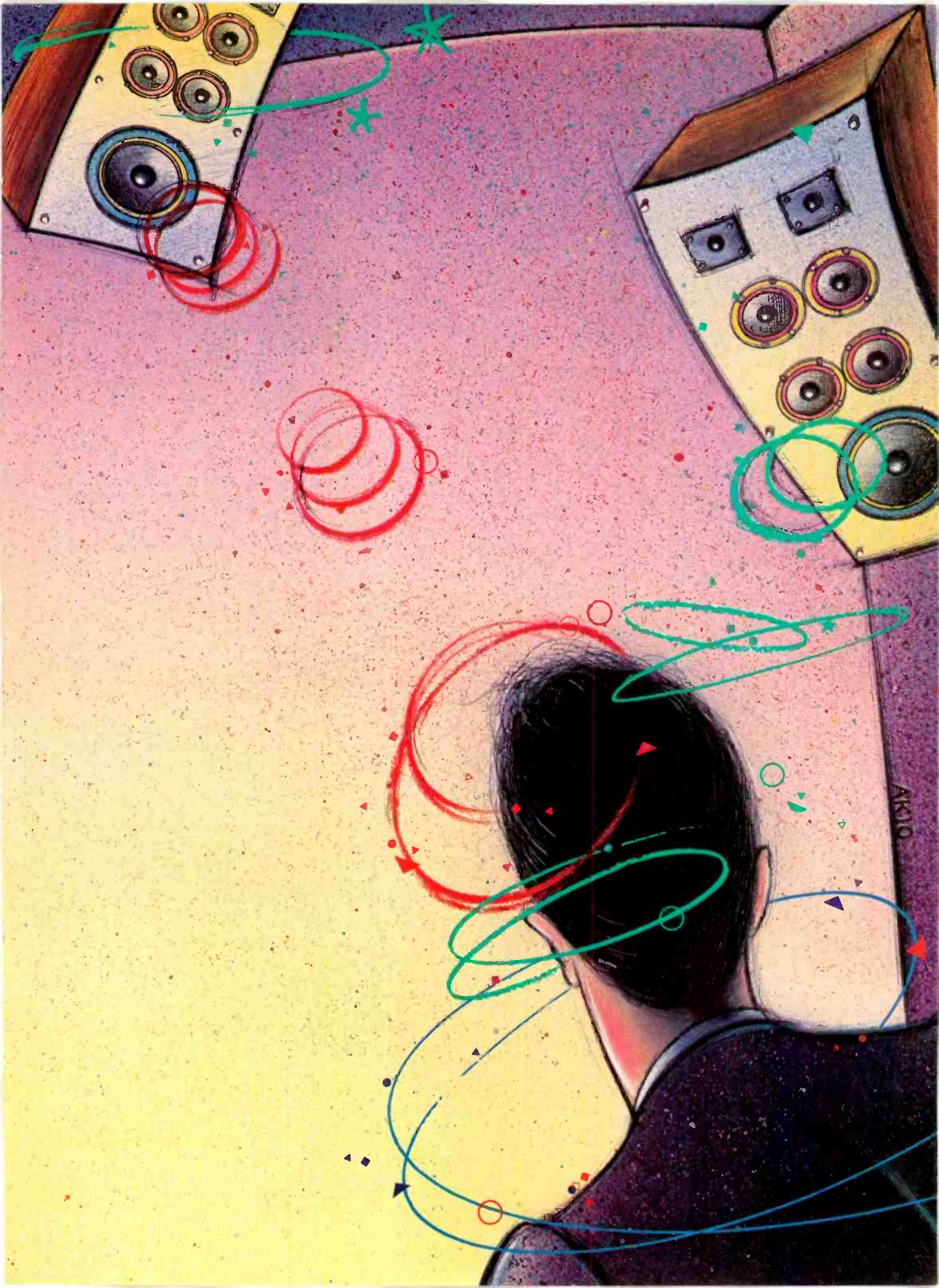


Fig. 1—Localization by Interaural Intensity Differences.

Mono Versus Stereo

Stereo is an essentially psychoacoustic phenomenon. That is, a listener is required for the sound localization process to take place. Early experimentation with reproduction of sounds in stereo revealed that the human hearing process perceived certain limitations in the sonic image produced by multiple speaker systems. Using essentially the same speakers as had been used in earlier mono systems, the sound field was perceived to be limited by the physical positions of the loudspeakers. Despite this limita-

Illustration: Akio Matsuyoshi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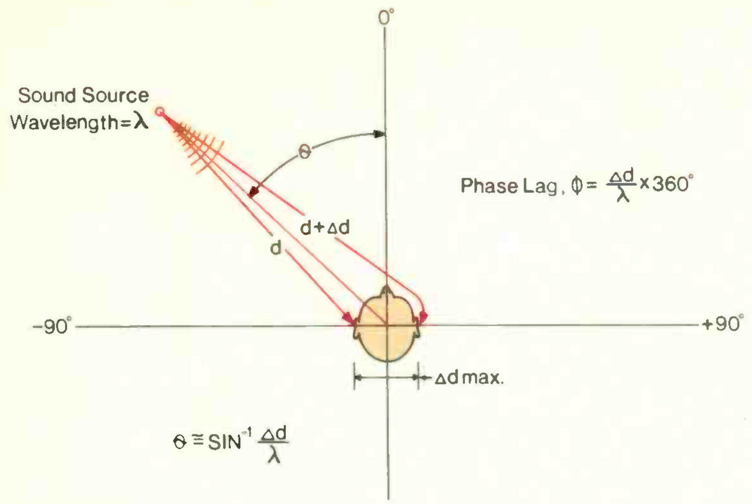


Fig. 2—Localization by Interaural Phase Differences.

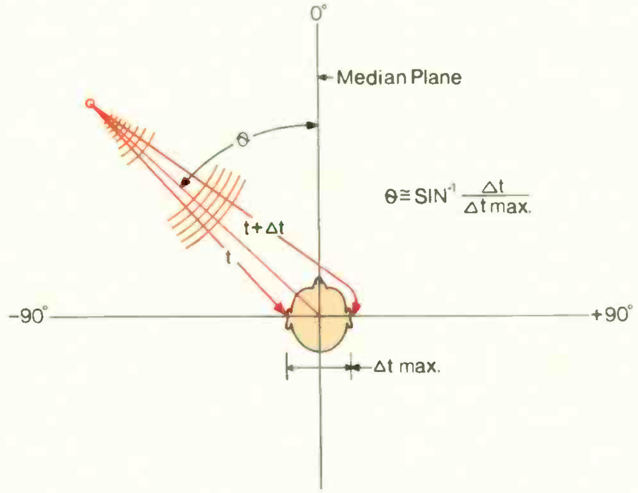


Fig. 3—Localization by Interaural Time Delay (ITD), where t is the time required for sound to reach the nearest ear and Δt is the delay in reaching the other ear, also known as the Interaural Time Delay.

tion, stereo imaging was a great improvement over the monaural image, and stereo became an unqualified success. Once stereo was firmly established, attempts were made to present a more complete sound field, the most notable of these attempts being the ill-fated four-channel systems of the '70s. In the mid-'70s, several of us at Polk began to wonder whether it was necessary to use additional channels to create a more realistic sonic image. We could show that, in theory, there was enough information contained in two normal stereo channels to define at least a 180° sound stage, and indications were that even more might be possible. This gave us confidence that a more complete sound stage might be reproduced from existing stereo recordings. Recognizing that the equipment being used to reproduce stereo was basically unchanged from monaural equipment, we saw that we would have to expand our concept of what the equipment was being asked to do. More than asking the equipment simply to reproduce an input signal, we proposed to make the equipment work with, rather than against, psychoacoustic principles, to re-create a sound stage in the listener's mind.

Directional hearing is primarily a binaural process. In simplest terms, the brain compares the sounds heard by the two ears and uses the difference to determine the direction and distance of the sound source. The differences between the sounds at the two ears are perceived in three ways: Intensity, phase, and arrival time. (See Figs. 1 through 5.)

In each case, the listener uses two signals, one at each ear, to localize the sound source. However, a stereo system has two speakers, and will provide the listener with a total of four signals (see Fig. 7). The sound from each speaker that crosses the listener's head to the opposite ear is known as interaural crosstalk. Experimenters in directional hearing were the first to be troubled by interaural crosstalk since its existence prevents the independent control of phase and arrival time of sounds at each ear. Interaural crosstalk was also thought to be the primary cause for the limitations on stereo imaging. The obvious solution was, of course, to use headphones, thereby eliminating the interaural crosstalk sound paths. This was a very satisfactory means to an end for psychoacoustic research, but it was not as successful in the reproduction of music. Although the elimination of interaural crosstalk seemed to give significant advantages to headphones, the phones still failed to produce a convincing sonic illusion. Clearly, there were numerous questions still to be answered about the stereo imaging process before approaching the final question of how the reproducing equipment should interact with the listener to produce a believable sonic illusion.

It seemed natural to focus on the last link in the reproducing chain, the loudspeaker, in an effort to develop the necessary understanding and control of the stereo imaging process. The fact that two loudspeakers could produce a phantom image between them was well known; the basic mechanism is shown in Fig. 7. The major difficulty here is that the two speakers will provide the listener's ears with four signals, whereas only two can be properly used. To avoid confusion, the hearing mechanism selects only one of the two sounds at each ear, according to a principle known as the precedence effect. First described in 1949 by Helmut Haas, the precedence effect simply states that only the first arrival at each ear will be used for directional location (see Fig. 6). It is not difficult to apply this concept intuitively to the stereo listening situation shown in Fig. 7. If both speakers produce the same sound at the same time, the first sound to arrive at each ear will be the direct sound from the speaker on that same side. The second sound at each ear will be the interaural crosstalk signal which has been delayed by traveling the extra distance across the listener's head. Since the direct sounds arrive first, they will be the only ones considered, and since they arrive coincidentally, and with near-equal loudness, the listener will perceive a phantom sound source as if it were centered between the speakers.

Although this situation was easy to analyze intuitively, we realized that more complex cases would be easier to approach with an appropriate mathematical notation. Two quantities characterize each of the signals arriving at the listener's ears, arrival time and intensity. Ignoring any electrical delays, the arrival time of the sound will be proportional to the distance traveled in reaching the ear. Relative intensity is easily expressed as a ratio. So, the signals reaching the ears can be expressed as a function of the time required to reach the ear, multiplied by the sound intensity relative to that at the other ear.

Accordingly, the left and right loudspeaker signals were considered as functions of time. If the time required for the sound from the left loudspeaker to reach the left ear is t, that signal at the left ear would be written as L(t). If the interaural time delay for the same signal to pass across the listener's head to the right ear is Δt_l, then the time required for the left signal to reach the right ear will be $t + \Delta t_l$. That crosstalk signal would then be written as $L(t + \Delta t_l)$. Using this notation, the signals at each ear in Fig. 7 will be:

Right Ear

$$Re = R(t) + L(t + \Delta t_l) \quad (1a)$$

Left Ear

$$Le = L(t) + R(t + \Delta t_l) \quad (1b)$$

From this point on, I will use Δt_l as the notation for the interaural time delay associated with the positions of the loudspeakers.

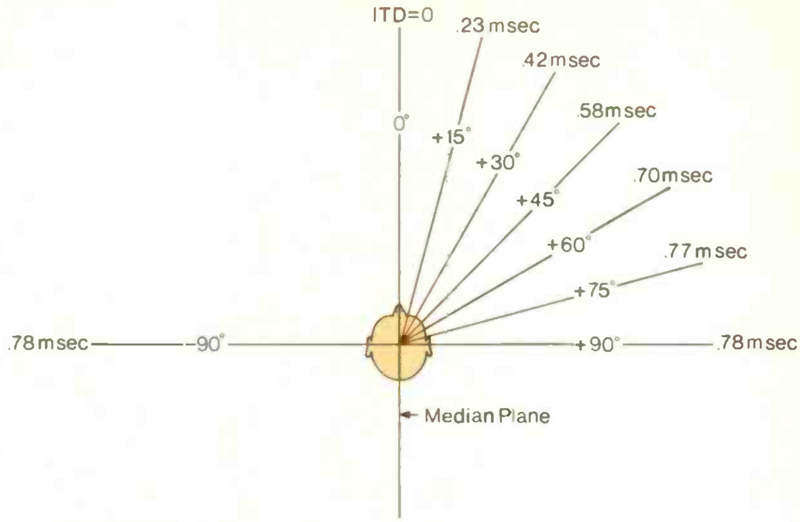


Fig. 4—Experimentally determined values for the interaural time delay for various angles of incidence.

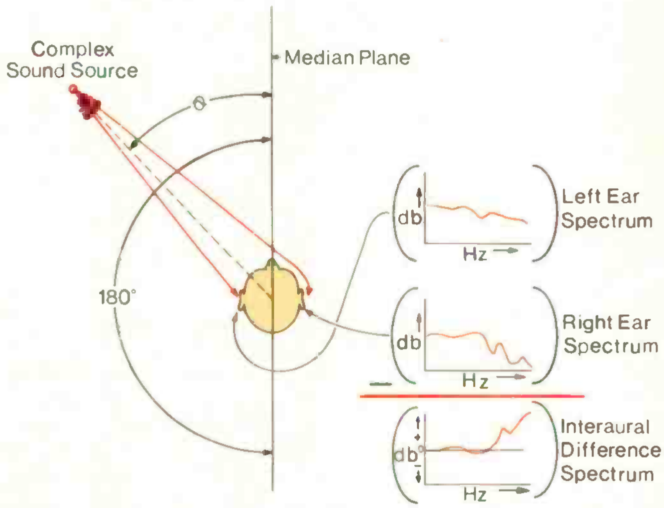


Fig. 5—The Interaural Difference Spectrum (IDS).

Interaural Crosstalk Distortion

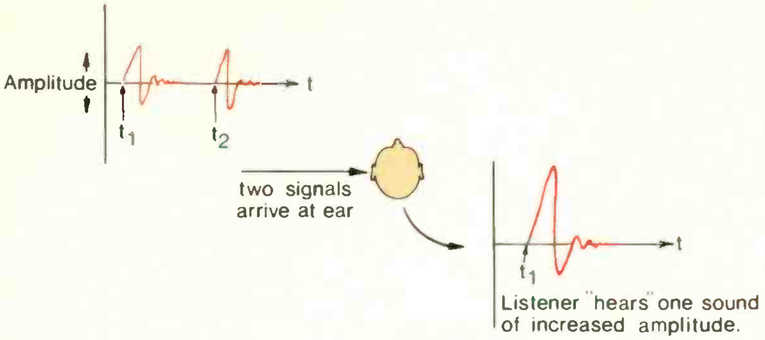
Two speakers will produce a convincing center image—but what happens as the image moves to the side? In Fig. 7, each ear receives two signals, the direct sound followed by the interaural crosstalk signal (Eq. 1). Turning the right speaker off would represent the most extreme leftward shift of sonic image on the basis of interaural intensity difference. Only one signal at each ear would remain:

$$Re = L(t + \Delta t_l) \quad (2a)$$

$$Le = L(t) \quad (2b)$$

In the absence of a right-speaker signal, the crosstalk signal becomes the first right-ear arrival and causes the sound to be perceived as coming from the left loudspeaker. The same would happen on the other side if the left-channel signal were turned off. The presence of the interaural crosstalk signals effectively cuts off the sound stage at the loudspeaker positions.

Suppose that one channel is delayed relative to the other. This also will cause the sonic image to shift. If right is delayed by Δt relative to left, we have:



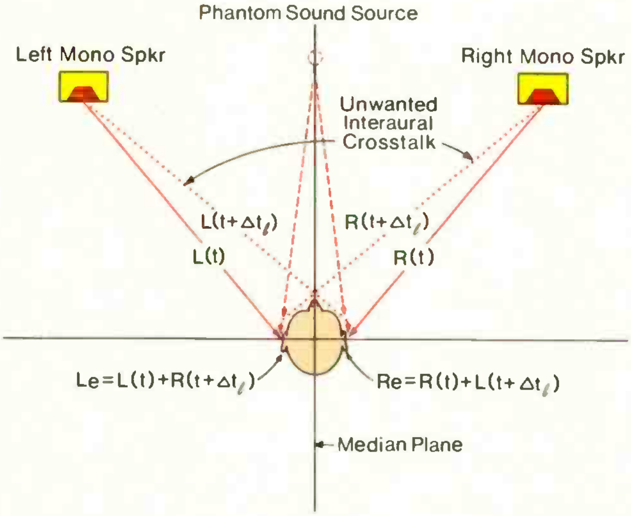


Fig. 7—Stereo localization of a phantom source. If left and right channels are of equal loudness and leave the speakers at the same time, the sound will seem to originate directly between the speakers.

$$Re = R(t + \Delta t) + L(t + \Delta t_l) \quad (3a)$$
$$Le = L(t) + R(t + \Delta t + \Delta t_l) \quad (3b)$$

As the right-channel delay increases, the sonic image will shift progressively to the left. As long as the delay of the right channel, Δt, is less than the interaural delay, Δt_l, for the left-speaker crosstalk signal, localization will be controlled by the right-channel signal. When the right-channel delay exceeds the crosstalk delay, the interaural crosstalk signal will become the first arrival and will again limit the image shift to the position of the loudspeaker. It began to appear to us that the existence of the interaural crosstalk signals caused the stereo image to be linked more to the positions of the loudspeakers than to the musical content of the stereo signals.

Next, we tackled the problem of headphones. Despite the fact that headphones eliminate interaural crosstalk, they still do not usually produce a convincing stereo image. We looked again at one channel delayed relative to the other. The signals at the ears for headphones were the same as those in Eq. (3), but without the crosstalk terms. Accordingly, for right delayed relative to left:

$$Re = R(t + \Delta t) \quad (4a)$$
$$Le = L(t) \quad (4b)$$

Assuming the left- and right-ear signals are of roughly equal intensity, localization of the sound will be entirely controlled by the time delay, Δt. The sonic image will shift to the left as the magnitude of the delay increases. When the delay becomes equal to the maximum naturally occurring interaural time delay, Δt_{max} (see Fig. 3), the sonic image will be shifted all the way to the left. If the delay between channels increases further, what will happen? The image can shift no further! The directional hearing mechanisms are closely related to the physical dimensions of the head and ears. The maximum naturally occurring interaural time delay (ITD) corresponds to the distance between the ears, roughly 6¾ inches. If the apparent ITD presented by the headphones is increased to correspond to a distance of several feet, the listener cannot respond in any predictable way. It would be like trying to locate the direction of a sound while holding long cardboard tubes against each ear.

As we saw in Eq. (3), the interaural crosstalk signals produced by loudspeakers limit the side-to-side image shift. But, in doing so, they also prevent the problem of non-localizable sounds that occurs with headphones. In Fig. 8, sound sources A through F are shown being recorded by two microphones set the same distance apart as a person's ears. Loudspeakers tend to localize everything as being in front. This is because the positions of the loudspeakers forward of the listener, obviously, must create the appropriate frequency spectra at each ear for forward localization. The bottom half of Fig. 8 shows the apparent positions of the sounds when played back over two mono loudspeakers. Due to the limitations we have just discussed, the sonic images of sounds C through E will "pile up" in the same direction as the left loudspeaker while the sounds A and B will have distinct images between the speakers.

Although this piling up of sound images is observed on many recordings, the prediction that the image could spread no further than the loudspeaker positions was initially disturbing. Sometimes a single pair of loudspeakers can produce a sonic image which extends slightly outside the bounds of the speaker positions. We realized that in each case where we had observed this, the speakers were placed very close to the listener and had some unusual directional characteristics which, we speculated, were contributing to a partial elimination of interaural crosstalk sound paths. This was not a measurable phenomenon, but it opened our minds to the idea that interaural crosstalk could be eliminated by acoustic methods.

The Full Potential of Stereo

Although binaural recording techniques have produced startling results with headphones, our goal was to reproduce a more complete sound stage from existing stereo recordings. Binaural recordings being in regrettably short supply, we realized that, whatever system was devised, it would have to cope with the broad range of available recordings. Consideration of prevalent recording practices within the context of the directional hearing mechanisms had revealed that the sound imaging abilities of both loudspeakers and headphones were limited, but in different ways. The width of sound stage presented by loudspeakers is limited by interaural crosstalk. The stability of the sonic image of headphones is limited by the lack of realistic directional cues. This meant that we would have to do more than eliminate interaural crosstalk. In addition, we would have to find a way for the directional cues contained in the recordings, such as they are, to reach the listener's ears in a manner acceptable to the hearing process.

Rather than trying to imagine what nature of speaker system might do all of these things and still sound good, it seemed more appropriate to try to capture our needs in mathematical notation. We wanted a system which, when balanced all to one channel, would provide the listener with a sonic image directly to the side, at 90°, but which would remain stable regardless of the interchannel delay. The signals required for a left-side signal would be:

$$Re = R(t) \quad (5a)$$
$$Le = R(t + \Delta tmax) \quad (5b)$$

Conversely, a right-side signal would be:

$$Re = L(t + \Delta tmax) \quad (6a)$$
$$Le = L(t) \quad (6b)$$

Adding these will give the more general case for both channels operating:

$$Re = R(t) + L(t + \Delta tmax) \quad (7a)$$
$$Le = L(t) + R(t + \Delta tmax) \quad (7b)$$

The second term at each ear looks very much like a crosstalk signal with an ITD equal to Δtmax, but in reality it is sort of a stabilizing dimensional signal which limits the perceived ITD to values within the naturally occurring range.

A Directional Hearing Primer

Directional hearing works mainly by comparing the sounds heard by the two ears of a listener. Specifically, three quantities are compared, intensity, phase, and arrival time. A sound arriving from one side of the head will be partially blocked in reaching the ear on the other side, giving rise to a difference in loudness between the two ears (see Fig. 1). The precise difference created depends both on the angle of incidence of the sound and on the frequency. The unique combination of loudness difference and frequency is linked to the angle of incidence of the sound in the horizontal plane. High frequencies are blocked more easily by the head, leading to greater loudness differences.

Intensity differences also play a role in locating complex sounds. For a given angle of sound incidence, each frequency has its own characteristic loudness difference. The sum of these will create an interaural difference spectrum (IDS) which corresponds to a specific angle of incidence (see Fig. 5). The exact characteristics of these difference spectra enable the listener to distinguish between sounds coming from the front and sounds coming from the rear.

In addition, the hearing mechanism is sensitive to the difference in relative phase of a sound which appears at both ears, though this is limited to continuous tones. A sound arriving from one side of the head experiences a time delay in reaching the farther ear. The listener senses an interaural phase difference which depends on the angle of incidence of the sound and on the frequency (see Fig. 2). However, for higher frequencies the phase lag may become greater than 180° and hence indistinguishable from a phase lead in the opposite direction. Appropriately, the hearing mechanism is relatively insensitive to phase differences above 900 Hz, a frequency whose half-wavelength is nearly equal to the interaural distance.

Transient sounds are localized mainly on the basis of the difference in arrival time at the two ears. Since most naturally occurring sounds are transient, this is both the most important and most accurate method of directional location. The interaural time difference (ITD) increases roughly as the sine of the angle of sound incidence up to 90° left or right of the median plane. At this point the sound must travel entirely across the head to reach the far ear, and the ITD becomes equal to Δtmax (see Fig. 3). Figure 4 shows experimentally determined values of ITD versus angle of incidence.

Finally, two related mechanisms, forward masking and the precedence effect, help the listener to discriminate between the many sounds reaching the ears at any given time (see Fig. 6). Basically, if two similar sounds of equal loudness arrive at one of the listener's ears separated by a short period of time, the listener will hear only one sound but of greater loudness than either of the individual sounds. The maximum interval for forward masking of musical sounds in a live room is about 35 mS. However, the maximum interval for masking of test clicks over headphones may be as low as 3 mS. The precedence effect is observed in the case of two signals at each ear, where the perceived direction of the sound source will be determined on the basis of the arrival of the first sound at each ear.

An example of phantom source localization from two speakers is shown in Fig. 7. Here, each ear receives two signals, one from each speaker. However, due to the precedence effect, only the first sound at each ear is considered. These are the direct sounds from each speaker, labelled L(t) and R(t). If the listener is centered between the speakers, these sounds will arrive at the same time. If they are also of approximately equal loudness, a phantom sound source will be perceived midway between the speakers.

In practice, most stereo image location takes place on the basis of intensity differences. This is due to the existence of interaural crosstalk signals which restrict the possible range of interaural time delays. As shown in Fig. 8, the location of phantom sound sources is limited to within the loudspeaker positions. *M.P.*

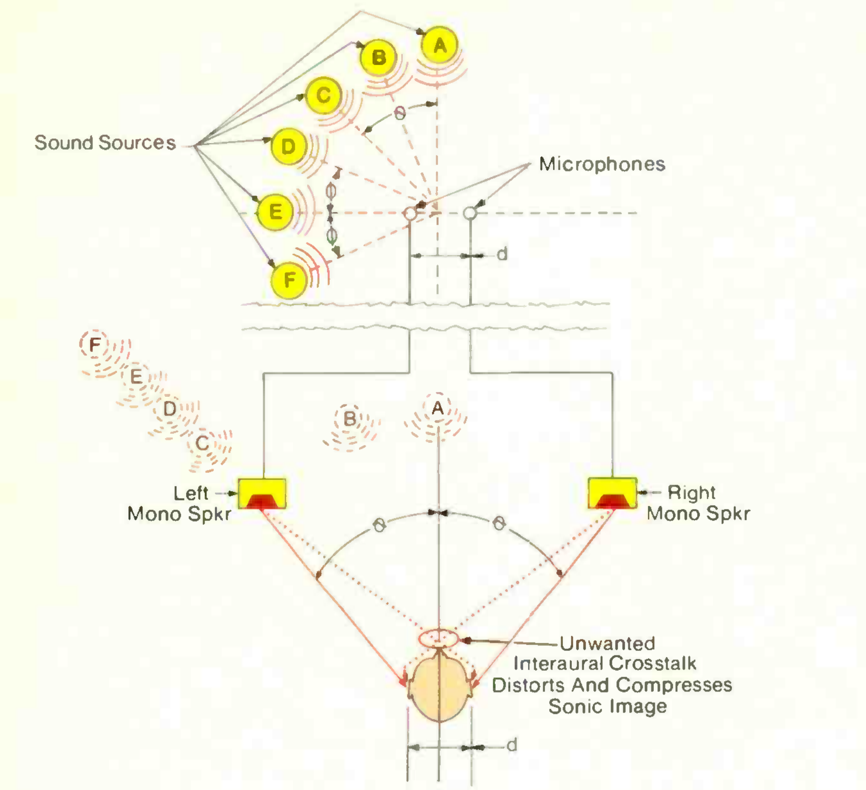


Fig. 8—Normal stereo imaging with sounds recorded by two microphones at locations A through F. When reproduced by two mono loudspeakers, the existence of interaural crosstalk will limit the phantom images to the locations shown in the lower half.

At this point, we made a decision that the sound sources, whatever they might be, should be placed in a forward position relative to the listener. This would eliminate the need for any complicated filtering to replicate the necessary interaural intensity differences for forward localization of sounds. However, if the sound sources were loudspeakers we would again be limited by the existence of interaural crosstalk signals. If we include the crosstalk signals in the expressions for the idealized signals above, we then have:

$$Re = R(t) + L(t + \Delta t_i) + L(t + \Delta tmax) \quad (8a)$$
$$Le = L(t) + R(t + \Delta t_i) + R(t + \Delta tmax) \quad (8b)$$

The second term at each ear is the crosstalk signal, which arrives earlier than the desired dimensional signals represented by the third terms. In order to take advantage of the later-arriving dimensional signals, the crosstalk signals would have to be eliminated or substantially reduced in loudness. Recalling that we had observed partial elimination of crosstalk signals due to unusual directional characteristics, and recalling the well-known phenomenon of low-frequency cancellation between two out-of-phase speakers, we guessed that it might be possible to acoustically cancel the interaural crosstalk signals. If this were done, the signals at the ears would be:

$$Re = R(t) + L(t + \Delta t_i) - L(t + \Delta t') + L(t + \Delta tmax) \quad (9a)$$

$$Le = L(t) + R(t + \Delta t_i) - R(t + \Delta t') + R(t + \Delta tmax) \quad (9b)$$

The new third term in each expression should be thought of as a phase-inverted equivalent of the crosstalk signal, timed to arrive at the correct ear at the same time as the original crosstalk signal. This was a very attractive idea, but we were not at all sure how it would be accomplished.

Timing the Delay

In order to cancel the crosstalk, a phase-inverted version of the sound could be acoustically delayed to arrive at the proper ear at the precise time to cancel the crosstalk signal. Creating the acoustic delay is no great trouble—you simply place the sound source farther away. It immediately seemed that if we had two pairs of acoustic sources, it would be possible to do this; the idea was to use one pair to cancel the crosstalk produced by the other. The cancellation source would have to be the same distance from the ear where the cancellation was to occur as the main source whose crosstalk signal was to be cancelled. In addition, the cancellation source should be placed so as to minimize cancellation of the direct sound reaching the other ear. Figure 10 shows an arrangement of drivers which allows the proper cancellation to take place. The signals arriving at the two ears for this arrangement would be:

$$Re = R(t) + L(t + \Delta t_i) - L(t + \Delta t') - R(t + \Delta t' + \Delta t_i) \quad (10a)$$

$$Le = L(t) + R(t + \Delta t_i) - R(t + \Delta t') - L(t + \Delta t' + \Delta t_i) \quad (10b)$$

Here $t + \Delta t'$ is the time required for the sound from the cancellation drivers to reach the nearest ear. So long as $\Delta t'$ is equal to Δt_i, the main driver crosstalk signals (second term) will be cancelled by the direct sound from the cancellation drivers (third term). The fourth terms are the crosstalk signals generated by the cancellation speakers themselves. For each ear they are the same signal as the direct sound from the main driver (first term), but arrive considerably later. Due to the precedence effect, they will not interfere with the localization process.

The placement of drivers shown in Fig. 10 also answered the requirement that the listening position be flexible. The center-to-center distance between the main and cancellation drivers on each side is the same as the distance between a person's ears, roughly 6¾ inches. As long as the listener remains on the axis between the two speakers and the cabinets face straight forward, sound from the cancellation drivers will arrive at the proper time to cancel the crosstalk signals regardless of how close or far away the listener sits. The remaining problem with this arrangement, however, was the lack of the stabilizing dimensional signals necessary to prevent the type of non-localizable sounds that can occur with headphones. Consider the effect of having no right-channel signal on this system:

$$Re = L(t + \Delta t_i) - L(t + \Delta t') = \text{nothing} \quad (11a)$$
$$Le = L(t) - L(t + \Delta t' + \Delta t_i) \quad (11b)$$

In nature, a sound is not normally heard in one ear only, and, presented with such a situation, a listener would not be able to assign an accurate direction to the sound. The solution to this problem was to use a stereo difference signal as both the dimensional and the cancellation signal. The difference signal has long been known to contain mostly ambient information, but in this case, we recognized that its components represented the two signals that we needed. The R − L signal was fed to the right dimensional/cancellation driver, and the inverse signal, L − R, was fed to the left dimensional/cancellation driver. In each case the positive portion of the difference signal is the stabilizing dimensional signal, while the negative portion is the cancellation signal. The entire system is shown in Fig. 11. The resulting signals at each ear would be:

$$Re = R(t) + R(t + \Delta t') + L(t + \Delta t_i) - L(t + \Delta t') - R(t + \Delta t' + \Delta t_i) + L(t + \Delta t' + \Delta t_i) \quad (12a)$$

$$Le = L(t) + L(t + \Delta t') + R(t + \Delta t_i) - R(t + \Delta t') - L(t + \Delta t' + \Delta t_i) + R(t + \Delta t' + \Delta t_i) \quad (12b)$$

Writing these out in plain language, without reference to the particular speakers, we have:

(Signals arriving at the ear) = (main driver direct signal) + (dimensional driver direct signal) + (main driver crosstalk signal) − (dimensional driver direct signal) − (dimensional driver crosstalk signal) + (dimensional driver crosstalk signal).

In all, each ear receives six signals. For clarity the equation has been labelled to indicate the driver from which the signals originate. Crosstalk signals break the median plane in reaching the ear in question, whereas the direct signals do not. The various time delays are defined as follows:

t = time required for sound from main driver to reach nearest ear.

$t + \Delta t'$ = time required for sound from dimensional driver to reach nearest ear.

Δt_i = ITD for main driver crosstalk sound to reach opposite ear.

$\Delta t'$ = ITD for dimensional driver crosstalk sound to reach opposite ear.

Δtmax = the maximum naturally occurring ITD.

At this point it appears helpful to explain each term. Term 1: The direct sound from the main driver will be the first arrival at the ear and will be the primary sound used by the localization process when the sonic image shifts for sounds on that side. Term 2: The positive component of the direct sound from the dimensional driver. Since it is the same signal as the first term, but arrives later, it will always be ignored by the localization process. Term 3: The main driver crosstalk signal; if it were not cancelled, it would limit the width of the sonic image. Term 4: The inverted component of the direct sound from the dimensional driver, otherwise known as the cancellation signal. It arrives coincidently with the main driver crosstalk signal and cancels it. Term 5: The inverted portion of the dimensional driver crosstalk signal is also a late arrival and will be ignored in the localization process. Term 6: The positive portion of the dimensional driver crosstalk signal, or dimensional signal; it insures a stable sonic image by placing an upper limit on the possible values of perceived ITD generated by the system.

Now, if we turn off the right channel sound as we did in Eq. (11), keeping in mind that for this arrangement $\Delta t'$ equals Δt_i, the signals at the two ears are:

$$Re = L(t + \Delta t_i) - L(t + \Delta t') + L(t + \Delta t' + \Delta t_i) = L(t + \Delta t' + \Delta t_i) \quad (13a)$$

$$Le = L(t) + L(t + \Delta t') - L(t' + \Delta t' + \Delta t_i) \quad (13b)$$

With signals at both ears, the listener will have no trouble localizing the direction of the phantom sound source. The perceived ITD will be the sum of $\Delta t'$ and Δt_i, which will produce a phantom image well outside the speaker positions as shown in Fig. 11.

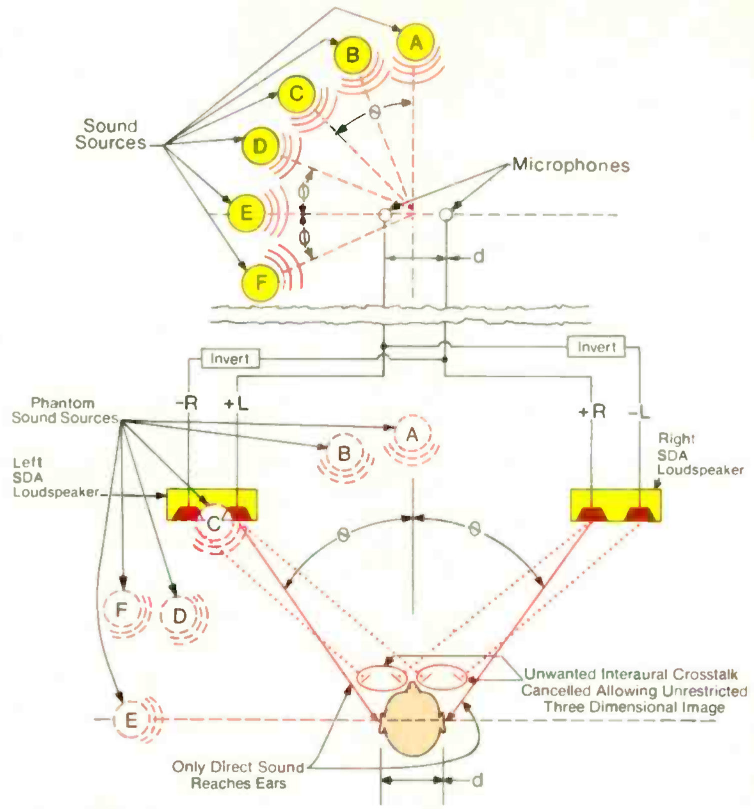


Fig. 9—Stereo dimensional imaging. If the interaural crosstalk signals are cancelled, the stereo stage will be unrestricted, allowing proper imaging of sound sources A through E. Sound source F will still be ambiguously located due to the lack of front-to-back directional cues.

The Stereo Dimensional Loudspeaker

The stereo dimensional speaker system described here in theoretical

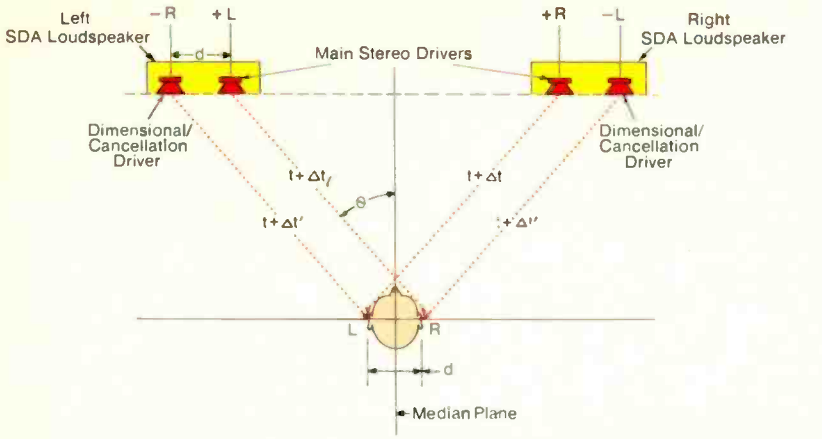


Fig. 10—Geometry for providing flexibility of listener location. Cancellation drivers are placed at the interaural distance from the main drivers and just outside them. The left cancellation driver receives the inverted right signal and vice versa. Proper cancellation of interaural crosstalk will occur for any location on the central axis between the speakers.

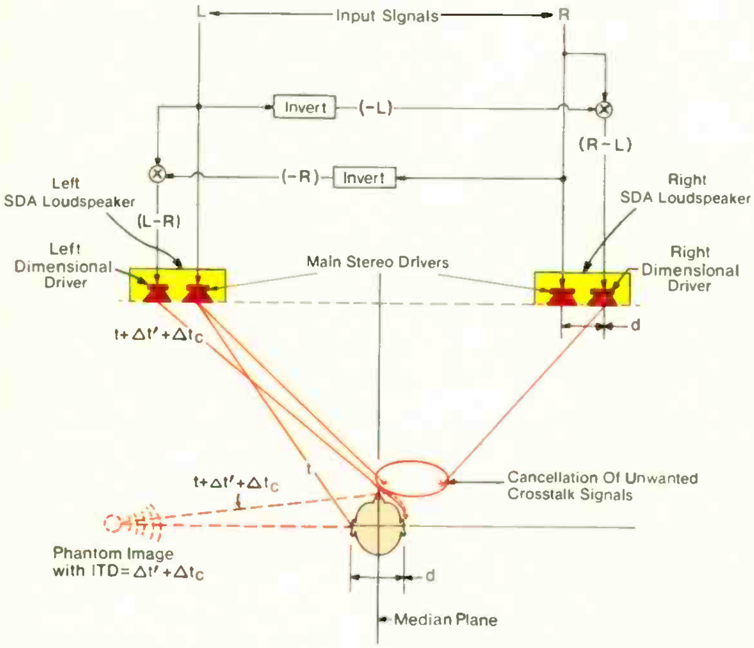


Fig. 11—Block diagram of complete stereo dimensional speaker system. Use of stereo difference signals at the cancellation drivers provides necessary image stabilization cues and limits the induced ITD of the system to naturally occurring values. Optimum sound-stage width occurs when the listener forms an equilateral triangle with the speakers.

terms seems to offer all that we had hoped for. Using the theory we had developed as a guide, we set about constructing prototypes of what we hoped would be the first loudspeaker system capable of realizing the stereo imaging and dimensional capacity of available program material. The prototypes were constructed with four identical sets of drivers for the main and dimensional arrays. The Polk 6½-inch mid-woofer was used since its size allowed, precisely, for the interaural spacing of 6¾ inches required between the main and dimensional arrays on each side. In addition, the wide frequency response of the driver would cover most of the frequency range crucial for directional location. We constructed a single cabinet to house both of the driver arrays on each side, which fixed the geometrical relationship between them. The left and right speaker cabinets were interconnected with a cable to provide the components of the stereo difference signal to the dimensional drivers, and a complex crossover matrix was designed to provide the correct frequency response for each array as well as the critically important phase relationships between them. As soon as the prototypes had been debugged, we hooked them up to some music. It was immediately apparent to us that the idea was a success.

As each set of prototypes was completed, tested and evaluated, more unsuspected pieces of information were uncovered. The finished system shown in Fig. 12 contains many important features discovered during the refinement process. For example, phase matching between the main and dimensional arrays was found to be necessary at surprisingly low frequencies, well below 100 Hz. As a result, the main and dimensional drivers of the finished system share the same acoustic volume, ensuring that they will see identical acoustic loading. However, the most significant realization coming out of the refinement process was of the complete inadequacy of our existing measurement techniques to assess the performance of this system. Although we have since made considerable progress in developing a more relevant measurement system, the human ear remains our most discriminating design tool.

Audible Benefits

The finished system, in many respects, has exceeded our expectations. The flexibility of listening position is greater than was expected, allowing not only front-to-back movement, but substantial side-to-side tolerance as well. Analysis of signals at the ears for listening locations off the central axis somewhat justifies this, but predicts a more dramatic image shift than the "changing seats in a concert hall" effect actually observed. More easily explained is the observation that phantom sources localized to the sides seem to remain stationary as the listener moves away from the system, rather than moving with the listener. As we recall from Fig. 11 and Eq. (13), the perceived ITD will be the sum of Δt' and Δt_l. Due to the geometry of the system, this quantity will decrease as the listener moves away, causing the sound stage to narrow and preserving the perspective of greater distance. Less explainable, however, is the experience of having some sounds seem to actually originate from the rear of the listening area. Since this occurs primarily on pop recordings, we can only speculate that the recording studio has inadvertently created an interaural difference spectrum appropriate for rearward localization. Nevertheless, the effect is startling.

The newly designed Polk SDA systems are, we think, the world's first true stereo loudspeakers, strongly realizing the capabilities of the stereo medium. The unique ability of the system to place sonic images over an unrestricted stereo stage allows the listener to hear the recorded instruments or vocalists firmly located in the original acoustic environment. In addition, due to the system's preservation of directional information, each sound becomes better separated and more distinct. Crucial to the accomplishment of these sonic goals has been the elimination of interaural crosstalk by effectively cancelling the sounds indicating the loudspeaker positions and replacing them with the correct directional signals for the recorded sounds.

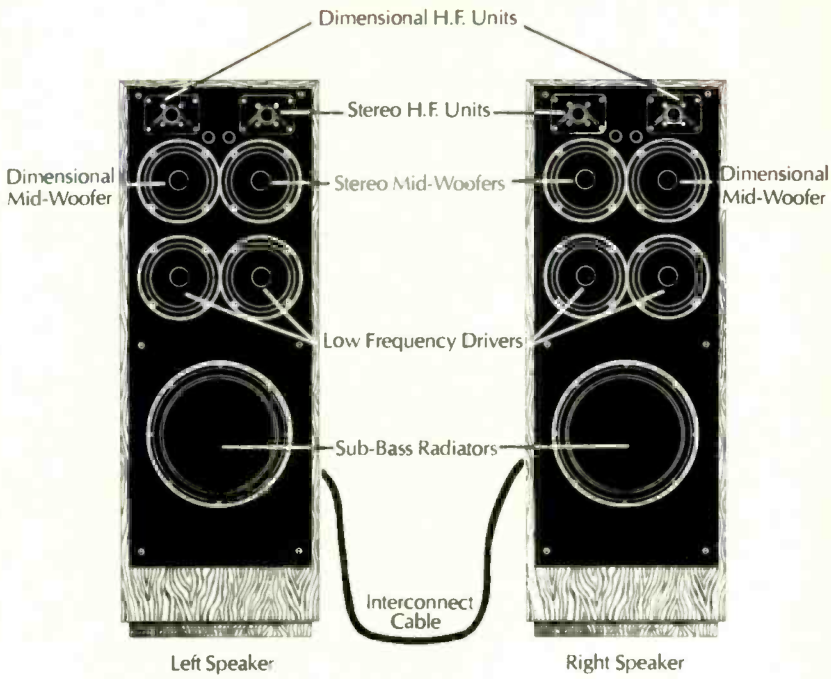


Fig. 12—Physical configuration of the finished system. The four tweeters and four upper 6½-inch mid-woofers form the main and dimensional driver arrays. The inside array in each cabinet is the main array, while the other is the dimensional array. The two lower 6½-inch drivers, together with the passive radiator in each cabinet, operate below 75 Hz.

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SPEAKER IMPEDANCE

More Complex Than One Number

RICHARD C. HEYSER

A loudspeaker's actual impedance can vary widely from the specified value. A close look at the speaker's complex impedance can reveal problems the designer ignored.

To impede means to obstruct or hinder. The electrical impedance of a loudspeaker is a measure of the amount by which it impedes the passage of current. The higher this impedance, the more voltage it takes to pass current through the speaker. Impedance is measured by determining the voltage required to pass a fixed amount of current.

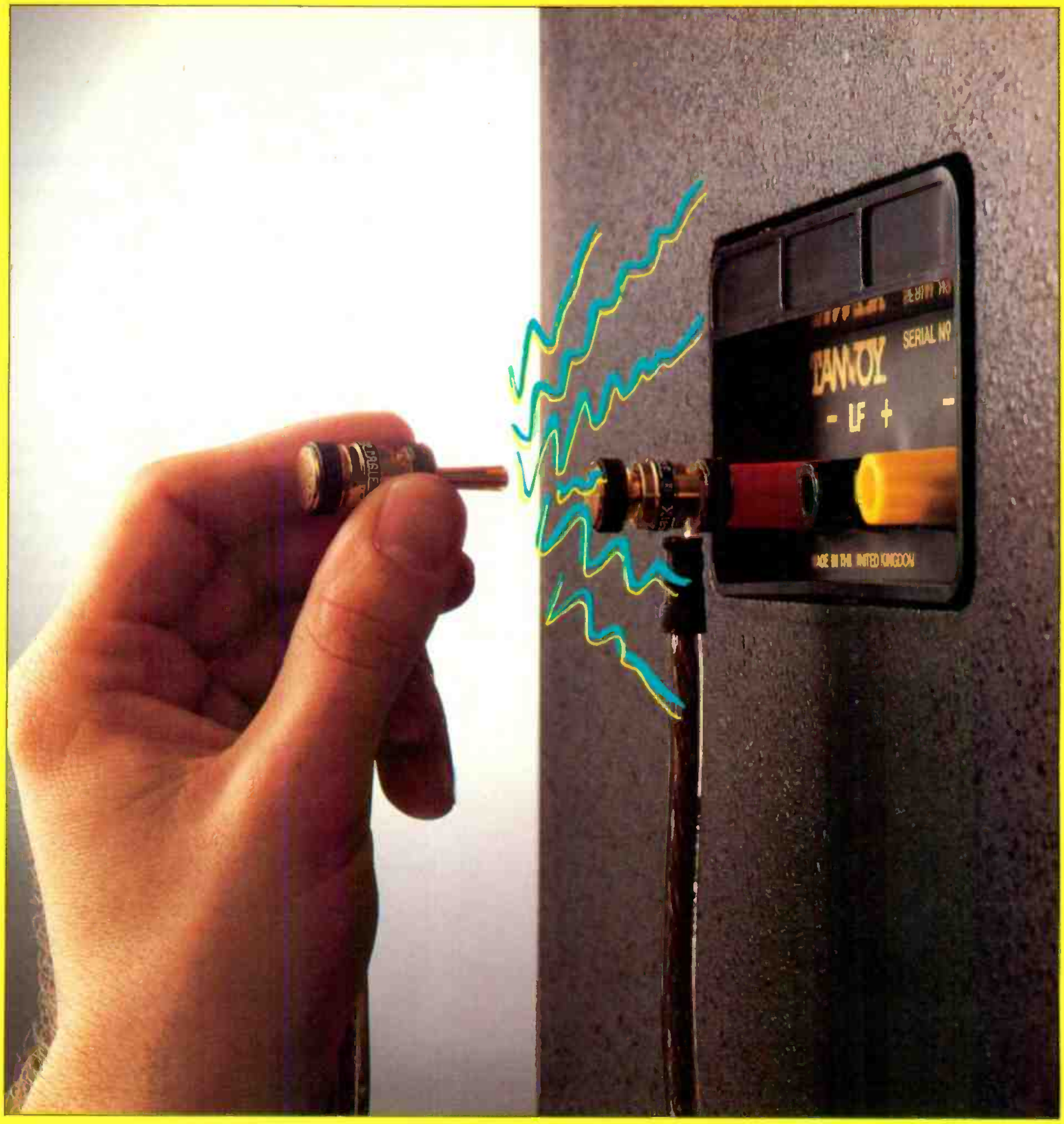
It is important to know the loudspeaker impedance because this determines the type of effort which the power amplifier must exert in order to deliver clean sound. In addition, the subtle wiggles and bumps on an impedance plot often give telltale clues concerning how well or badly the loudspeaker has been designed.

Impedance comes in two types: A resistance part and a reactance part. This is because a loudspeaker can temporarily store some of the energy it gets from the amplifier, as well as dissipate that energy in the form of heat and sound. The part that represents dissipation is resistance; the part that represents storage is reactance. The unit of measurement is the ohm. One ampere of current produces one volt drop across one ohm impedance.

Audio produces two separate impedance plots for our loudspeaker reviews. The first is the total amount of impedance as a function of frequency. Figure 1 is a typical example of the form such a plot may take. The second plot is a breakout of the resistance and reactance, and it may take the form shown in Fig. 2. Both plots describe the same loudspeaker impedance, but from different perspectives.

Before describing how these plots are useful, there is a possible point of confusion which must be clarified. It is a relic of a bygone era that we still try to use a single number for the impedance of a loudspeaker, usually a resistance value of 4, 8, or 16 ohms. Modern loudspeakers, particularly those which incorporate separate units to cover different parts of the frequency range, have anything but a constant impedance. The actual impedance may vary all over the place, yet the specification sheet may, for example, still call it an 8-ohm speaker. That single value is nothing more than a nominal number to be used for crude comparison purposes. The lower the number, the more current needed to deliver the same amount of power. The actual impedance is what we measure and plot for you. That single-number impedance bears a relationship to actual impedance somewhat like that which the EPA mileage estimate bears to what you will actually get from your new car.

Another very important point to bear



in mind is that an impedance plot is just that, an impedance plot. It is not a plot of sound. Wiggles and bumps in the impedance plot do not signify lack of smoothness of the sound from that loudspeaker.

The impedance plot of Fig. 1 serves two useful purposes: First, it identifies the lowest net impedance that the power amplifier must drive, and second, it shows the way a loudspeaker's net impedance changes with frequency. The smallest wire size to use in hooking up a loudspeaker can be determined by minimum net speaker impedance and how wildly that impedance changes with frequency. This minimum impedance also tells us whether it is safe to hook additional extension loudspeakers to the same power amplifier. Circumstances vary, so the narrative portion of each review is intended to provide user guidance in such matters.

Often, a loudspeaker will have knobs or switches that can be used to change the balance of sound. These adjustments may change the impedance. If that happens, we generate separate impedance plots for each major combination of adjustments.

The complex impedance plot, shown in Fig. 2, is aimed straight at a prime audio question: Why do certain

Photograph: Carl Zapp

The subtle wiggles on an impedance plot often give telltale clues as to how well or badly a speaker has been designed.

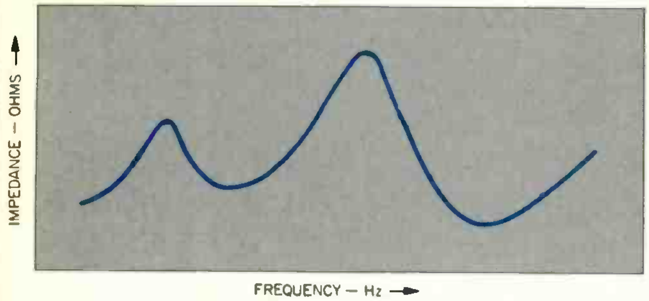


Fig. 1— Conventional plot of the magnitude of impedance as a function of frequency.

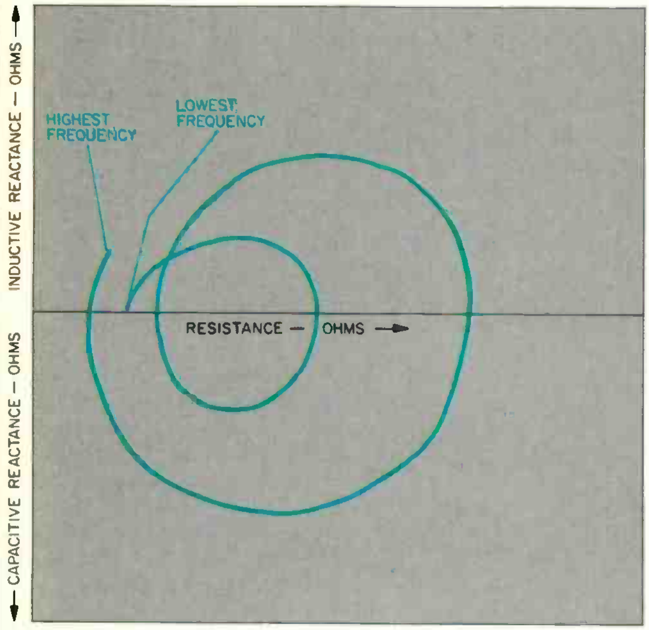


Fig. 2— The same speaker as in Fig. 1, but now plotted as a complex impedance as a function of frequency.

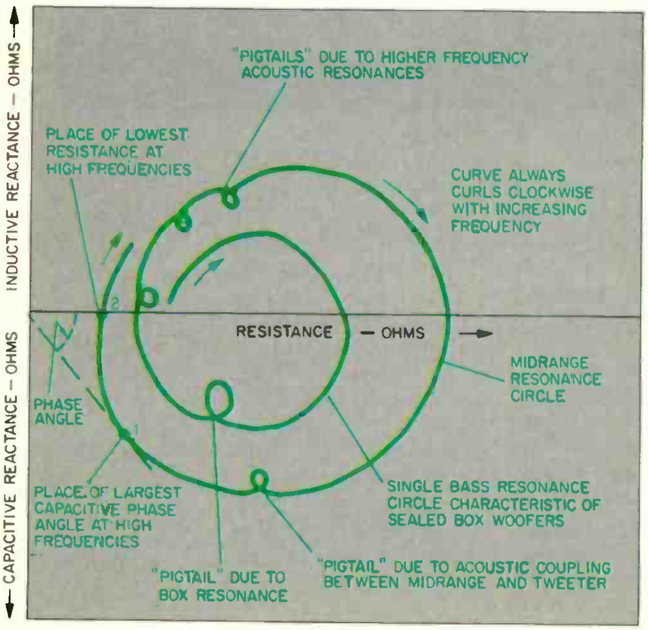


Fig. 3— Some of the things to look for in a complex impedance.

power amplifiers sound bad with some loudspeakers?

At least some part of this problem must be due to the nature of the load which the loudspeaker presents to a power amplifier. During musical passages, as current passes into and out of the loudspeaker, amplifier circuitry must take up the voltage difference between a steady power supply in the amplifier and the voltage which the speaker needs for that current. Energy flow between amplifier and speaker is expressed by the instantaneous voltage and current. If a loudspeaker were a pure resistance load, energy would only pass from the amplifier to the speaker, where it could be converted to heat and sound. But a loudspeaker is not a pure resistor. It grabs energy, stores it, and kicks some of it back at the amplifier as that amplifier attempts to maintain control of signal voltage. Some loudspeakers aggressively fight the power amplifier, kicking and screaming their defiance through complicated musical passages. The only time we are aware of that battle is when we hear something wrong in the sound coming out of the loudspeaker.

Figure 2 plots the reactance, as well as resistance, which the loudspeaker presents to a power amplifier. The amount of inductive reactance, in which the loudspeaker tries to prevent any change in current, determines the height of the curve above the horizontal axis. The amount of capacitive reactance, in which the loudspeaker tries to prevent any change in voltage, determines the level of the curve below the horizontal axis. The horizontal axis plots the resistance, or dissipative, component.

The complex impedance plot looks like a string which has been dropped on the paper. In a sense it is a string, a string that traces out the impedance we encounter as we progress through the frequency range.

The string always curls clockwise as we progress upward in frequency. The plot looks like, and is, circles on circles. The circle form is a fundamental expression of energy exchange. There will be one complete circle component for each condition of energy resonance. As an electromechanical device, the loudspeaker will have a number of impedance resonance modes.

A complex impedance plot can often show why an amp will sound bad with certain speakers, ones which fight the amplifier.

Woofers show fundamental signatures on this plot. A sealed woofer will have one bass resonance circle, while most vented woofers will have two. This can reveal information that even the loudspeaker designer was not aware of. For example, a poorly sealed system may have an air leak. Can't fool Mother Nature; the leak will show as an unexpected circle in this measurement. This is a clue to degraded low-frequency performance.

Another situation is the distinction between the nice, simple resonance, generally assumed by designers, and the real world. We know the woofer pushes air and makes sound; the sides of the box also push air and make sound, but that's not what the designer had in mind. The effect of box sound is often visible in our review data as a deformation of the otherwise perfectly circular form of simple bass resonance (see Fig. 3). This will also show up as an apparent clockwise rotation about the origin of the plot by the bass resonance circle.

If the lower bass-resonance frequency in a vented system falls much below 15 Hz, watch out. Subsonic audio components, such as those due to record warp and tonearm resonance, might cause unnecessarily large cone excursions at high sound levels. The sonic effect can be pure mud. It is not the loudspeaker's fault as much as it is the program material's. When it occurs, use a rumble filter to cut out subsonic components.

Sometimes separate drivers in a system will talk to each other, like chatty neighbors over a backyard fence. Acoustic coupling between drivers is always unavoidable, but if improper crossover design allows two or more drivers to carry on simultaneous conversations in the same frequency range, each driver will hear the other talking and show it as a change in impedance. Small extra loops, which look like pigtails added to the string, are telltale clues to this interspeaker chitchat.

Progressing upward in frequency, the string shows wanted, as well as unwanted, resonances. Space does not permit complete discussion of everything to look for, but one condition can cause amplifier distress. Most constant-voltage amplifiers drive resistors and inductive loads better than they do capacitive loads, particularly at high frequencies. Figure 3 illustrates what to watch for. At high frequencies, where slew rate becomes important, point 1 on curve A is a harder load to drive than point 2 because the current demand leads the voltage being controlled. This means that the amplifier must deliver its peak current demand prior to the time that the voltage waveform reaches its peak value. The worst case is reached when the peak current occurs at the same time the voltage is passing through its maximum rate of change. This would be a purely capacitive load, represented by a complex impedance point on the negative vertical axis. Under this condition, the power amplifier must deliver maximum current when there is a very low instantaneous voltage on the speaker but the highest waveform slew rate. (The term slew, or slue, means to turn or swing around. Early gun-control servomechanisms were required to slew the gun mounts at high rates to follow precise pointing signals from the fire-control radars. There was a maximum swinging rate, or slew rate, which the amplifiers could follow and maintain complete control of the gun mount. Thus, by devious pedigree, the term slew rate came to mean maximum voltage rate which an amplifier could deliver.)

The smaller the net impedance at point 1, the harder the drive requirements. If this condition prevails in the upper registers, brass, strings, and vocals can go harsh at high sound levels.

A loudspeaker makes a very good microphone. In the case of the conventional moving-coil loudspeaker system, every sound in your listening room is picked up by the loudspeaker. The sounds are converted to current, which the loudspeaker tries to drive back into the power amplifier. It does this even when the power amplifier is supplying an audio program. If you could hook up a sensitive ammeter to the loudspeaker wires, and could "buck out" the simultaneous audio program, it would be possible to measure sound in the room at the same time that music was being played. This is not a ridiculous idea and can actually be accomplished under special conditions.

Of course, the usual situation is that the sound in the room is principally caused by the loudspeaker itself. In that case, the "microphone" pickup current is related to the "program" current in the speaker wires. When we apply a voltage to the terminals, and measure the resultant current that flows, we are measuring current passing from the amplifier into the loudspeaker as well as current passing back to the amplifier. If we pause for a moment and think about it, that is exactly the type of information contained in the impedance measurement.

Therefore, loudspeaker impedance contains a great deal more information than is assumed by the manufacturer when he states ". . . this is an 8-ohm system." Some of the information can be downright embarrassing to the manufacturer, such as when it shows that his "sealed" box has an unwanted leak, or when it shows that the midrange and tweeter acoustically talk to each other at the same time over a broad band of frequencies, or when it shows that his "solid" walnut-covered enclosure resonates like a bass drum at some unwanted frequency.

Some of the information tells us about the acoustic coupling between the loudspeaker and the room, and how good (or bad) the acoustic match may be. Because of that, I try never to measure impedance with the speaker facing a hard, reflecting surface. If I have any suspicion that some of the squiggles on the complex impedance plot are caused by the measuring room, I will move the loudspeaker and repeat the measurement.

Because present-day loudspeakers are designed to produce sound pressure based upon constant voltage applied to the speaker terminals, it would make sense to measure the amount of current that is drawn at this rated voltage. This is just the inverse of impedance. Whereas impedance is a measure of the voltage drop produced by a fixed amount of current, admittance is a measure of the current drawn when a fixed voltage is applied. In the simple case of the loudspeaker, admittance is the inverse of impedance.

Personally, I would prefer to measure the complex admittance of a loudspeaker, since this tells me how much current is drawn if I put, say, 4 V across the speaker terminals at 1 kHz. Speaker current is then the product of a sig-

The complex impedance will often show information that even the speaker designer was not aware of.

nal voltage times a factor called admittance. Instead, I must remember that speaker current is equal to signal voltage divided by the factor called impedance. I am lazy, and it is mentally much easier for me to multiply than to divide. But over half a century of tradition has been developed around the concept of loudspeaker impedance, and I grudgingly bow to this tradition in quantifying the driving-point properties of loudspeakers. Besides, that is the property cited by the manufacturer when he sells you the product, and we are trying to see how well he meets his commitment to you.

Admittance, like impedance, *must* have two parts, and these parts are related to dissipation and storage of energy. The part related to dissipation is called conductance, and the part related to storage is called susceptance. The units of measure for these parts is the inverse of the units of measure for impedance. A 1-ohm resistance corresponds to a 1-siemens (we used to call it "mho," for ohm spelled backward) conductance, and an 8-ohm resistance corresponds to a ⅛-siemens conductance.

In defense of the impedance measurement, impedances in series are added. Thus, a ½-ohm speaker wire adds ½ ohm to the impedance seen by the amplifier. And there is, technically, nothing contained in an impedance measurement that is not contained in an admittance measurement, and vice versa. The reason I bring up the subject of admittance is to describe another aspect of our loudspeaker measurements in *Audio*.

It is no secret that I have tried to present a format of data, in the guise of the complex impedance plot, which can be of great value in the design of better power amplifiers. Loudspeakers are not resistors, and those who design power amplifiers to drive resistor loads exclusively are simply fooling themselves. Furthermore, no two different loudspeaker designs have the same impedance (or admittance) properties, and as loudspeaker designs evolve over the years, the type of loads which they present to amplifiers also evolves.

The output stages of the amplifier, which must take it on the chin when driving a loudspeaker, have their safe and their unsafe operating regions. It is no great difficulty for a power amplifier designer to produce a plot of exactly what regions of load current are safe under various signal conditions. When I say "safe," I am referring not only to whether or not the transistor, FET or whatever will blow up, but how the feedback margin and slew rate of the amplifier are affected.

Don't think, for example, that the feedback factor of a power amplifier is not affected by the load which it drives; it is. Consider, for example, what happens to the feedback signal if you short-circuit the output terminals; those amplifiers whose feedback is obtained from the output terminals are then operating in an open-loop condition. That amplifier which operates essentially without distortion into a 4-ohm resistor may have substantially altered distortion properties when driving a 4-ohm complex load.

If the amplifier designer plots the value of allowed complex impedance versus drive level, drive duration, and feedback properties, including internal slew-rate limitations, he need only overlay a plastic transparency of *Audio*'s impedance plot to see whether his amplifier will cut the mustard with that particular speaker. Furthermore, an overlay of the corresponding complex admittance diagram will indicate such niceties as peak instantaneous current under conditions of XYZ speaker cable interconnect.

The complex impedance (and admittance) plot is sufficiently difficult to perform that the vast majority of loudspeaker manufacturers do not, themselves, know what the complex load properties of their products are. Therefore, *Audio* publishes these measurements. After many years of such published measurements, I believe that there can be no excuse for a power amplifier designer who produces a product optimized for a mythical load resistor. One intent of the complex impedance measurement is to archive data which can allow for better audio amplifier design, and thus the importance of the measurement extends far beyond the particular review in which it is published.

As a final consideration, loudspeakers are notoriously nonlinear in their electromechanical properties. Impedance (and admittance) is a function not only of instantaneous drive level, but of the immediate past history of signal which has been applied to the speaker. They are non-Markovian in their signal-handling properties. (A Markov process is one in which the immediate present is strictly dependent only upon the immediate past and statistically dependent upon the more distant past. If the value of a signal from the distant past has an effect on the manner in which the present value is to be processed, other than an additive memory contribution, then the processing is non-Markovian.) There are recoverable hysteretic effects in the drive properties which modify the impedance at a particular drive level. And there are nonlinear suspension properties which can cause a woofer cone to drift in and out of its average no-signal position under special combinations of excitation. These all modify the nature of the load which the loudspeaker presents to a power amplifier.

Due to space limitations, the *Audio* measurements are those of the small-signal linear impedance. I watch for nonlinear drive properties during the higher power distortion measurements which I also perform on the loudspeaker. If I spot problems, I comment on them in the narrative part of the review.

Let me wrap up this little discussion by commenting on something that is true of all of the measurements in *Audio*'s reviews. The measurements are technically difficult to perform and require highly specialized equipment. But they are world-class measurements, not simply something that happens to be available in a particular piece of commercial test equipment. The data is presented in such a way as to be of value to readers at several levels of audio involvement. First, a narrative is provided for those who could not care less about highly technical matters and only want to know what to watch out for in nontechnical terms. These narratives also include more technical matters that are discussed in relation to the measured data which is supplied as plots. And, finally, the technical content of the measurements is sufficient to be of value to professionals who design the products which you listen to. They, too, read *Audio* magazine.

At Last— Stereo TV!!!

LEONARD FELDMAN

Illustration: Marc Yankus

The audio industry has been waiting for it for more than five years. The TV broadcast industry has wanted it much longer than that. It's been available in Japan for nearly six years and in West Germany for nearly four. "It" is stereo TV, and by the time you read this, TV broadcast stations will be getting ready to go on the air with this new audio service, and TV receiver manufacturers (not to mention leading audio manufacturers) will be feverishly gearing up to produce the hardware needed to receive stereo transmissions.

While there's no point in rehashing the reasons that stereo TV has been so long in coming to the United States, it is important to note that we in the U.S., having finally arrived at a decision and selected a system, will more than likely benefit from the long delay. As a result of the long deliberations which led to the selection of a system, we will probably end up with the highest quality of audio possible within the present NTSC broadcast standards. Furthermore, unlike the Japanese or the German TV systems, we will be able to enjoy *simultaneous* stereo and bilingual or secondary audio programming. Bilingual soundtracks may well prove to be as important as, or even more important than, stereo sound for TV. Many regions of the United States

Stereo TV has been long in coming here, but we'll probably get the best sound possible with NTSC as a result.

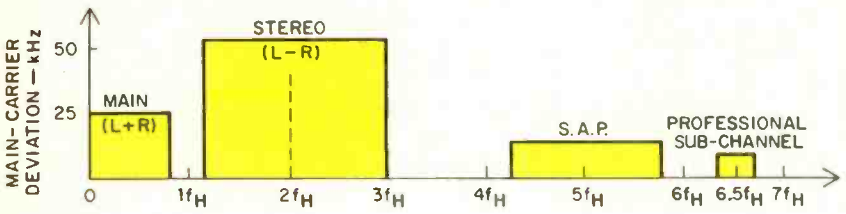


Fig. 1—Base-band frequency allocations of Zenith multi-channel TV sound system; f_H is the TV horizontal-line frequency (15,734.26 Hz).

are populated by large ethnic minorities whose first language is not English, and these viewer/listeners will be able to enjoy their favorite TV programs accompanied by soundtracks in their native languages. This will enlarge the stations' audiences, raising their ad revenues (especially if the commercials are also bilingual). Stations expect to make money on this, but not to make much on stereo. Luckily, both stereo and a second language can be transmitted at once; in the Japanese multi-channel TV audio system, the broadcaster must choose either a stereo soundtrack or a second language soundtrack.

Last December 22, various segments of the video industry assembled in Washington to vote for one of three multi-channel audio transmission systems that had been undergoing tests for several years. One of the major decisions to come out of the initial series of tests was that there was an obvious need for noise reduction or "companding." Experiments with "compatible companding" revealed that some companding could be tolerated by people owning older TV sets not equipped with the necessary expander circuits, but that it was difficult to devise an effective companding system without altering sound balance for those owning the older, mono TV sets. So, after a great deal of deliberation, it was decided that companding should be applied only to the stereo difference (L − R) channels and not to the mono (L + R) sum channel, which the mono listener would continue to receive as before.

A separate committee task force was set up to evaluate several companding systems. This task force conducted extensive subjective listening tests, using experienced listeners—ranging from recording and broadcast engineers to musicians and audio critics and journalists—who where asked to make a large number of "forced choices" in blind A-B comparisons between pairs of companding systems. The tests were conducted using noise and interference levels simulating those which would occur with each of the three transmission systems in close-in (strong signal) and suburban or fringe area (weaker signal) locations. It was agreed that noise reduction would be even more important in the case of the Second Audio Program (S.A.P.) channel, the one used to transmit a second-language audio track or a secondary audio program. (As we will show shortly, this second audio program channel is normally noisier than the stereo channel). The action of the various proposed companding systems was judged by the auditors for the S.A.P. channel as well. In addition to these subjective tests, extensive laboratory measurements were made to evaluate the performance of each of the proposed noise-reduction systems.

Zenith Transmission System

After two days of presentations by all proponents, the vote was finally taken. The winning transmission-system proponent was Zenith, while the winning companding-system proponent was dbx. Figure 1 shows the spectrum occupancy and modulation standards of the chosen transmission system. The main-channel modulation consists of an L + R audio signal. An L − R stereo difference audio signal causes double-sideband, suppressed-carrier amplitude modulation of a subcarrier at twice the horizontal-line frequency. Audio bandwidth of each signal extends to 15 kHz, and the main channel pre-emphasis remains as it has been in the past, 75 µS. Pre-emphasis of the stereo subchannel is a part of the companding system, which will be described shortly.

The combined peak deviation of the main channel and stereophonic subchannel is always 50 kHz, with the main channel accounting for 25 kHz of this. When the L and R channels are statistically independent (as will usually be the case), the main and subchannel signals interleave, so peak deviation due to the stereo subchannel can *also* be up to 50 kHz; this helps keep S/N from falling as low in stereo as it otherwise might. When the L and R

Table I—Signal specifications for multi-channel TV sound.

Service or Signal	Mod. Signal	Maximum Mod. Freq., kHz	Pre-Emphasis, µS	Subcarrier Freq., ± kHz	Subcarrier Modulation Type	Subcarrier Dev., kHz	Main-Carrier Peak Dev., kHz
Mono	L + R	15	75				25
Pilot				f_H			5
Stereo	L − R	15		$2f_H$	AM-DSB-SC		50
S.A.P.		10		$5f_H$	FM	10	15
Prof. Channel	Voice	3.4	150	$6.5f_H$	FM	3	3
	or Data	1.5	0	$6.5f_H$	FSK	3	3
							Total: 73

Notes
f_H = 15,734.26 Hz; DSB = double sideband; SC = suppressed carrier; FSK = frequency-shift keying.

The Japanese system won't allow simultaneous stereo and bilingual use, but our system will.

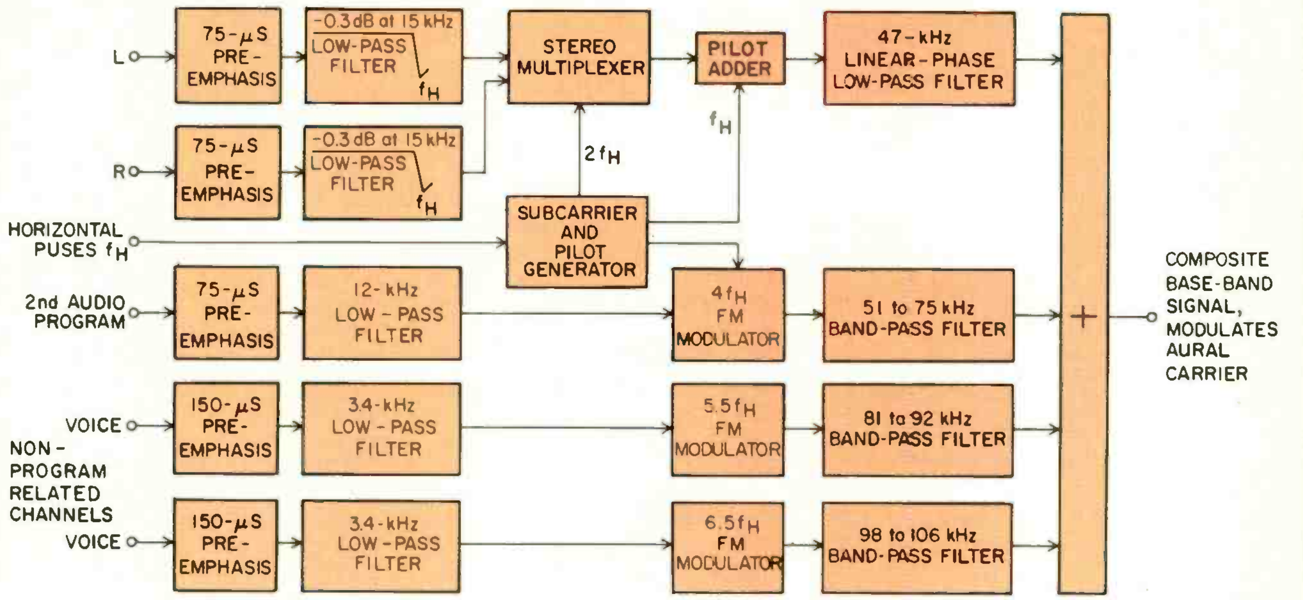


Fig. 2—Encoder for Zenith multi-channel TV sound system.

signals are not statistically independent (which will be most true as the signals approach mono), or when the L + R and L − R do not have matched pre-emphasis characteristics, the relative levels of L + R and L − R components assume their respective, natural levels, as dictated by the acoustic scene.

A stereo pilot signal is also transmitted, as a continuous-wave frequency of 15,734.26 Hz (the TV horizontal-line rate) with a main-carrier deviation of 5.0 kHz. The subcarrier for the S.A.P. channel is at five times the horizontal-line frequency (or 78.67 kHz). The S.A.P. channel is frequency-modulated to a peak deviation of 10 kHz by a signal that is band-limited to 10 kHz; when not modulated, it is locked to 78.67 kHz. The pre-emphasis on the S.A.P. channel is, again, part of the chosen companding system. Main-carrier deviation due to this subcarrier is 15 kHz. The S.A.P. channel is noisier than the main-channel or stereo-subchannel audio, due both to its own low level of modulation and its low deviation of the main carrier.

A third subcarrier, known as the Professional Subchannel and intended for voice or data transmission, is located at approximately 6.5 times the horizontal-line frequency. This last subcarrier causes 3-kHz deviation of the main carrier.

Figure 2 is a simplified block diagram of the encoder required at a transmitter to broadcast the new system, while Fig. 3 shows a basic block diagram of the elements of a decoder circuit for multi-channel-sound TV receivers or tuners. It is expected that appropriate ICs will be available for both the basic decoder and compander.

The companding circuits are not shown in these diagrams. In the encoder, a compression circuit would go in the L − R line between the stereo multiplexer and pilot adder, and another would be inserted just before the S.A.P.'s FM modulator. In the decoder, the L − R signal would be expanded in the stereo decoder, and the S.A.P. would be expanded in its decoder.

dbx Companding System

Although the companding system chosen by the industry for noise reduction bears the dbx name and was proposed by dbx, its operation is more sophisticated than that of the familiar dbx noise-reduction system used in consumer tape recording. The compander works in two stages. First, it provides wide-band amplitude compansion to reduce dynamic range in the transmission channel at all audio frequencies. This section utilizes a 1:2:1 linear dB compander, similar to dbx's noise reduction for tape recording. In addition, the compander provides variable pre-emphasis/de-emphasis which adapts itself to the spectral distribution of the program material, to take full advantage of the limited channel-headroom available. The spectral compressor is able to boost or reduce high-frequency levels, depending upon the input signal spectrum.

Rms detectors are used to control both the amplitude and spectral companders, thereby providing minimum sensitivity to impulse noise while maintaining appropriate reaction times for music signals. A clipper is provided within the compressor control loop for preventing channel overload without inducing compressor/expander tracking errors. Band-limiting filters are also included in the compressor design. Compensation for the phase errors caused by band-limiting throughout the system is provided in the form of a complementary filter in the L + R channel. The compressor design is shown in block diagram form in Fig. 4, while the expander block diagram is shown in Fig. 5.

When stereo FM was approved, noise reduction hadn't been invented. Happily, the new stereo TV system includes it.

How Good Is the Chosen System?

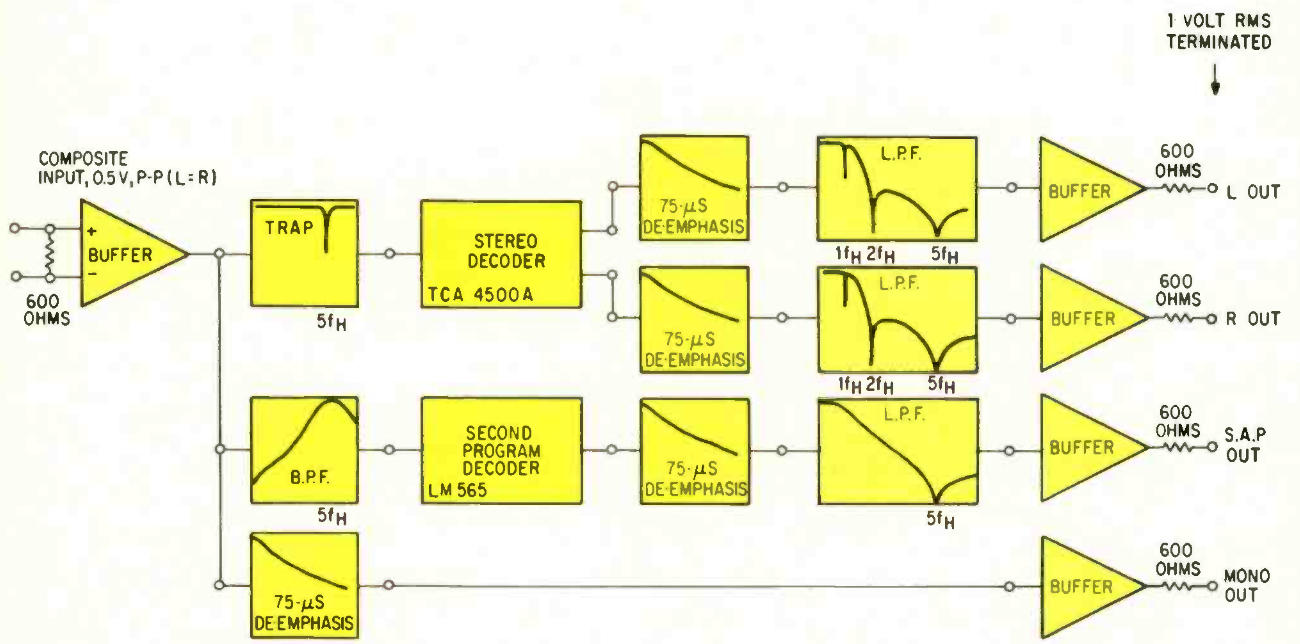
As anyone who has switched from stereo FM to mono reception of the same FM signal knows, unless you are in a strong signal-reception environment, stereo FM is a lot noisier than mono. The full impact of this signal-to-noise deterioration is especially severe when you are listening to a station whose transmitter is many miles away. Unfortunately, when stereo FM broadcasting was approved back in 1961, noise-reduction systems such as Dolby, dbx and the like had not been invented. Happily, as we enter the stereo TV era, we have an excellent noise-reduction system built into the new system to take care of the signal-to-noise deterioration that would otherwise have occurred as we switch from mono to stereo TV sound (or to the Secondary Audio Program channel, be it bilingual service or an entirely different audio program).

The following data was extracted from the many, many pages of data in the report submitted to the FCC by the Electronic Industries Association Multichannel TV Sound Committee to support the industry recommendation. In "City Grade" reception tests, the chosen systems yielded S/N ratios between 65 and 68 dB for stereo reception, with a split-sound type of receiver, while the S.A.P. channel, using the same type of receiver, yielded S/N ratios between 78 and 79 dB.

The real advantage of companding showed up more definitively when tests were conducted for "Grade B" signal-reception conditions. Such conditions are represented by a video carrier-to-noise ratio of only 30 dB, as might be expected in outlying areas served by a TV station. Again, using a split-sound receiver, signal-to-noise ratio of the Zenith system, without companding, was just over 50 dB in stereo. With dbx companding added, the signal-to-noise ratio increased to between 63 and 64 dB. The improvement was far more dramatic in the case of the normally noisier S.A.P. channel. With no companding, S/N measured a very noisy 43 dB. When dbx companding was added, S/N improved to a remarkable 77 or 78 dB! With intercarrier types of receivers (those that do not have separate video and audio i.f. circuits), S.A.P. signal-to-noise without companding in a Grade B signal environment was even poorer, between 36 and 42 dB. With the chosen dbx companding system added, S/N improved to between 62 and 63 dB, still an acceptably low level of background noise.

Once stereo TV transmissions begin, I expect that we'll see a number of new product categories appearing in both

Fig. 3—Decoder for Zenith multi-channel TV sound system.



SHERWOOD S-2680CP RECEIVER

Manufacturer's Specifications

FM Tuner Section

Usable Sensitivity: Mono, 9.3 dBf (1.6 µV/300 ohms).

50-dB Quieting Sensitivity: Stereo, 36.3 dBf (35 µV/300 ohms).

S/N: Mono, 80 dB; stereo, 75 dB.

Selectivity: 80 dB.

Capture Ratio: 1.2 dB.

Frequency Response: 20 Hz to 15 kHz, +0.5, −1.0 dB.

THD: Mono, 0.1% at 1 kHz; stereo, 0.1% at 1 kHz.

Stereo Separation: 50 dB at 1 kHz.

AM Tuner Section

Usable Sensitivity: 300 µV/meter, bar antenna.

S/N: 45 dB.

Amplifier/Preamplifier Section

Power Output: 70 watts per channel, continuous, from 20 Hz to 20 kHz, 8-ohm loads; 100 watts per channel at 1 kHz, 4-ohm loads.

Rated THD: 0.05%.

SMPTE-IM Distortion: 0.05%.

Damping Factor: 70, at 1 kHz, 8-ohm loads.

Input Sensitivity (for Rated Output): Phono, 2.5 mV; high level, 150 mV.

Phono Overload: 270 mV at 1 kHz.

Frequency Response: Phono, RIAA ±0.5 dB; high level, 5 Hz to 40 kHz, +0, −3.0 dB.

S/N: Phono, 85 dB (75 dB unweighted); high level, 100 dB (90 dB unweighted).

Tone Control Range: Bass, ±10 dB at 100 Hz; treble, ±10 dB at 10 kHz.

High Filter: −3 dB at 8 kHz, 12 dB/octave.

Ultra-Low Bass EQ: +5 dB at 30 Hz, −9 dB at 15 Hz.

General Specifications

Power Consumption: 460 watts, maximum.

Dimensions: 17.3 in. (43 cm) W × 4.3 in. (11 cm) H × 13.8 in. (35 cm) D.

Weight: 21.6 lbs. (9.8 kg).

Price: $479.95.

Company Address: 17107 Kingsview Ave., Carson, Cal. 90746.

For literature, circle No. 91

Sherwood's top receiver is distinctively different in appearance from anything this venerable company has produced during its several decades of existence. Still, one guiding principle seems to have been retained all through the years: Sherwood products offer excellent performance at very reasonable prices. When you consider the fact that this receiver, with its relatively high power rating of 70 watts per channel, has a price tag barely higher than that of component tuners which perform not much better than the tuner section of the Sherwood S-2680CP, the excellent value inherent in this unit becomes obvious.

Control Layout

There are no rotary control knobs or other protrusions on the receiver's front panel. All controls and switches take the form of light-touch, silver-colored buttons or sliders, blending neatly with the silver-framed panel and the dark-colored, smoked, transparent plastic display areas which cover most of the front panel's surface.

A power switch is at the upper left of the panel, with two speaker selector buttons and a stereo headphone jack arranged below. When power is applied, two LEDs (one for each channel) illuminate in the power-output display area to the right of the power switch. These LEDs are, in fact, the lowest indicators of two vertically oriented indicator banks (seven LEDs per bank) which tell the user how much power is being delivered by the amplifier section. In order to provide a useful range greater than that which might be available with such a small number of LEDs, this metering system has two ranges: From 0 to 10 watts per channel, and from 0 to 140 watts per channel. When the low-power range is selected, the first LED in each bank will light with output powers of as little as 0.006 watts per channel. Readings are, of course, referenced to 8-ohm loads; if 4-ohm speakers are used, the readings must be doubled. (The owner's manual contains an error in this regard, telling you to divide the readings by two, in complete defiance of Ohm's well-established law!)

Three horizontal sliders below the power display area handle bass, treble and balance control functions. All are nicely detented—not just at their center positions, but in 10 discrete increments, making it easy to return to desired settings with a great deal of precision. These sliders, as well as the vertical slider for adjusting overall volume of the receiver, have been sculptured to fit your fingertip.

A fluorescent display to the right of the power metering system shows AM or FM frequencies when you are in the tuner mode, but it is extinguished when you use such program sources as phono, CD player, or other high-level inputs. A five-LED signal-strength meter to the right of the frequency display operates for both AM and FM tuning. To its immediate right is a single red LED which illuminates when FM stereo signals are received. A red "Memory" touch button and eight numbered station buttons, arrayed below the frequency display area, permit preselection and memorization of eight FM and eight AM stations for instant recall. When the numbered buttons are used to choose a station, a tiny green light above the button depressed lights up to denote that fact. To the right of these buttons is an "Auto/Manual" tuning button and a "Down/Up" tuning bar. When the bar is depressed at either end, tuning will occur either in

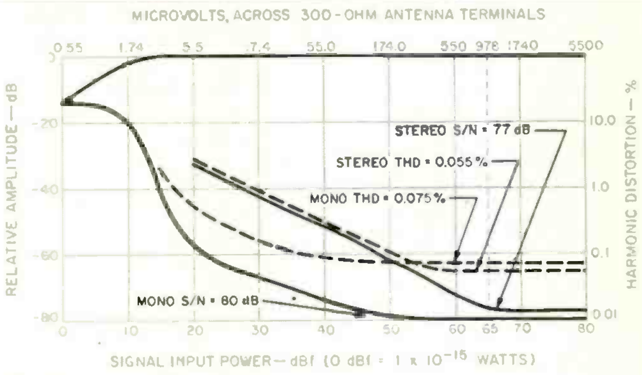


Fig. 1—Mono and stereo quieting and distortion characteristics, FM tuner section.

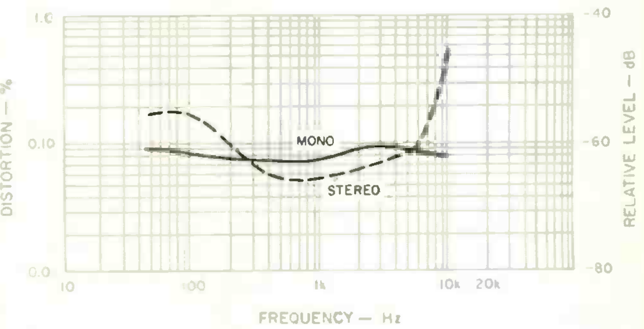


Fig. 2—THD vs. modulating frequency, FM tuner section.

increments of 0.1 MHz or 10 kHz if you are in the manual tuning mode, or, in auto mode, until a usable AM or FM signal is encountered.

Thirteen silver-colored square touch buttons are arranged along the lower right portion of the front panel. The first of these is used to select the appropriate power meter range. "Ultralow Bass EQ" and high-cut filter are activated by the next two buttons. "Mute Off/Mono" and loudness buttons are next, followed by selectors for tape "Monitor," "2/1," and "Dubbing." The remaining five buttons are interlocked and used to select program source (AM, FM, AUX, CD, and phono). The vertically oriented master volume-control slider is located at the extreme right of the panel.

The Sherwood S-2680CP's rear panel is equipped with a swing-away AM antenna bar; two sets of tape in/out jacks; two pairs of color-coded, spring-loaded speaker-cable terminals; 300-ohm/75-ohm FM and external AM antenna terminals; a chassis ground terminal, and a pair of a.c. convenience receptacles (one switched, the other unswitched). The usual array of phono and high-level inputs are on the rear panel (near the chassis ground terminal), as well as an increasingly more common input for a CD player. A fuse-

Unwanted 19-kHz, 38-kHz and distortion components were extremely low as compared with results I have obtained from many other receivers.

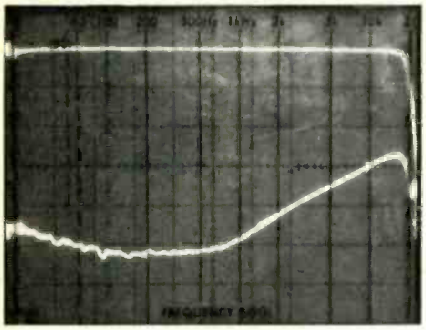


Fig. 3—Frequency response (upper trace) and separation vs. frequency, FM tuner section.

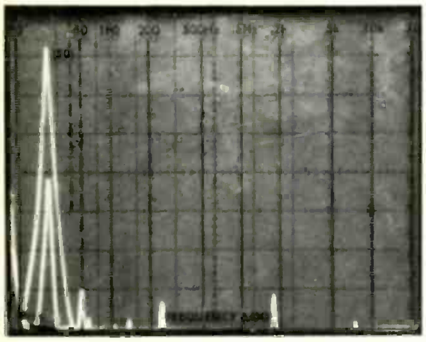


Fig. 4—Crosstalk and distortion products with 5-kHz modulating signal.

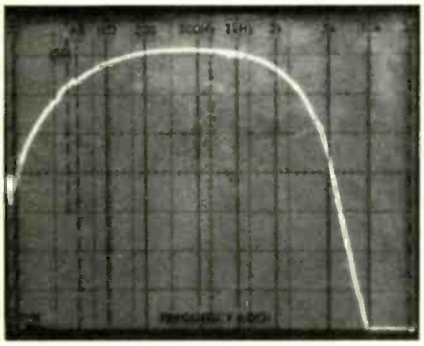


Fig. 5—Frequency response, AM tuner section.

holder containing a 5-ampere line fuse is also accessible at the rear panel.

Circuit Highlights

Unlike many manufacturers of audio equipment, Sherwood continues to supply its customers with a complete schematic diagram—a very worthwhile addition to any owner's manual, should servicing become necessary when it is inconvenient to send or bring the unit to an authorized service center.

Four major circuit boards and several smaller ones contain all of the components of the S-2680CP. The r.f. amplifier of the FM tuner front-end utilizes a dual gate FET, and separate bipolar mixer and oscillator stages. Ceramic filters are used as tuning circuits between i.f. stages, and multi-purpose ICs are used for limiter-detector and multiplex-decoder circuitry. A microprocessor IC is located on the memory/display board along with the necessary driving circuitry for the frequency displays. Phono preamplifier circuitry is also mounted on the tuner board, and input stages for the phono circuits use FETs. Eight semiconductors are used for each channel of phono preamplification, with RIAA equalization incorporated in the usual feedback arrangement between stages.

A single IC handles the active circuitry of the tone controls, which are incorporated in an inverse feedback loop of the familiar Baxandall arrangement. Power amplifier circuitry is contained on its own separate p.c. board, with hybrid monolithic IC packages containing the power output modules. Relay protection circuits are incorporated in series with the amplifier's left and right output lines. The power transformer used in this receiver has separate secondary windings for high and low regulated supply voltages. All secondary lines are fused, as is the fuse found in the primary line of the power transformer.

Tuner Measurements

Usable sensitivity in mono measured 12.0 dBf (2.2 µV across 300 ohms), a bit short of Sherwood's ambitious claim of 9.3 dBf but of no major concern to me, since the "least usable sensitivity" specification has long since ceased to be important from a practical point of view. Sensitivity for 50-dB quieting, on the other hand, measured 15 dBf (3.1 µV at 300 ohms) in mono and 36.0 dBf in stereo, both of which are very good figures. S/N ratio measured 80 dB in mono, exactly as claimed, and 2 dB better than claimed in stereo, or 77 dB. Harmonic distortion, for a 1-kHz 100%-modulation signal, was also lower than claimed, both in mono and stereo; it was 0.075% in mono and 0.055% in stereo. Distortion anc quieting characteristics as a function of signal strength are plotted in Fig. 1. In Fig. 2, I have plotted harmonic distortion as a function of modulating frequency for both mono and stereo reception. At 100 Hz, THD in mono measured 0.085%, while in stereo the reading at this modulating frequency was 0.17%. At 6 kHz, THD in mono was 0.085%; in stereo it remained a very low 0.09%.

Figure 3 is a 'scope photo of a spectrum-analyzer sweep showing FM frequency response (upper trace) and stereo separation. Deviation from flat response was −0.7 dB at 30 Hz and −1.1 dB at 15 kHz. Separation measured 51 and 50 dB at 1 kHz for the left and right channels, respectively. At 100 Hz, separation from left to right channel was still a very high 48 dB, and 49 dB from right to left channel. Separation decreased to 30 dB (left to right) and 29 dB (right to left) at the 10-kHz test frequency.

Figure 4 shows results obtained when a 5-kHz modulated FM signal was applied to the antenna terminals of this unit, with the outputs examined over a linear frequency range from 0 Hz to 50 kHz. The tall spike at the left is the desired 5-kHz output signal as seen at the left-channel output. The shorter spike and other crosstalk products were obtained by examining the right-channel output. Unwanted 19-kHz, 38-kHz and distortion components were extremely low compared with results I have obtained when this test was applied to many other receivers. In fact, in a separate mea-

The front-panel controls are well laid out and clearly identified. My fingers seemed to go directly to the controls I needed.

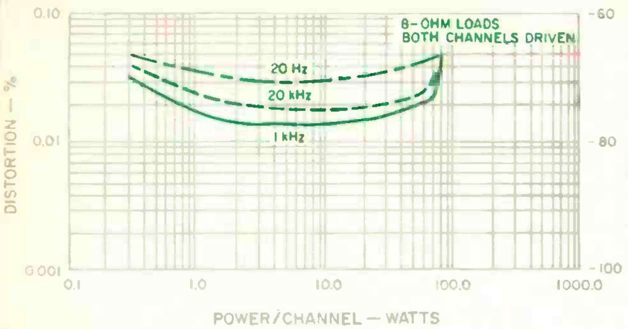


Fig. 6—Harmonic distortion vs. power output per channel at three frequencies.

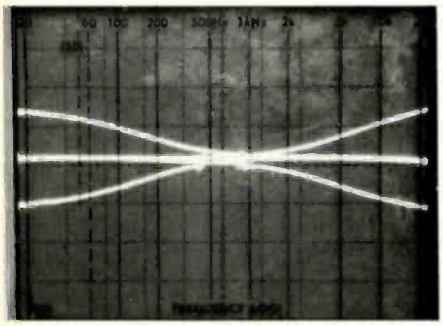


Fig. 7—Tone control boost and cut range.

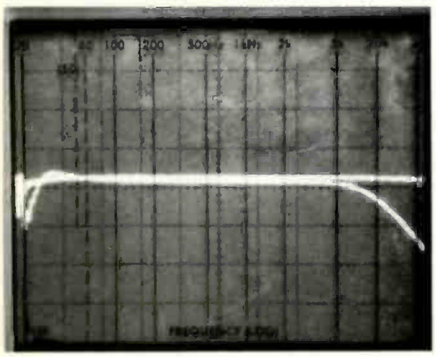


Fig. 8—High-cut filter and ultra-low bass EQ characteristics, shown relative to flat response curve.

surement I determined that subcarrier product rejection was better than 71 dB, while SCA rejection was 69 dB.

Alternate channel rejection was excellent, at 82 dB, and capture ratio, though falling a bit short of the claimed 1.2 dB, measured a perfectly satisfactory 1.5 dB for this tuner section. Image, i.f., and spurious rejection all measured in excess of 90 dB.

AM frequency response was, as usual, plotted with a spectrum analyzer, this time sweeping logarithmically from 20 Hz to 20 kHz. The results shown in Fig. 5 are, to put it mildly, disappointing; the −6 dB points were reached at approximately 60 Hz and 2.5 kHz.

Power Amplifier and Preamplifier Measurements

The power amplifier section of the Sherwood S-2680CP delivered 78.1 watts per channel at mid-frequencies for its rated THD of 0.05% while driving 8-ohm load impedances. At the frequency extremes, power output dropped somewhat, to just under 75 watts per channel for the same level of distortion. At rated output (70 watts per channel, 8-ohm loads), THD dropped to 0.025%, while SMPTE-IM distortion measured 0.04% as against 0.05% claimed. Dynamic headroom was just over 1.0 dB. Damping factor, referred to 50 Hz and 8-ohm loads, measured 58 as opposed to the 70 measured by Sherwood using a 1-kHz signal and 8-ohm loads. Figure 6 shows the levels of THD as a function of power output for three key frequencies (1 kHz, 20 Hz, 20 kHz). CCIF-IM distortion (twin-tone measurement method) was 0.008% at rated output; IHF IM measured a somewhat higher 0.05% at the same level of power output.

Figure 7 shows the maximum boost and cut range of the bass and treble controls. Vertical sensitivity in this display was 10 dB per division and, as in the case of Figs. 3, 5 and 8, the frequency sweep is logarithmic, from 20 Hz to 20 kHz. Figure 8 shows the effect of turning on the high-cut filter and the ultra-low bass EQ circuit. The latter provides a modest amount of bass boost at around 30 Hz and then attenuates all lower frequency signals sharply. Users of this receiver who also own turntables which exhibit a moderate amount of rumble will find this circuit especially useful, since it effectively attenuates rumble frequencies without audibly affecting even the very lowest musical bass tones present in a recording.

Although Sherwood continues to quote input sensitivity figures and signal-to-noise ratios referred to rated output, I measure these important characteristics in accordance with IHF (now EIA) standards, so my results cannot be easily compared with Sherwood's. Input sensitivity for the phono inputs measured 0.32 mV for 1-watt output. For the high-level inputs, 19 mV of input were required to drive the amplifier to a 1-watt output level with the volume control at maximum. Phono signal-to-noise ratio, using a 5-mV input signal and with the volume control set for 1-watt output, measured 80 dB, A-weighted. With a 0.5-V signal applied to the high-level inputs and again adjusting volume for a 1-watt output, noise was 78 dB lower than the reference 1-watt level. At minimum volume setting, noise was 84 dB below 1 watt, A-weighted. Phono overload measured 290 mV, well over the level claimed. Frequency response for the phono inputs deviated from precise RIAA equalization by no more than +0.2 dB at the treble end of the spectrum and −0.5 dB at 30 Hz. High-level inputs exhibited flat frequency response (within 1 dB) from 5 Hz to 21 kHz, and the −3 dB roll-off points were at 2 Hz and 30 kHz.

Use and Listening Tests

Most of the 12-page owner's booklet explains the function of each pushbutton and control on the front panel and the hookup diagram of the rear panel. Only one page of the booklet actually details step-by-step operating instructions for listening to the various program sources and for "memorizing" favorite AM and FM stations. I mention this not by way of a criticism, but rather as an indication of how well the


REYNOLDS TOBACCO COMPANY
CAMEL LIGHTS
It's a whole new world.
20 FILTER CIGARETTES
CAMEL
LIGHTS
LOW TAR
CAMEL TASTE
Today's
Camel Lights,
unexpectedly
mild.
Warning: The Surgeon General Has Determined
That Cigarette Smoking Is Dangerous to Your Health.
9 mg. "tar", 0.8 mg. nicotine av. per cigarette by FTC method.

We built Laser XE to outperform the competition. We gave it a turbo you can trust.

We built Chrysler Laser XE to win. We engineered its turbo to endure. Laser's turbo is the sophisticated new wave. A water cooled bearing reduces critical turbo temperatures to prevent oil "coking" and bearing failure. Horsepower is boosted 43%. A multi-point injection system "spritzes" fuel in at 4 points and moves Laser like light. With 5-speed your time to 50 mph is 5.4 seconds. Camaro Z28, Trans Am, Toyota Supra and Nissan 300 ZX are in your remote-controlled side view mirrors.

We gave Laser XE world-class performance. In the slalom Laser beats all entries—from Trans Am to Mustang GT. Laser does it when you equip it with turbo and performance handling package with nitrogen charged shocks.* Laser does it with front wheel drive, dual path suspension system and quick ratio power steering. In the slalom Laser finishes No. 1.

Laser beats Nissan 300 ZX in the slalom.

Laser outperforms Trans Am in braking.

Laser is faster than Camaro Z28 from 0-50 mph.

We gave it high-performance braking. Laser XE stops you where Trans Am doesn't. We think total performance calls for performance braking. So we gave Laser XE semi-metallic brake pads, power brakes all around and optional wide 15" alloy wheels with Goodyear Eagle GT radials. Result: Laser stops quicker than Z28, Mustang GT, Toyota Supra, 300 ZX, Trans Am.

We gave it a brain—and a performance seat that performs. Laser XE thinks with you. Its 19-feature electronic monitor even talks your language, while its color graphic displays make you a calculating driver. Laser XE's AM/FM stereo remembers what you like to hear and its self-diagnostic system is the nearest thing to an on-board mechanic. Your seat responds with cushions you pump up for thigh and lumbar support, and you can choose a 6-way power seat and Mark Cross leather.

We gave it our best: a 5 year/50,000 mile Protection Plan. Even your turbo is protected. We believe a performer has to be a survivor, so we back your entire powertrain with 5/50 protection, with outer body rust-through protection for the same period.** See dealer for details. Buckle up for safety.

35 Est. Hwy.
22 EPA Est. MPG†

Chrysler

The best built, best backed American cars.††

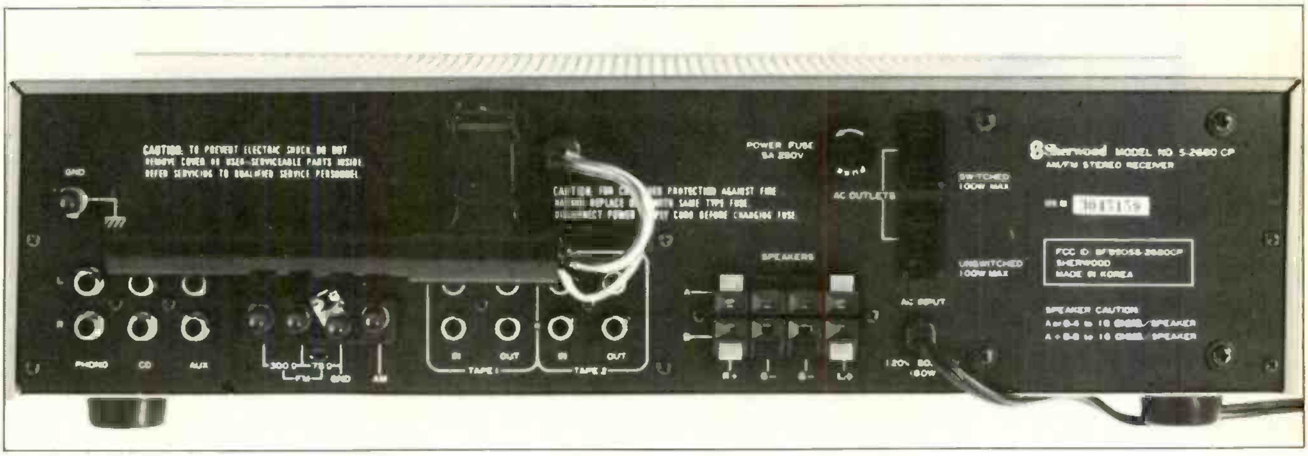
*Based on overall results of USAC tests against standard equipped models. Laser XE equipped with optional handling suspension, Turbo package and 15" road wheels and tires. **5 years or 50,000 miles, whichever comes first. Limited warranty. Deductible required. Excludes leases. †Use EPA est. mpg for comparison. Actual mileage may vary depending on speed, trip length and weather. Hwy. mileage probably less. ††Based on lowest percent of National Highway Traffic Safety Administration recalls for '82 and '83 models designed and built in North America.

CHRYSLER LASER

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

Lee A. Iacocca

If one section must be singled out, the FM tuner section is the winner. Auto tuning was precise, as one expects (but unfortunately doesn't always get).



Note that one input on the Sherwood S-2860's rear panel is labelled "CD."

front-panel controls are laid out and how clearly they are identified. My fingers seemed to go directly to the controls and touch buttons I needed when I was putting the receiver through its paces during bench and listening tests. The LED and fluorescent displays were clear and easily read, even at a distance.

As for the performance of the receiver during listening tests, I found the FM tuner section to be the winner, if one section of this receiver must be singled out above the others. Auto tuning was always precise, as one would expect (but doesn't always get) from a frequency-synthesized tuning system. The amplifier section, while not unusual in its performance, delivered adequate power for use with speakers of medium-to-high efficiency—even when the program source was Compact Discs (as it very often is, now, in my listening tests). The phono inputs handled my best moving-magnet cartridges well, but users should note that the 47-kilohm resistances provided at the inputs to the left and right phono stages are shunted with 150-pF capacitors. If your cartridge is optimally loaded with around 250 pF or even a bit less (as most popular MM cartridges are), you may have to hunt for some low-capacitance audio cable or else keep the length of the cables from turntable to phono inputs extremely short to prevent a high total capacitance from attenuating treble response. (Of course, if you are handy with a pair of cutting pliers and a screwdriver, you could get inside the receiver yourself and clip out the 150-pF capacitors altogether.)

Overall, I found the S-2680CP receiver to be a worthy entry in Sherwood's line of products, especially in view of its modest price and its superior FM and stereo FM performance.

Leonard Feldman

3

MICRO SEIKI CD-M1 COMPACT DISC PLAYER

Manufacturer's Specifications
Frequency Response: 20 Hz to 20 kHz, ±0.5 dB.
S/N Ratio: Greater than 90 dB.
Dynamic Range: Greater than 90 dB.
Channel Separation: Greater than 90 dB at 1 kHz.
Harmonic Distortion: Less than 0.005% at 1 kHz.
Output Level: 2.0 V.
Number of Programmable Selections: 24.
Power Consumption: 30 watts.
Dimensions: 16-15/16 in. (43 cm) W × 5-3/16 in. (13.2 cm) H × 13⅝ in. (34 cm) D.
Weight: 18½ lbs. (8 kg).
Price: $1,100.00.

Company Address: Scientific Audio Electronics, P.O. Box 60271, Terminal Annex, Los Angeles, Cal. 90060.
For literature, circle No. 92

The Micro Seiki CD-M1 offers just about every feature that listeners to CDs are likely to ever want, except for remote control and fast audible scan of recorded programming. Up to 24 tracks, index points, or a combination of both can be committed to the player's microprocessor memory and can be played back in any random order.

More and more, CD software is beginning to take advantage of the index numbering feature inherent in the CD format. To take full advantage of such indexing, the Micro Seiki unit provides easy access to a given point in a disc by index number within a track, as well as by track number or even by elapsed time within a track.

Control Layout

Like so many other CD players I have tested, the Micro Seiki CD-M1 is a front-loading machine with a hinged disc-compartment door that accommodates a vertically positioned disc. To the left of the disc door is a power on/off pushbutton, while immediately to the right of the compartment are four separate display areas, one below the other. The top display has three LED lights, for "Stand By" (illuminated during the stop mode or when a track is being searched), "Pause," and "Play." A "Track No." display just below indicates the number of the track currently being played or about to be played. The next display is multipurpose. It indicates time elapsed since the beginning of the track being played and, if the "Total Time" button (elsewhere on the front panel) is pressed, total elapsed time from the beginning of the disc being played. Finally, this display will also indicate index number within a track when such a number is being programmed. The fourth display area is much like a tuner's dial scale. An illuminated red dot moves to the left or right to show the relative location of the laser pickup to the disc surface.

Major operating buttons are located to the right of the displays. Included are seven touch buttons for "Play/Start," "Stop/Eject," "Pause," reverse and forward skip, reverse, and fast forward. The reverse and forward skip buttons move the laser pickup either to the beginning of the current track or to the beginning of the following one. A set of keys numbered from "0" to "9" to the right of the operating buttons is used to program desired program or index numbers and/or track starting times. A "Memory" button, used to enter track or index numbers during programming, and a "C/AC" (Clear/All Clear) button are to the left and right, respectively, of the "0" key. When the "C/AC" button is touched once, it clears an error you may have made during programming. Touched twice in succession, the button clears or erases all programmed entries from memory.

Six small buttons in a vertical row at the right of the front panel take care of the remaining functions. Included here are a "Phrase" button for initiating repeat-play of a desired musical phrase, an "Index" button for selecting desired index points, a "Time" button for programming by starting time rather than by track or index number, a "Memo Call" button for visually reviewing memory content in the order in which it was programmed, a "Repeat" button for repeat playing of any given track, and a "Total Time" button for viewing total time since the beginning of the disc's first track.

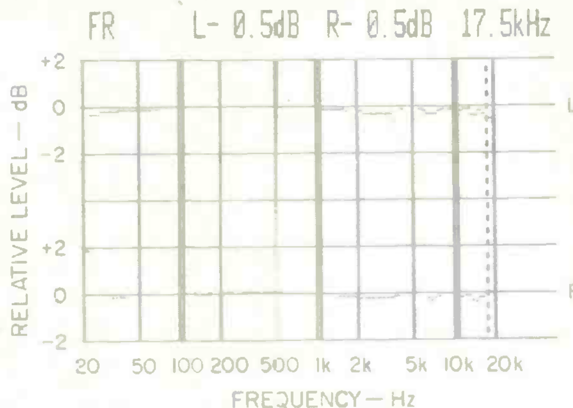


Fig. 1—Frequency response, left (top) and right channels.

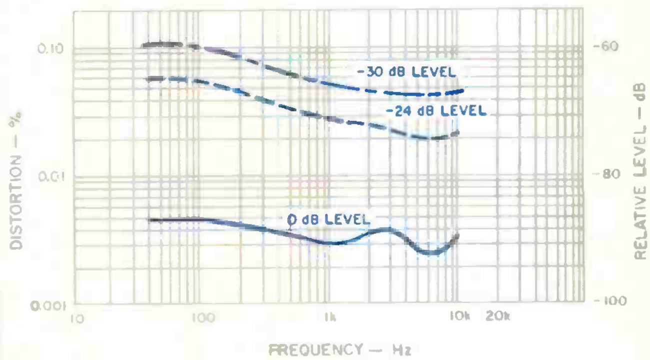


Fig. 2—THD vs. frequency at levels of 0, −24, and −30 dB (see text).

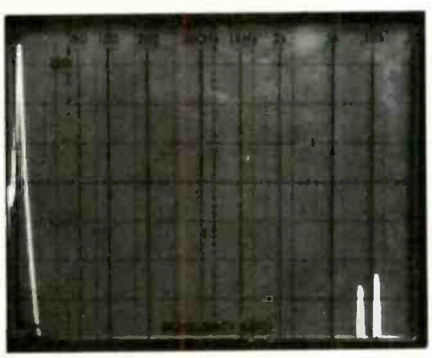


Fig. 3—Outputs from Micro Seiki CD-M1 contained spurious high-frequency signals at around 44.1 kHz, the D/A sampling frequency.

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Introducing the 500 CROLYN™ HG Audio Cassette. Clear sound, clear shell...clearly superior.

The new 500 CROLYN™ High Grade cassette will exceed even *your* high standards. We engineered it for you, the audiophile. We want to hear from you. We challenge you to compare it with the likes of XL-IIS and SA-X. Hear the difference genuine chromium dioxide tape makes versus cobalt-iron oxide imitations or other "chrome equivalent" tapes. Also, ask about 1100 Metal HG and Tri-Oxide Ferro HG.

Buy a 500 CROLYN™ HG cassette. Use it—test it—under *your* standards. Send us your comments (plus outer wrapper and sales receipt). We'll send you a 500 CROLYN™ HG Cassette FREE! We're betting you will agree with our results.*

Only the people who invented the compact cassette (Philips, the "P" in our name), and chromium dioxide (Du Pont, the "D" in our name), could bring you a tape this great.

Rating vs. Leading Premium Cassettes

	500 CROLYN™ HG
Tape Background Noise	SUPERIOR
S/N, Low Frequency	SUPERIOR
S/N High Frequency	EQUAL
Dynamic Range	SUPERIOR
Frequency Response	EQUAL
Shell Quality	EQUAL
Overall Listening Quality	SUPERIOR

Specific test results available on request. For free cassette offer, technical information or the PDMagnetics dealer serving your area, write us at address below.

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A legacy of quality from Philips and Du Pont.

*Offer expires July 30, 1984.

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Enter No. 37 on Reader Service Card

I liked the fact that the CD-M1 didn't swallow or grab discs. I always feel that self-closing doors may someday close early, with disastrous results.

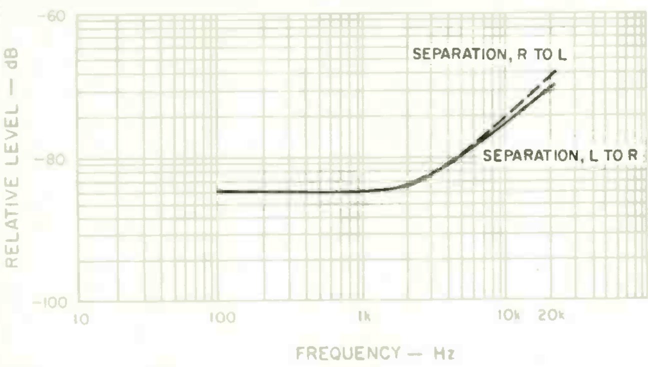


Fig. 4—Channel separation vs. frequency.

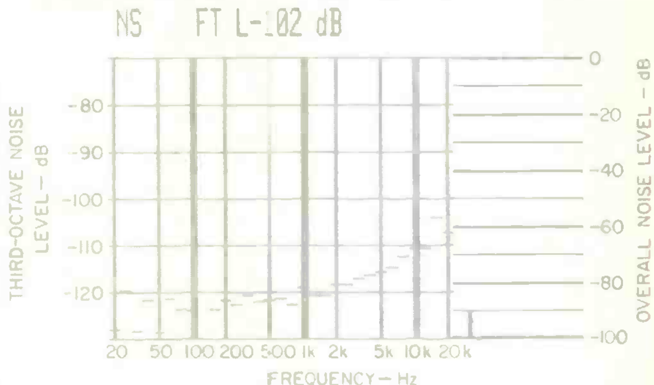


Fig. 5—Third-octave analysis of S/N.

On the rear panel of the CD-M1, in addition to the usual left and right output jacks, there is an output-level control which adjusts left and right channel simultaneously.

Operation of the player, for all its programming features, is relatively simple. I particularly liked the fact that the disc-compartment door did not "swallow" or "grab" discs when I inserted them. It is necessary to push the disc all the way down until a click is heard, and then to close the door manually. While the self-closing doors on some machines are elegant to watch, I always have the feeling (probably unjustified) that some day the door will close before the disc is properly positioned, with disastrous consequences for both disc and player. Retaining a certain amount of control over the mechanism is, to my mind, somewhat reassuring.

Measurements

Figure 1 is a plot of frequency response for both left and right channels of this CD player. The vertical scale is expanded to 2 dB per division, and the plot is from 20 Hz to 20 kHz. At 17.5 kHz, response was down about 0.5 dB on both channels; at 20 kHz, response was down 0.8 dB from the 1-kHz reference level.

Harmonic distortion for maximum recorded level measured a very low 0.003% at mid-frequencies, rising to 0.005% at the lowest test frequency of 41 Hz. Note that in Fig. 2 I was unable to provide a meaningful plot of distortion above 10 kHz. That is because some spurious super-audible components, centered around 44.1 kHz (the sampling frequency used for CDs), were present at the outputs of the player. The presence of these unwanted frequencies is illustrated in the spectrum analyzer sweep shown in Fig. 3. In this display, sweep was linear from 0 Hz to 50 kHz, rather than logarithmic, and you can see two distinct spurious spikes at around 43 and 45 kHz, near the right edge of the screen. The tall spike at the left is, of course, the desired 1-kHz test signal present on the test disc. While the unwanted high-frequency signals cannot be heard during playback of a CD, they nevertheless influence any attempts to read harmonic distortion for high-frequency signals. (For THD readings below 10 kHz, I used a band-pass filter so as to reduce or eliminate the effects caused by these spurious high-frequency signals.)

Output linearity was accurate to within 0.3 dB from 0-dB reference level down to −75 dB. Stereo separation is plotted for left and right channels in the graph of Fig. 4. I measured separations of around 85 dB at mid-frequencies and approximately 75 dB at 10 kHz.

SMPTE intermodulation distortion measured a negligibly low 0.0025% at maximum recorded output level, increasing to 0.02% at −20 dB recorded level. Signal-to-noise ratio readings were also difficult to perform using a single-meter method because of the presence of those spurious high-frequency signals at the outputs of the player. Using an a.c. VTVM, I read an S/N of only 85 dB, unweighted, and 86 dB, A-weighted. Yet, when I measured S/N using my Sound Technology 1500A tester, which limits its analysis of noise to the audio band only (from 20 Hz to 20 kHz), the S/N reading, as shown in Fig. 5, was a superb 102 dB, *unweighted*.

Examination of a reproduced 1-kHz square wave (Fig. 6) revealed that the Micro Seiki CD player employs digital filtering and oversampling, similar to that employed by Philips in the players that are sold under the Magnavox name in this country. Micro Seiki claims that, unlike Philips and others who employ oversampling, they are actually using 16-bit D/A converters rather than 14-bit D/As. In addition to digital filtering, "soft" analog filtering is used in post-D/A circuitry. The appearance of the recovered unit-pulse test signal (Fig. 7) confirms that this circuit approach is being used, and the excellent phase relationship between the low (2 kHz) and high (20 kHz) signals of Fig. 8 offers further confirmation of this circuit approach.

The usual error-correction and tracking tests were made, using a Philips test disc, to see how well the player could handle simulated scratches, dust particles, and fingerprint smudges on the surface of a CD. The player successfully tracked the scratch-simulation opaque wedge up to the 900-micron width. This is about average for the players I have tested to date. As for the simulated dust particles (black dots of increasing diameters), the CD-M1 did not do quite as well, audibly muting when trying to traverse a dust spot of only 600 microns. This is well below average compared with other machines previously tested. As for the simulated fingerprint smudge, the player had no trouble playing through it, nor have any of the other players tested

The CD-M1 uses digital filtering and oversampling, like Philips, but Micro Seiki claims to use 16-bit rather than Philips-style 14-bit D/A converters.

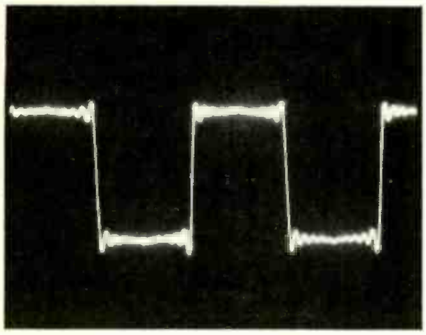


Fig. 6— Reproduction of 1-kHz square wave.

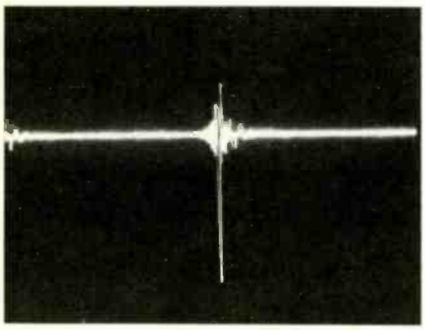


Fig. 7— Single-pulse test.

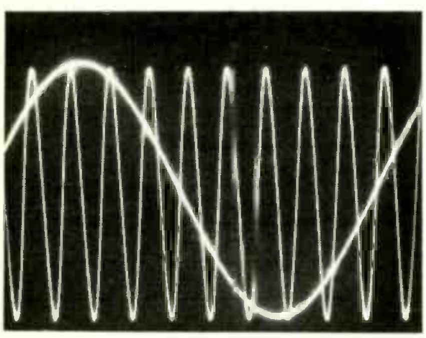


Fig. 8— Phase linearity test, 2- and 20-kHz signals.

been tripped up by this simulated defect in the test record's surface.

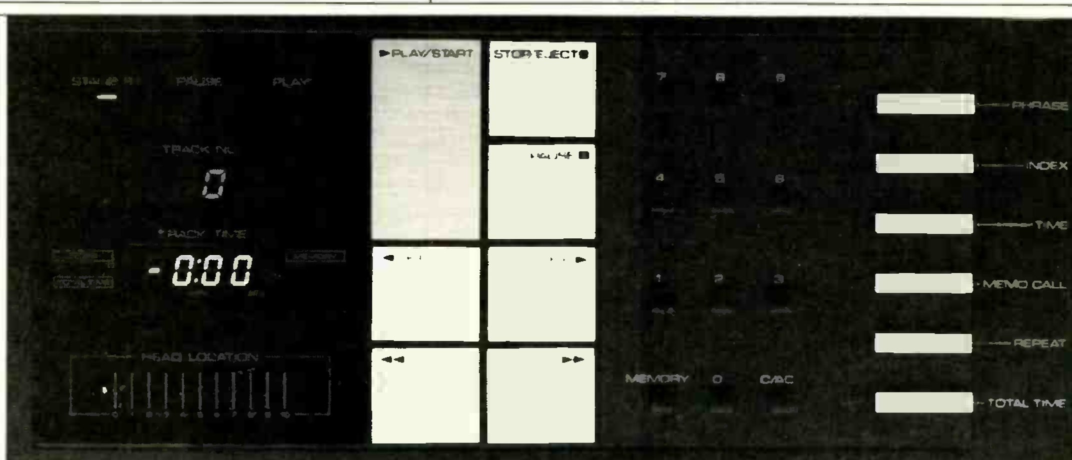
Use and Listening Tests

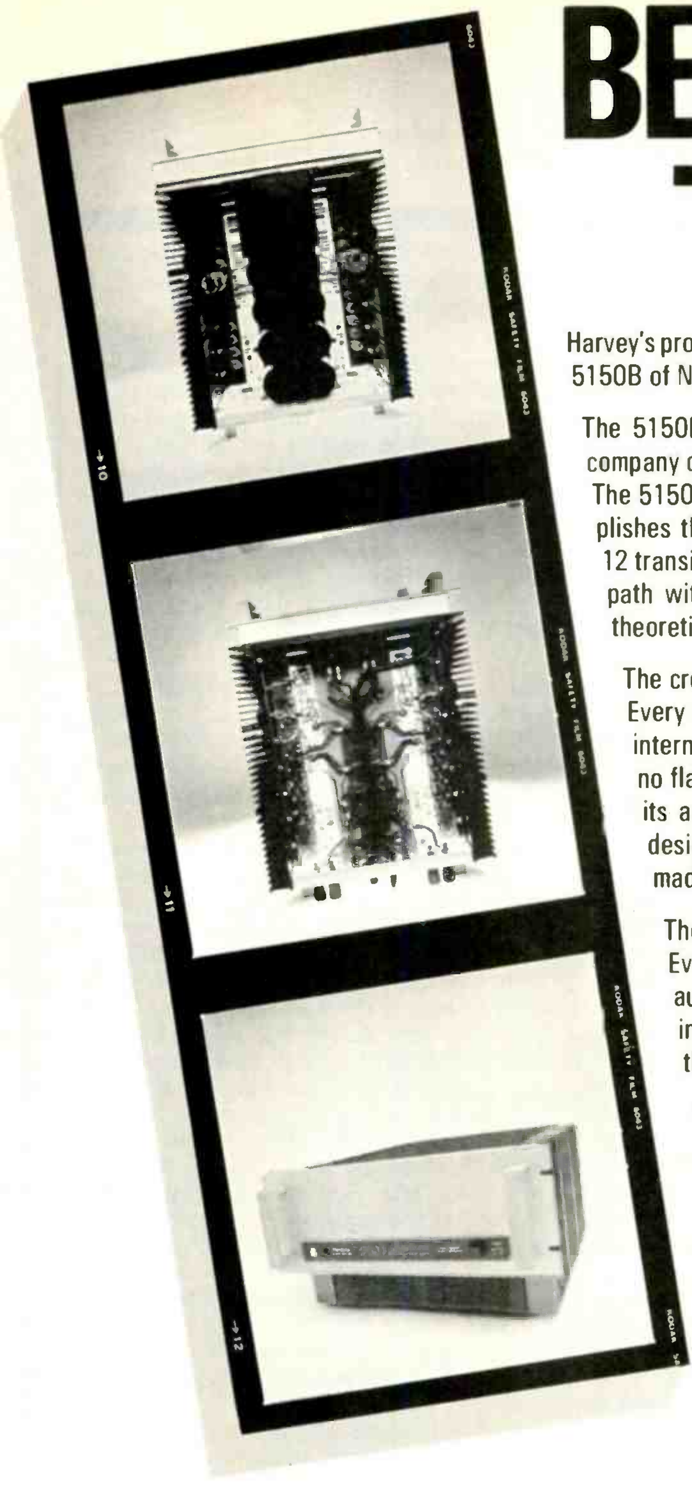
The Micro Seiki CD-M1 performed flawlessly in terms of programming facilities and in terms of sound quality. Now that my software library has expanded to include a good deal of well-recorded classical fare (and even a bit of beautifully engineered and recorded jazz material), I must confess that I am beginning to be able to differentiate between the sounds of various CD players. Yes, there *are* sonic differences, however subtle they may be. In my opinion, the Micro Seiki circuit approach to decoding and playing CDs is a good one, and I believe that in future months and years we will see an increasing number of manufacturers turning to the digital filtering/oversampling approach already employed by Micro Seiki and others. I certainly don't mean to imply that those manufacturers using steep-analog filters are producing inferior-sounding machines. I still maintain that all CD players I have tested, given decent software, offer tremendous advantages over even the best analog recordings and analog audio systems. It's just that those of you who are very critical listeners may be able to distinguish between the sounds of various CD players and, like me and many of my colleagues, may prefer the kind of sound reproduction offered by players such as this Micro Seiki unit.

Are there any negatives concerning the CD-M1? Yes, one or two. For one thing, it is not as shock-resistant as some other players I have tested. You don't want to bang your fist on its surface, or even on the table or shelf on which it stands while it is playing a CD. For another, at its suggested retail price, I rather wish that it had provisions for a remote-control unit (preferably wireless), even if the remote were an option at added cost. Especially with pop CDs, there's so much music on a single disc that I often find myself wanting to skip ahead when I listen to a disc for the first time and haven't yet programmed it to play specific tracks. To most listeners, these minor deficiencies may not even be regarded as substantive. The fact is that the Micro Seiki CD-M1 looks good, sounds good, and works well.

Leonard Feldman

The feature-laden CD-M1 can access up to 24 selections—by time, track or index point.





BEAUTY AND THE BEST.

Harvey's proudly present to the world the ultimate power amplifier... The Perreaux 5150B of New Zealand. An engineering masterpiece of the highest order.

The 5150B is actually capable of harnessing all the electricity your power company can supply. Yet its brute strength is derived from its elegant simplicity. The 5150B has no integrated chips or complex trick circuits. Perreaux accomplishes this demanding task with only 5 transistors in the driver stage and 12 transistors at the output. This most powerful of amplifiers has the shortest path with the fewest components—A virtual straight wire with gain, the theoretical ideal of amplifier design.

The creation of this leviathan that serves the art of music is an art in itself. Every Perreaux audio component is completely handcrafted. The 5150B's internal beauty and simplicity is reflected by its external design. There are no flashing lights or panels that glow in the dark. It has no need to shout its authority. The 5150B's statement is made by the rows of Perreaux designed heat sinks with over 60 dissipation ribs per inch. And by the hand made front panel with its beveled edges and meticulous etched finish.

The impressive performance is also derived by this attention to detail. Every transistor is tested, calibrated and matched by Pereaux. Every audio component created undergoes several hundred quality control inspections. Only Perreaux completely handcrafts in one facility, from the cutting of the metal to insertion of the components to final testing.

THE POWER Suffice it to say the 5150B's power is enough. There is no wattage rating given. The power supply can deliver 2,000 amps peak current to the circuit boards. Each channel is capable of delivering over 30 amps continuous current at the output along with 220 volts peak to peak. In addition to the extensive heat sinking, convection cooling is utilized to silently draw cool air into the amplifier. The 5150B is the greatest power available dedicated to the reproduction of music.

THE PERFORMANCE Perreaux was not satisfied with creating an amplifier of such power magnitude unless it was also the finest sounding and performing. The 5150B's bandwidth extends to 3,000,000 Hz. Its phase accuracy is $\pm 1°$ 20 to 20,000 Hz. and T.I.M. distortion is unmeasureable by most test equipment. The sound emanating from this brute is smooth, delicate and accurate.

The 5150B's production is very limited. Perreaux's 10 years of manufacturing experience is brought to a culmination for those who demand the utmost in power, performance and quality.

Price $3,500

Awarded the Audio/Video Magazine Hi Fi Grand Prix for its "Mercedes-like construction" Perreaux pre-amplifier and power amplifier combinations start at two thousand dollars.

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At 20 kHz, the right channel was flat within 0.1 dB, but the left channel was up 3.7 dB, indicating a ringing analog filter.

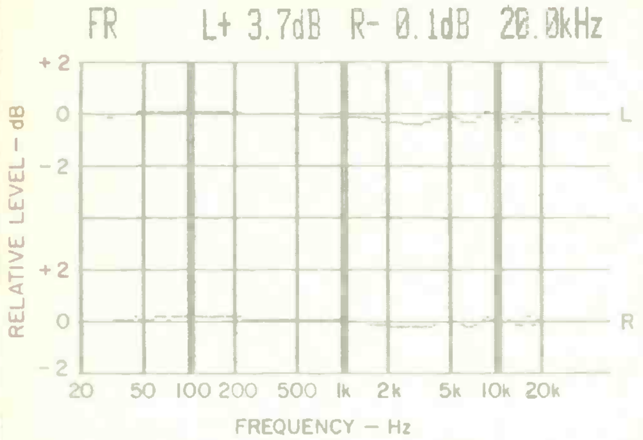


Fig. 1—Frequency response, left (top) and right channels, at 0-dB (maximum) level.

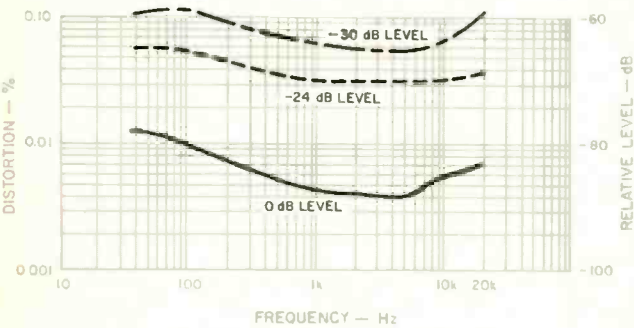


Fig. 2—Harmonic distortion vs. frequency at levels of (from top to bottom) −30, −24, and 0 dB.

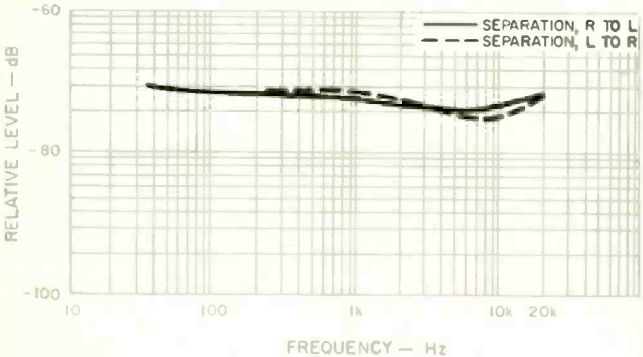


Fig. 3—Separation vs. frequency (0-dB level).

chose to use an all-black front panel with silver-colored touch buttons, while Akai uses—you guessed it—an all-silver front panel with black touch buttons!

When I realized that the two units are essentially the same physically, I was half tempted to abort the tests on the Akai and simply use the test results obtained from the Micro Seiki unit. The published specifications of both units read much the same, and after consulting *Audio*'s Annual Equipment Directory (October 1983), I noted that the features are about the same as well. Even the output filter system claimed for both is the same. Fortunately, I proceeded with the tests anyway. To my surprise, the test results and, apparently, the circuitry are quite different, adding to the mysterious aspects of these two seemingly identical units. If some of the descriptions that follow seem unusually familiar, now you know why.

The Akai CD-D1 is a full-featured unit, but there is no provision for remote-control operation. Up to 24 tracks, index points, or a combination of both can be committed to the player's microprocessor memory and can be played back in any random order. For those CDs that contain index numbers (subdivisions within a given program track), the CD-D1 provides easy access to any point in a disc by index number, as well as by track (program) number or even by elapsed time within a given track.

The Akai CD-D1 is a front-loading machine with a hinged disc-compartment door that accommodates a vertically positioned disc. To the left of the disc door is a power on/off pushbutton, and immediately to the right of the door are four display areas. The uppermost display has three LEDs, for "Stand By" (illuminated during the stop mode or when a track is being searched), "Pause," and "Play." The "Music No." display indicates the number of the track currently being played or about to be played, while the next display indicates time elapsed since the beginning of the track being played. If the "Total Time" button, at the lower right of the front panel, is pressed, this display will indicate total elapsed time from the beginning of the disc being played. Finally, this display will also indicate index number within a track, when such an index number is being programmed. The fourth display area, configured much like a tuner's dial scale, has a red-light dot which moves left or right to indicate the relative location of the laser pickup along the Compact Disc's surface.

Major operating buttons, to the right of the displays, are "Play/Start," "Stop/Eject," "Pause," forward and reverse "IPLS" (which skip the laser pickup to the beginning of either the current or the following track), "F. Rev" and "F. Fwd." A set of keypads, numbered from "0" to "9" and located to the right of the major operating buttons, is used to program desired track or index numbers and/or track starting times. A button labelled "Set" is used to enter track or index numbers during programming, while another button in the keypad area identified as "C/AC" (Clear/All Clear) is used either to clear an error you may have made during programming (if touched once) or to clear or erase all programs from memory (touched twice).

Six small buttons arranged in a vertical row at the right end of the front panel take care of the remaining functions. Included here are a "Phrase" button to initiate repeat-play of

Sherwood's new car stereo - Everything you're looking for plus something more: AM STEREO

The broadcast industry has been talking about AM stereo for a long time. But the talk is over. Stations all over are now using this exciting new technique.

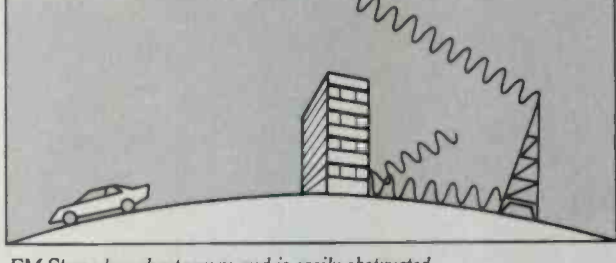
Why AM stereo?

The excitement of AM stereo is revolutionizing AM programming. Music, of course, takes on new realism, but that's just the beginning. Talk radio, a growing trend in AM broadcasting, is more exciting, more intimate in stereo.

What about FM Stereo?

Stereo FM is terrific. The new CRD-150, like all Sherwood receivers, sounds great on FM. But sometimes you can't pull in FM clearly, no matter what receiver you have, because FM signals have short range and travel in straight lines.

This wouldn't matter if we lived (and drove) on a flat, open surface. But since the earth is curved and covered with obstructions, it's difficult to get and hold clean FM where signals are weak or in congested urban areas or moving cars. That's when you need AM stereo.



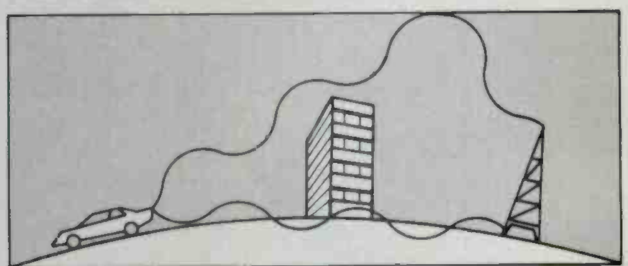
FM Stereo has short range and is easily obstructed.

No "fupp, fupp, fupp."

On the edge of clear reception FM makes a "fupp, fupp, fupp" noise, a result of its short range and directional nature. AM signals bounce off the earth's atmosphere, creating an "energy umbrella" from above. So with AM stereo there's no "fupp, fupp, fupp."

Not just for the boonies.

Because AM stereo is long-range, most people think it's just for remote areas. Not so. In big cities, too many FM stations make for poor selectivity, and high-rise structures make good FM reception even tougher. AM stereo is for the country *and* the city.



AM Stereo has long range and is not directional.

An all new car stereo at a price you can afford.

Now you can enjoy the benefits of AM stereo as well as all the features you would expect in an advanced cassette/receiver. Sherwood's new CRD-150 has digital readout, 10 station presets, Dolby* noise reduction, separate bass and treble controls, metal tape capability, and more. (The radio even plays when the tape deck is in fast forward or rewind.) And, like all Sherwood products, the CRD-150 gives you quality and innovation *at a price you can afford.*

To experience AM stereo and find out just how good (and how affordable) Sherwood's new CRD-150 is, see your nearest Sherwood auto sound dealer. To find him, call (800) 841-1412 during West coast business hours.

*Dolby is a registered trademark of Dolby Laboratories.

Sherwood

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Since its beginning in 1949, the McIntosh tradition for Excellence and technological leadership and more than thirty-five years of lived history provide the theoretical and practical background for years of dedicated research and exploration that has produced the XR 1051 'Xtra Real' loudspeaker.

The McIntosh XR 1051 is the finest expression in the loudspeaker scientist's repertoire. It is imbued with the McIntosh tradition for Excellence in technologically superior design, a significant advance in low distortion performance, in depth and spaciousness of stereo imaging, a cabinet finish that is the pride of the cabinet craftperson's art, lasting long-term value, and best of all, 'Xtra Real' music.

XR1051
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Suggested Retail Price $1199 each

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Unweighted signal-to-noise ratio measured an even 100 dB, one of the highest S/N readings I have obtained for any CD player.

a desired musical phrase, an "Index" buttón to select desired index points, a "Time" button to program by starting time rather than by track or index number, a "Memo Call" button to visually review memory content in the order in which it was programmed, a "Repeat" button to repeat-play any given track, and the "Total Time" button.

In addition to the usual left and right output jacks on the rear panel of the CD-D1, there is an output-level control which adjusts left and right channel outputs simultaneously.

Measurements

Figure 1 is a plot of frequency response for both left and right channels of this CD player. The vertical scale is expanded to 2 dB per division, and the plot is from 20 Hz to 20 kHz. At 20 kHz, response for the right channel was virtually flat (down only 0.1 dB), but for the left channel, response at that specific frequency was actually *up* a full 3.7 dB. This appears to indicate the presence, solely, of an improperly terminated analog filter that was exhibiting an inordinately large amount of ringing. In our Annual Equipment Directory, Akai had listed their filtration system as digital as well as analog. Furthermore, the Micro Seiki unit, which the Akai seems to emulate in its physical details, *does* use digital, as well as analog, filters. The mystery deepens!

Harmonic distortion at mid-frequencies, for maximum recorded level, measured a very low 0.0045%, rising to 0.013% at the lowest test frequency of 41 Hz. At 20 kHz, THD rose negligibly to 0.007%. Graphic plots of harmonic distortion versus frequency for three different levels of output are shown in Fig. 2.

Output linearity was accurate to within 0.1 dB from 0-dB reference level down to −60 dB and down to −80 dB within 0.3 dB. Stereo separation is plotted for left and right channels in Fig. 3. I measured separation of around 72 dB at mid-frequencies and approximately 71 dB at 20 kHz.

SMPTE intermodulation distortion measured a negligibly low 0.005% at maximum recorded output level, increasing to 0.015% at −20 dB recorded level. Unweighted signal-to-noise ratio for the Akai CD-D1 measured an even 100 dB—one of the highest S/N readings I've obtained for any CD player. A spectrum analysis plot of noise versus frequency is shown in Fig. 4.

Examination of a reproduced 1-kHz square wave (Fig. 5) revealed the familiar ringing pattern along the top and bottom of the square wave that is always associated with sharp-cutoff, multi-pole *analog* filters and not with pre-D/A digital filters such as those in the Micro Seiki, Magnavox, Marantz, and other units. This fact is further confirmed by examination of the reproduced unit-pulse signal (Fig. 6). I should mention, too, that the sample had trouble tracking the square-wave signals on my Philips test disc. There were moments of muting while this test signal was being played. Since the disc is maintained in clean condition and continues to play through on other CD players, I can only suspect less than perfect tracking capability for the sample Akai.

As far as the digital-versus-analog filter mystery, I have no ready answers. Is it possible that the manufacturer of this Akai unit simply ran out of parts and substituted an alternative p.c. board, or at least alternative circuit chips, rather than stop production? Could the person who supplied the

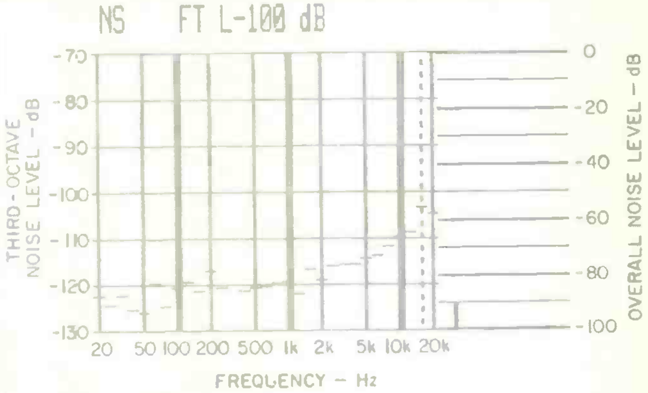


Fig. 4—Third-octave analysis of residual noise.

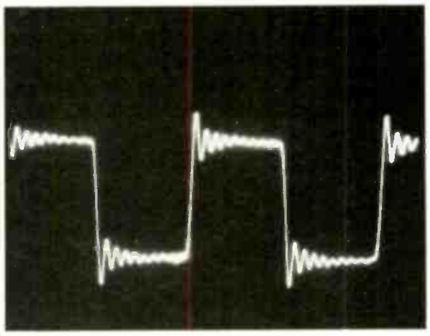


Fig. 5—Response to 1-kHz square wave.

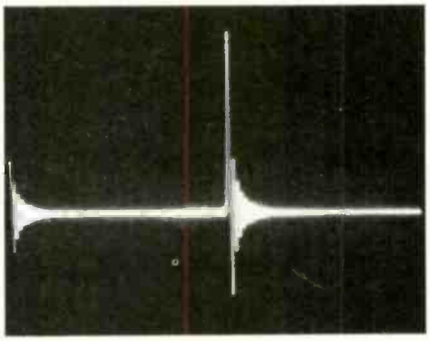


Fig. 6—Single-pulse reproduction.

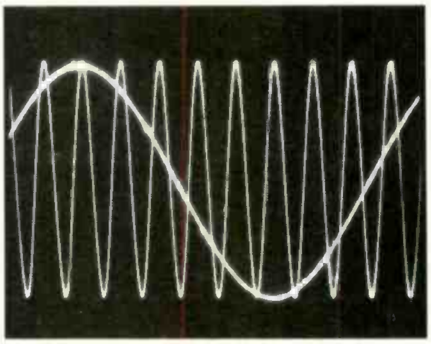


Fig. 7—Two-tone phase check (2 kHz left, 20 kHz right).

The Akai's programming features and front-panel controls performed perfectly. Access to a given track was extremely fast, and programming is simple.

information to *Audio* for the Directory have been working on the basis of preliminary data about the machine? I don't think we'll ever know the answer, but it certainly is an intriguing situation. The phase-response track on my test disc, which consists of a 2-kHz signal on one channel and a 20-kHz signal on the other, was also reproduced with the phase error (for the high-frequency signal relative to the lower frequency) that is typical of CD players employing multi-pole, analog post-D/A filtering. Results of this test are shown in the 'scope photo of Fig. 7.

The usual tests were made for error correction and tracking to see how well the player could handle simulated scratches, dust particles, and fingerprint smudges on the surface of a Philips test disc. The player successfully played all the way through the simulated scratch wedge, or right through opaque linear distances of 900 microns. In the case of the simulated dust specks, however, some mistracking occurred when black dots 600 microns in diameter were reached. As for the simulated fingerprint smudge, the CD-D1 had no trouble playing through it, nor have any of the other players tested been tripped up by this simulated defect in the CD's surface.

Use and Listening Tests

The programming features and front-panel controls of the Akai CD-D1 performed perfectly. Access to a given track was extremely fast, as specified by Akai, and programming is relatively simple and well documented in the owner's manual, which is translated in English, French and German. As for those analog filters, I did hear differences between the Micro Seiki and Akai units, using well-recorded program material. I suspect, though, that more of what I *didn't* like about the sound of the Akai can be attributed to the peaking at the high end in one channel than to the presence of one particular type of filter. As always, it is unfortunate that I am limited to one sample in such tests. I would be most curious to learn if all of the Akai units use this type of filtering, and, if they do, if other samples have a smoother high-end response in both channels. For all of this nit-picking, the Akai player sounded very good indeed, albeit not quite as good as the Micro Seiki—which I had tested just hours before and was still available for a direct A-B comparison.

As was true of the similarly configured Micro Seiki unit, I particularly liked that the disc compartment did not "swallow" or "grab" discs when I inserted them. In other words, it is necessary to push the disc all the way down, until a click is heard, and then to push the door closed manually. Retaining a certain amount of control over the mechanism is, to my mind, somewhat reassuring.

The Akai CD-D1 is somewhat prone to mistracking in the presence of mechanical shocks. However, aside from the mistracking noted while it played the square-wave test signal and the error-correction test tracks, I experienced no mistracking with any of the musical discs that I played so long as I refrained from pounding on its surface with my fist.

As for the "mystery" of why two units whose front panels look the same don't have the same "insides," I suspect after this report is printed I'll be hearing from one or both of the manufacturers in question. If I do, I'll let you know what the explanation is in a future issue. *Leonard Feldman*

5

AUDIO RESEARCH SP-10 PREAMP AND D-70 AMP

Manufacturer's Specifications

Preamplifier

Frequency Response: 5 Hz to 30 kHz, ±0.25 dB; −3 dB below 1 Hz and above 100 kHz.

Maximum Output: 60 V (into high impedance).

Harmonic Distortion: 0.01% at 2 V rms output, 20 Hz to 20 kHz; mid-band, typically 0.002%.

SMPTE and IHF IM: 0.002% at 2 V rms equivalent.

Input Sensitivity: Phono (MM or MC), 0.125 mV; high level, 35 mV.

Phono Overload: 300 mV at 1 kHz; 1 V at 10 kHz.

S/N Ratio: Phono (MM or MC), 86 dBA; high level, 90 dB below 1-V in.

MM Phono Input: Capacitance, 40 pF; impedance, selectable, 10, 30, 100 ohms, 10 or 47 kilohms.

Dimensions: Two pieces, each 19 in. (48.3 cm) W × 5¼ in. (13.3 cm) H × 10¼ in. (26 cm) D, plus 1⅝ in. (4.1 cm) forward extension for handles and ⅞ in. (2.2 cm) projection for rear fittings.

Weight: 31 lbs. (13.9 kg).

Price: $3,450.00.

Amplifier

Power Output: 65 watts per channel, 4-, 8- or 16-ohm loads, 20 Hz to 20 kHz, 1% THD.

Power Bandwidth: 10 Hz to 60 kHz; 15 Hz to 30 kHz at 1% THD.

Slew Rate: 12 V/µS.

Input Sensitivity: 950 mV.

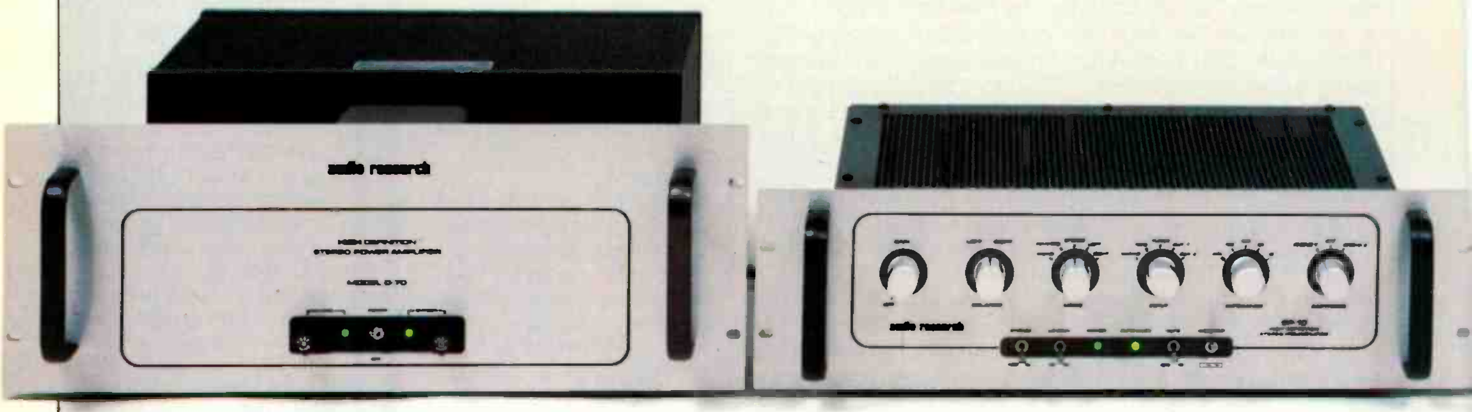
Dimensions: 19 in. (48.3 cm) W × 7 in. (17.8 cm) H × 16½ in. (41.9 cm) D, plus 1⅝ in. (4.1 cm) forward extension for handles.

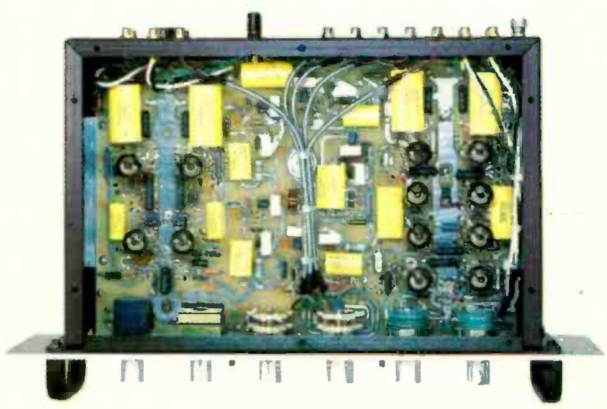
Weight: 51 lbs. (22.9 kg).

Price: $1,995.00.

Company Address: 6801 Shingle Creek Pkwy., Minneapolis, Minn. 55430.

For literature, circle No. 94





Audio Research's SP-10 is their most-evolved, top-of-the-line preamplifier. The D-70 is the smallest of three models that represent the company's current thinking on tube power amplifiers.

Among the design principles involved in these units are the use of 6DJ8 dual triodes, "Wonder Cap" polypropylene coupling and bypass capacitors, new signal circuitry, elaborate power-supply regulation, use of superior-sounding wire in the signal and power-supply construction, and new output transformer designs.

The SP-10 consists of two parts, the preamp itself and a separate power supply; both are 19-inch rack width. Interconnection is via a 1-meter cable with gold-plated "aircraft type" connectors. Rotary controls on the preamp front panel are, from left to right: "Gain," "Balance," "Mode," "Input" selector, phono loading "Impedance," and phono "Cartridge" selector. Toggle switch controls include: Bypass/normal, high/low gain, mute, and tape monitor. Also on the lower center portion of the front panel are two green LED indicators, one to indicate power on, and the other, by alternately flashing dim and bright, to indicate automatic mute mode. On the rear panel are the usual signal connectors, power-supply connector, and a pair of binding posts for connecting the chassis to signal common—a useful feature in rack installations, to break ground loops.

Controls on the power supply's front panel are two toggle switches for preamp and outlet power; green LED indicators show when these are switched on. Rear-panel features include the three-wire a.c. power cord, a connector for voltages to the preamp. line and high-voltage fuses, and one unswitched and three switched three-wire a.c. outlets. The third or ground wire of the power cord goes to the third wire of the a.c. outlets and to the chassis and signal ground.

Since the preamp and power amp both have third-wire-ground a.c. plugs, I would recommend grounding only *one* of the units, preferably the power amplifier, to the a.c. line via the power plug, and isolating the other units (and any other equipment in one's system). One way to do this is by equipping the other components having three-wire power cords with ground-lifter adaptor plugs. This will avoid unwanted ground loops between units.

The D-70 power amplifier is also rack width. Its one front-panel control is a toggle switch for power. Two green LEDs show when power and output-tube screen voltage are on, and also serve as fuse-out indicators. Line and screen supply fuses are easily accessible on the front panel. (An aside on what a screen grid is: It is an accelerating grid, in pentode and beam power tubes, which gives the tubes high gain, high output impedance, and low saturation voltage drop, enabling higher power to be obtained from a given high-voltage supply than triode output tubes can.)

On the rear panel are the power cord, two signal input jacks, and two four-terminal barrier strips for output connections for 4-, 8-, and 16-ohm loads.

Two output transformers and the main power transformer are mounted behind the front panel. The bulk of the circuitry, including the output tubes and filter capacitors, is on one large p.c. board taking up the remainder of the top area of the chassis. A perforated screen covers the components on the p.c. board, keeping one from possible severe burn and shock hazards. The p.c. board and parts quality are first-rate. The boards have been drilled with many holes to let air flow up through them in the area of large heat-dissipating parts.

I find the Audio Research pieces very attractive and functional in appearance.

Preamplifier Circuitry

The signal circuitry in the SP-10 is a departure from past Audio Research preamps in that the tubes used are 6DJ8s, instead of 12AX7s, and the phono circuit is more elaborate. Overall, there are two blocks of gain, consisting of a phono preamp/equalizer and an output amplifier, yielding minimum circuit topology regarding number of amplifiers in the signal path. The first stage acts as a grounded-cathode (i.e., usual connection) amplifier which is RC-coupled to the second stage. Operation of this second stage is as a cascode connection of two tubes, the bottom of which is a grounded-cathode amplifier and the top, a grounded-grid amplifier. Resultant characteristics of this combination are high gain, linearity and speed. These are appropriate to the second stage. since signal level is higher than in the first stage. Output of this second stage is direct-coupled to the third stage, which operates as a grounded-plate or cathode-follower amplifier, yielding low output impedance and high

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One departure in the SP-10 preamp from past Audio Research practice is that the phono stage is more elaborate.

linearity for driving the outside world (tape output), the mode, volume and balance network, and the RIAA feedback network.

The output amplifier is of more usual topology and more like previous Audio Research circuits. It consists of a grounded-cathode first and second stage and, again, the cathode-follower output stage. Frequency-independent negative feedback is applied around the output amplifier for wide frequency range, low distortion, and low output impedance.

In the phono preamp, both elements of each 6DJ8 are connected in parallel. This gives the advantage of lower stage noise, which is most important in the first stage. Additionally, lower plate-resistor values, along with higher currents than were formerly used with 12AX7 tubes, give higher speed operation of the overall circuit. In the output amplifier circuit, single halves of 6DJ8s are used in the first and second stages, whereas two paralleled elements are used in the cathode-follower output stage.

Power-supply distribution and regulation is more elaborate in the SP-10 than any other preamp that I am aware of. To supply regulated and low-noise heater voltages to the preamp tubes, the SP-10 uses two transformer windings, each with its own bridge rectifier and filter capacitor, plus a total of six, three-terminal TO-3 power regulators. The basic high-voltage supply starts out with a full-wave, bridge-rectified, 550 V d.c., terminating in 100 µF of filter capacitance. The high-voltage regulator provides an output of 305 V d.c. and is a hybrid circuit using two triode-connected 6L6 output tubes connected in parallel as the series-pass element. A 12AT7 tube, with the two halves paralleled, is used as a voltage amplifier to drive the grids of the series-pass tubes. The error amplifier is a solid-state op-amp whose output drives the grids of the 12AT7 tube. This regulator is in itself a low-noise, highly regulated source of d.c. voltage. Four additional regulators, consisting of op-amp error amplifiers and Darlington-connected series-pass transistors, furnish 293 V d.c. to each channel's three phono stages and three output amp stages. The 293 V d.c. from the phono first-stage regulator is dropped down to +43 V d.c. in a two-transistor discrete regulator, and, finally, a circuit similar to the 293-V regulators supplies +32 V d.c. to the grids of the upper phono second-stage tubes! Polypropylene capacitors are liberally used as bypass elements in all the regulator circuitry.

A time-delay automatic mute circuit is provided to prevent gross turn-on/turn-off surges to connected power amplifiers. Delay time upon turn-on is about 2½ minutes. Automatic mute upon preamp turn-off is rapid enough to prevent output surges. Since the SP-10 really takes longer than 2½ minutes to settle out and stabilize, it is recommended that the "Mute/Operate" switch be placed in "Mute" (which actually shorts the preamp main outputs) when the preamp is turned on or off. One should wait about 5 minutes before switching the muting switch to "Operate" after turning the unit on. This is particularly important for high-power transistor power amps and is not so important for tube power amps. The auto-mute circuitry will also mute when the preamp is on and operating if the a.c. line voltage drops below about 100 V a.c., preventing really gross output

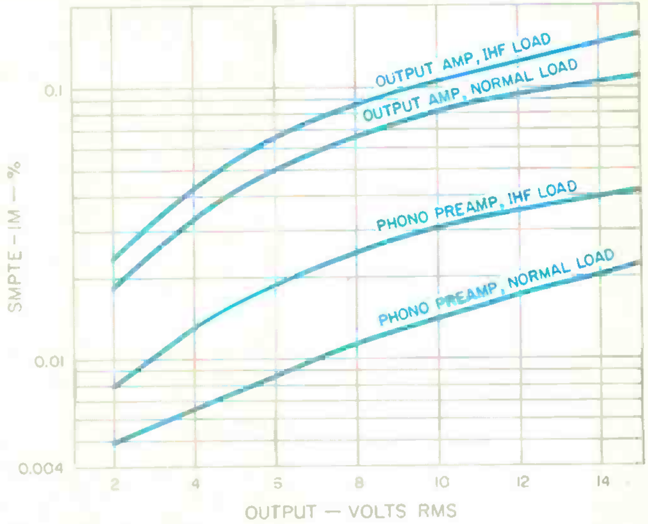

Fig. 1—SMPTE-IM distortion, SP-10 preamplifier.

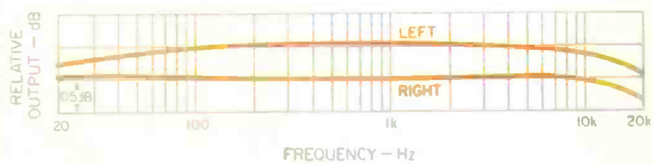

Fig. 2—Phono EQ error with IHF load at tape out, SP-10 preamplifier.

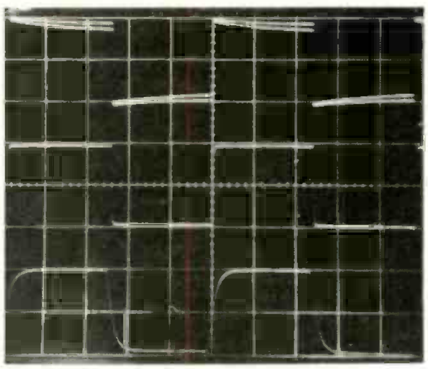

Fig. 3—Response of SP-10 phono section to pre-equalized square waves. Top, 40 Hz with 90 and 10 kilohms; middle, 1 kHz with IHF load; bottom, 10 kHz with IHF load.

An interesting test of phono EQ error is with a pre-equalized square wave; at 1-kHz, 10-V output, the SP-10 does very well.

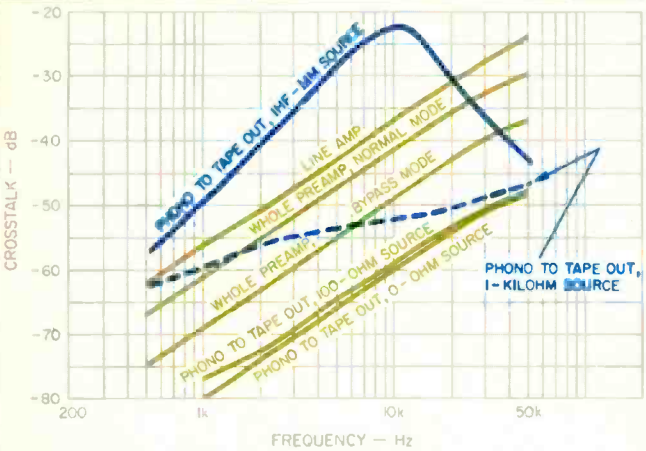

Fig. 4—Interchannel crosstalk (right to left) vs. frequency, SP-10 preamp. Line-amp crosstalk measured with 1-kilohm source and high-gain setting, volume control fully clockwise. Whole-preamp measurements made with high-gain setting, 0-ohm source, and volume control at 12 o'clock.

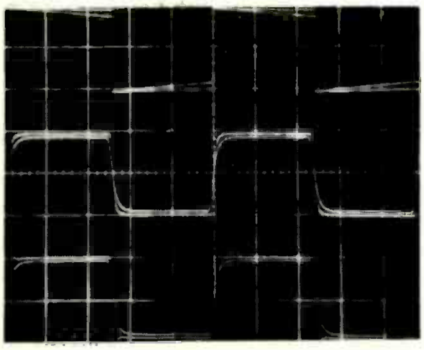

Fig. 5—Response of SP-10 line section to square waves. Top, 20 Hz with 90 or 10 kilohms; middle, 20 kHz with normal and IHF loads; bottom, same as middle but volume control at 12 o'clock.

surges that would occur if the power-supply regulators dropped out of regulation—which would happen at about 90 V a.c.

A word about the gain structure and signal path of the SP-10: The input noise of the phono stage is quite low for tube circuits, allowing a satisfactory S/N for medium-output moving-coil pickups without step-up devices. Further, the total maximum preamp gain of about 72 dB with the gain switch in the high position is entirely adequate for enough system acoustic output. The SP-10 was really designed with just this in mind. A more normal preamp gain of 60 dB is possible, for higher output moving-magnet cartridges, with the gain switch at low.

A nice purist feature of this preamp is a bypass switch which connects the output of the phono preamp directly to the volume control. This eliminates the switches and wiring of the selector, tape monitor, gain, and balance controls from the signal path. Under these conditions, one has full 72-dB gain (volume controllable, of course), committed phono operation, and no balance or mode functions. A related feature is the use of high-conductance rotary switches for phono input-resistance loading and "Phono 1/Off/Phono 2" selection.

Amplifier Circuitry

The first stage of the D-70 power amp is a push-pull, or differential, voltage amplifier using the two halves of a 6DJ8 tube. Often, such a first stage performs the phase-inversion function by having one input-tube grid grounded. The D-70 uses a single half of a 6DJ8 as a "plate-follower" inverting amplifier fed back to unity gain to feed one grid of the input stage, while the other grid is fed by the input signal itself.

Having established a solid push-pull or balanced signal out of the first stage, we proceed to the second stage, which I would best describe as a cross-coupled output-driver stage. This composite second stage uses two 6DJ8 tubes so arranged that the second of these tubes, whose plate signals are the outputs which drive the output-tube grids, has push-pull grid drive via direct coupling from the output of the first stage. Combination direct and capacitor coupling from the first stage is also used to drive the grids of the second stage's first tube, which is used as a cathode follower. The cathodes of this tube are cross-coupled to the cathodes of this stage's second tube. This ensures that each phase of the final output has both phases of the stage input involved in creating it. Such an arrangement yields better push-pull balance in the output phases, despite any drift and aging of the tubes involved.

The output of the second stage is capacitor-coupled to the grids of the output tubes, a pair of 6550 beam power tubes. Regulated fixed bias is used in this grid circuit. The primary winding of the output transformer is not screen-tapped as in ultralinear operation, because the output tubes are operated as pentodes with a regulated screen-supply potential of +325 V d.c. The B+ supply for the output-tube plates is 430 V; it is unregulated but has enormous filter capacitance for tube circuits, some 1,000 µF of electrolytic bypassed with 2 µF of polypropylene.

Since the final intent of this design is to have balanced push-pull feedback from the output back to the input stage, the 4-ohm tap of the output transformer secondary winding is grounded, causing the 0- and 16-ohm taps to have equal but opposite-phase voltages in respect to ground. To complete the picture, local output-stage negative feedback of about 6 dB is obtained by connecting the output-tube cathodes through 1-ohm, current-monitoring resistors to the "0" and "16" output taps. Having the 4-ohm instead of the usual 0-impedance tap grounded offers little practical difficulty in driving speakers, but one musn't have a common ground between the input ground and the 0-ohm tap during use or measurement, or one-half of the output transformer secondary will be shorted out.

The main regulator in the power supply for the screen supply is a hybrid design like that in the SP-10. A triode-connected 6550 tube is used as a series-pass element.

Voltage gain of the D-70 on the 8-ohm taps, loaded with 8 ohms, was 27.9 dB, close to the gain of 26 dB "normal" for a power amp.

Table I—Gain and IHF sensitivity, SP-10 preamplifier.

Condition	Gain, dB L	Gain, dB R	IHF Sensitivity, mV L	IHF Sensitivity, mV R
AUX or Tape to Main Out				
Low Gain, "Normal" Load*	12.7	12.7		
Low Gain, IHF Load	11.7	11.8	130.0	127.0
High Gain, Normal Load	24.6	24.6		
High Gain, IHF Load	23.6	23.8	32.5	32.0
AUX to Tape Out				
Normal Load	−1.21	−1.21		
IHF Load	−4.45	−4.45	835.0	835.0
Phono to Main Out				
Low Gain, Normal Load	59.8	59.7		
Low Gain, IHF Load	58.7	58.8	0.58	0.575
High Gain, Normal Load	71.7	71.7		
High Gain, IHF Load	70.6	70.8	0.147	0.144
Bypass, Normal Load	72.4	72.4		
Bypass, IHF Load	71.4	71.6	0.134	0.131
Phono to Tape Out				
Normal Load	46.0	46.0		
IHF Load	45.3	45.3	2.73	2.73

*See text

Table II—Phono noise, referred to input, SP-10 preamplifier.

Bandwidth	Source Impedance, Ohms	Referred Input Noise, nV L	Referred Input Noise, nV R
400 Hz to 20 kHz	0	190.0	240.0
20 Hz to 20 kHz	0	700.0	1500 (1/f)
A-Weighted	0	220.0	220.0
A-Weighted	100	230.0	220.0
A-Weighted	IHF MM	410.0	500.0

Table III—Phono and AUX IHF signal-to-noise ratios, SP-10 preamplifier.

Condition	Source Impedance, Ohms	IHF S/N, dB L	IHF S/N, dB R
MM Phono			
Low Gain	IHF MM	−76.5	−77.0
High Gain	IHF MM	−78.3	−77.5
Bypass	IHF MM	−77.8	−77.5
MC Phono			
High Gain	100	−64.5	−64.5
Bypass	100	−64.5	−64.5
High-Level Inputs			
Low Gain	1 kilohm	−77.2	−79.2
High Gain	1 kilohm	−82.0	−82.0

Input to the plate of the 6550 is 570 V, obtained from a separate winding and rectifier and capacitor system added to the 430 V for the output-stage plate supply. A 12AX7 tube with elements paralleled is used as a voltage amplifier to drive the control grid of the 6550. The error amp is a TLO-71 op-amp. A solid-state "zener-follower" regulator is connected between the raw 570-V and regulated 325-V output of the screen regulator, to provide a regulated 430-V supply to the plate resistors of the second tube of the amplifier driver stage. A full electronic-feedback regulator—with Darlington-connected, transistor series-pass elements and an op-amp error amplifier—is fed from the screen supply to deliver a regulated 327 V to the plate resistors of the amplifier's first stage and the plates of the first tube in the second stage.

Another winding on the power transformer is bridge-rectified and capacitor-filtered to −56 V, then electronically regulated to −42 V for the output-tube bias supply. This regulator uses Darlington-connected series-pass transistors, with a one-transistor error amplifier. The driver stage, output tubes, and screen-regulator series-pass tube heaters are a.c.-powered. The rest of the tube heaters are fed with regulated d.c.

As in the SP-10, the various regulator circuits in the D-70 power supply are liberally bypassed with polypropylene capacitors. A useful feature of this power supply is a circuit designed to prevent excessive a.c. inrush current upon amplifier turn-on. A thermistor, placed in series with the power-transformer primary winding, is bypassed by a relay after a suitable time delay. Control voltage for the relay coil is from the rectified d.c. for the tube heater supplies. Since heaters have a low resistance when cold, the amp's turn-on delay is essentially the time these heaters take to warm up to a higher resistance, allowing this d.c. voltage to rise and pull in the thermistor-shorting relay coil. Novel—and much easier on components.

Another interesting aspect of the power supply is an interconnection of the regulated bias-supply output and the 12AX7 in the screen supply. If, for some reason, the bias supply drops below some threshold value which would cause excessive output-tube dissipation, the screen voltage is also dropped, keeping dissipation in line.

Preamplifier Measurements

Interested readers are referred to my review of the Spectral DMC-10 in the September 1983 issue of *Audio* for helpful comments or IHF measurements. With this in mind, I won't repeat them here.

Table IV—Phono overload vs. (left-channel) frequency and loading, SP-10 preamplifier.

Frequency	Normal Load E in, mV	Normal Load E out, V	IHF Load E in, mV	IHF Load E out, V
20 Hz	34.0	61.0	15.0	24.5
100 Hz	71.5	63.0	30.5	24.5
1 kHz	251.0	51.0	121.0	22.4
5 kHz	510.0	39.0	300.0	21.3
10 kHz	565.0	23.2	432.0	16.0
20 kHz	615.0	12.8	485.0	9.0

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Ohm Walsh 2

Ohm Walsh 4

Here's What We Did

1 We reproduced the sound quality the New York Times described as "a spacious acoustic ambience with precise stereo imaging creating a 'reach-out-and-touch-it' realism that this listener has rarely experienced . . ."

2 We gave it the ability to play louder. The new Ohm Walsh 4 can handle 500 watts rms of music. It can reproduce a full orchestra at live levels in a normal listening room, flawlessly. It also can handle the new digital audio discs, effortlessly.

3 We made it play deeper. The Ohm Walsh 4 can reproduce over half an octave deeper bass. At 30 Hz the 4's put out 10 times as much volume as the superb 2's. Maybe only one record out of a hundred demands this—but the 4's are ready whenever you are. They let you physically *feel* the impact of a bass drum or timpani. An unusual luxury, but it's there.

4 We gave it more control range, so you can better match your own listening room to your musical taste. While most high-end speakers do have a high frequency control, the Ohm Walsh 2 has both a high frequency control and an additional Sub Bass Activator control to balance bass output—something no other speaker has ever had. The new Ohm Walsh 4 goes one better. We added a truly exciting and unique control called "perspective." This allows you to change your 'seat' in the audience from up front to in the rear—matching your taste, your music, your room and your state of mind.

5 We made the Ohm Walsh 4 even more convenient to live with. They come built with casters for easy placement or movement. Moreover, our three ambience controls are placed within easy reach on the rear. The speakers are tall enough (40") not be blocked by most chairs and sofas but small enough (only 12½" square at the top) to be inconspicuous in most rooms. They come in five finishes (all genuine wood veneer) to match your furniture.

Here's How We Did It

We used the same unique, patented technology as in the Ohm Walsh 2. The main transducer is in the shape of a conical pyramid, inverted like an upside down ice cream cone. This driver is driven full range and by its very nature gives perfect dispersion, so you can still sit anywhere in your room and hear and hear everything correctly. Our patented design mates this driver to a tiny super-tweeter supplementing the highest octave. They are in time and phase alignment at all listening positions. This perfect alignment is what prompted The Washingtonian to say ". . .the Walsh 2s are among the best 'imaging' speakers at any price, which means they create the original setting in which the music was recorded—Evoking the broad expanse of an orchestra or the compact spacing of a jazz combo, for example."

The inverted driver and cabinet of the Ohm Walsh 4 are much bigger, which allows it to handle more power and go deeper.

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Specifications	Ohm Walsh 2	Ohm Walsh 4
Frequency Response	45Hz to 16kHz ± 4 dB	32Hz to 17kHz ± 4dB
Size	32½" tall x 9¼" x 9¼" at top, 11½" x 11½" at bottom	40" tall x 12½" x 12½" at top, 15½" x 15½" at bottom
Weight	29 lbs.	63 lbs.
Sensitivity	87dB at 1 meter with a 2.83 volt input and all controls at maximum	87dB at 1 meter with a 2.83 volt input and all controls at maximum
Finish	Genuine wood veneer, walnut and oak standard. Scandinavian rosewood and black or white lacquer on oak finishes available on special order.	Genuine wood veneer, walnut and oak standard. Scandinavian rosewood and black or white lacquer on oak finishes available on special order.
Inputs	Press connectors accepting "banana plugs" or bare wire up to 12 gauge	Press connectors accepting "banana plugs" or bare wire up to 12 gauge
Controls	2 — low and high frequency each with 3 positions	3 — low, high and perspective each with 3 positions
Power requirement on Music	30 watts minimum/150 watts maximum	50 watts minimum/500 watts maximum
Impedance	4/4 ohms	4/4 ohms
Price per Pair	Under $995 Depending on finish	Under $1895 Depending on finish

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Spectral balance, harmonic structure, and revelation of detail were very good with the Audio Research SP-10.

Circuit gains and IHF sensitivities of the Audio Research SP-10 were measured first (Table I). Next, phono noise was measured for various bandwidths, weighting, and source impedances (Table II). IHF signal-to-noise ratios were measured for phono and high-level inputs, and results are presented in Table III.

Phono THD plus noise was measured at output levels of 2 and 5 V rms with an IHF load. At 2-V output, for the worse (right) channel, it was 0.1% at 20 Hz, 0.011% at 1 kHz, and 0.01% at 20 kHz. At 5-V output, it was 0.26% at 20 Hz, 0.024% at 1 kHz, and 0.02% at 20 kHz.

The SMPTE-IM distortion was measured as a function of output level and phono preamp loading, and results are shown in Fig. 1. Two-tone CCIF distortion, with frequencies of 10 and 11 kHz (equal amplitude), was measured at 3-V rms output from the phono preamp and was found to be less than 0.01%.

Phono overload versus frequency and loading at tape output is enumerated in Table IV. Relevant conditions are: Volume control full counterclockwise, tape monitor to "Source," and bypass switch to "Normal." The basic limitation at low frequencies is onset of clipping of the negative half-cycle of the output waveform. At high frequencies, a slewing aberration near the peak of the negative half-cycle is the limitation.

Phono equalization error versus frequency for a resistive source is plotted in Fig. 2. A test that I always look at in phono preamps (although not always reported), is how symmetry of a 1-kHz pre-equalized square wave varies with output level. This circuit looks just about perfect up to ±5 V output; at ±10 V output, the negative half-cycle has some tilt while the positive half-cycle is still straight. This is very good for this measurement. A 'scope photo of various pre-equalized square waves applied to the phono input is presented as Fig. 3. The top trace in this figure shows the effect of the 10-kilohm part of the IHF load causing more low-frequency tilt.

Phono input impedance could be represented to a satisfactory degree of accuracy by a resistance of 46.8 kilohms in parallel with 300 pF. Phono crosstalk was looked at with a short or zero-impedance source on the input of the undriven channel, which is the way I've usually measured this. One drives one channel with a pre-equalized sine wave and measures the leakage into the undriven channel in respect to the driven channel's output. Results are very good with the zero-impedance source and are plotted in Fig. 4.

Something devious within urged me to try terminating the undriven channel with my IHF moving-magnet noise-source impedance, which is a parallel network of a 500-mH inductor in series with 1,000 ohms and 125 pF of capacitance. As can be seen, this made matters much worse. The reason for the peaking at about 10 kHz is the resonance of the 500-mH inductor with the shunt capacitance of 125 pF in the IHF source and 300 pF in the SP-10. I don't know if this is unique to this preamp, and I suspect it's not, but it does suggest a possible reason why moving-magnet pickups with high inductance don't seem to have imaging and dimensionality as good as the better moving-coil pickups, which have much lower high-frequency electrical impedance. Crosstalk of the phono and line sections of this preamp are both in phase, which means that the leakage or crosstalk signal is positive-going for a positive-going pre-equalized square-wave edge in the driving signal.

To investigate how much phono crosstalk might be degraded by a moving-coil step-up transformer, which transforms the pickup impedance upwards by the step-up impedance ratio of the transformer, I measured phono crosstalk for terminating impedances of 100 and 1,000 ohms. Considering the various moving-coil impedances and step-up ratios of transformers, 1 kilohm is a reasonable value but not worst-case. This information is plotted in Fig. 4 along with crosstalk for the line section and a few combinations through the whole circuit. What does it all mean? A moving-coil pickup fed in directly will have superior channel-to-channel electrical crosstalk, virtually that of a zero-impedance source, while a moving coil fed in via a step-up transformer might have the crosstalk of a 1-kilohm source, which is considerably better than the crosstalk of most pickups themselves. High-inductance moving-magnet pickups will likely have crosstalk similar to that of the IHF source, which is on the order of the high-frequency crosstalk of most pickups.

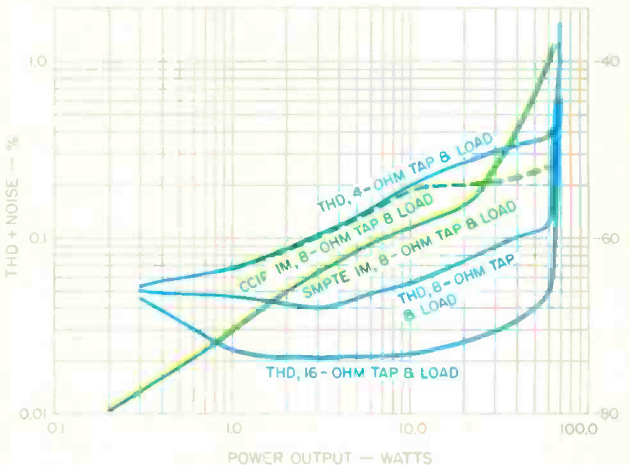


Fig. 6—Total harmonic distortion plus noise, SMPTE IM, and CCIF IM vs. power output, channel 2, D-70 amplifier.

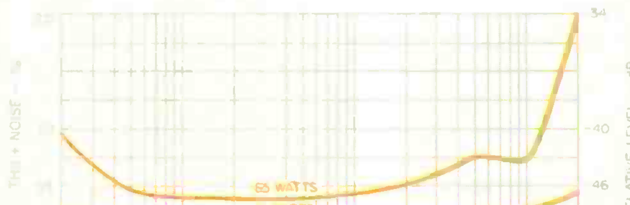


Fig. 7—Total harmonic distortion plus noise vs. frequency and power, channel 2, D-70 amplifier, with 4-ohm tap and load.

I personally prefer the sound of the Marantz 9s to this particular D-70, but I've heard good reports on the D-70 from people whose listening ability I respect.

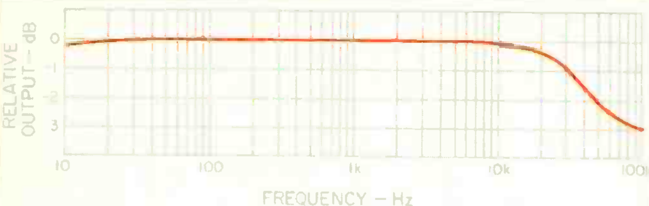


Fig. 8A—Frequency response of D-70 amplifier, 16-ohm load.

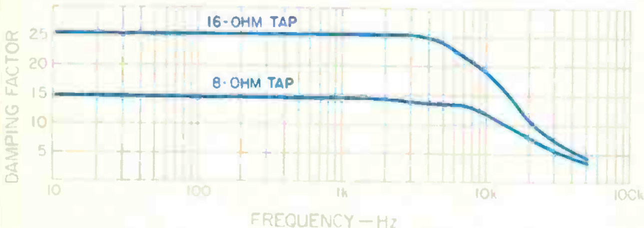


Fig. 8B—Damping factor vs. frequency, D-70 amplifier.

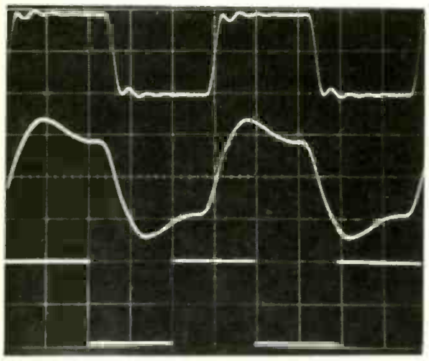


Fig. 9—The effect of a difficult load on the D-70 at high frequencies is shown by the difference in the 10-kHz square wave into a 16-ohm load (top) when the same load is paralleled by 2 µF (middle). The bottom trace is 50 Hz into a 16-ohm load.

These pure-phono-stage crosstalk considerations are somewhat complicated by the line section of the SP-10. For instance, in the bypass mode there is lower overall crosstalk than in the normal mode. The final point here is that the whole preamp will have better crosstalk with moving-coil pickups than with moving-magnet pickups of high inductance. It is to be emphasized that I'm not specifically condemning the SP-10 on this count, as further investigation may well reveal that other preamps have similar behavior.

Figure 1 shows the SMPTE-IM distortion for the output amplifier. My "normal" load is the parallel combination of the Sound Tech distortion meter input, 'scope, and interconnecting shielded cables. Resistance is about 90 kilohms, and capacitance is about 250 pF. The IHF load is 10 kilohms in parallel with 1,000 pF. Total harmonic distortion plus noise was measured as a function of frequency, output level, and loading for the line amplifier. At 2-V rms output, it was less than 0.01% with either load. At 5-V output, it was 0.013% at 20 kHz with normal load and 0.02% with the IHF load. Two-tone CCIF equal-amplitude 10- and 11-kHz distortion was less than 0.01% with either load at 3-V rms output.

Various square-wave responses of the output amplifier are illustrated in Fig 5. The top trace shows the effect on low-frequency tilt of decreasing the load from 90 to 10 kilohms. The middle trace shows the effect of adding the IHF load to the normal load on a 20-kHz square wave (the smaller amplitude wave is with the IHF load). The bottom trace shows the effect of the normal versus IHF load with the volume control at 12 o'clock (the faster waveform with some overshoot is with the normal load). Rise-time of the output amp with the volume control fully clockwise was 1.4 µS with normal load and 2.5 µS with the IHF load.

Slewing could be induced in the output amp and mostly occurred in the plus-to-minus transition of a pulse or square wave. At 35-V peak-to-peak output, it was −20 V/µS for the normal load and −6 V/µS for the IHF load. The reason for slewing in the negative direction is that single-ended follower circuits can't take a capacitive load in the negative direction faster than the cathode or emitter resistor can discharge the capacitance. Speed in the positive direction is higher because the follower device is actively turning on and becoming a lower dynamic impedance.

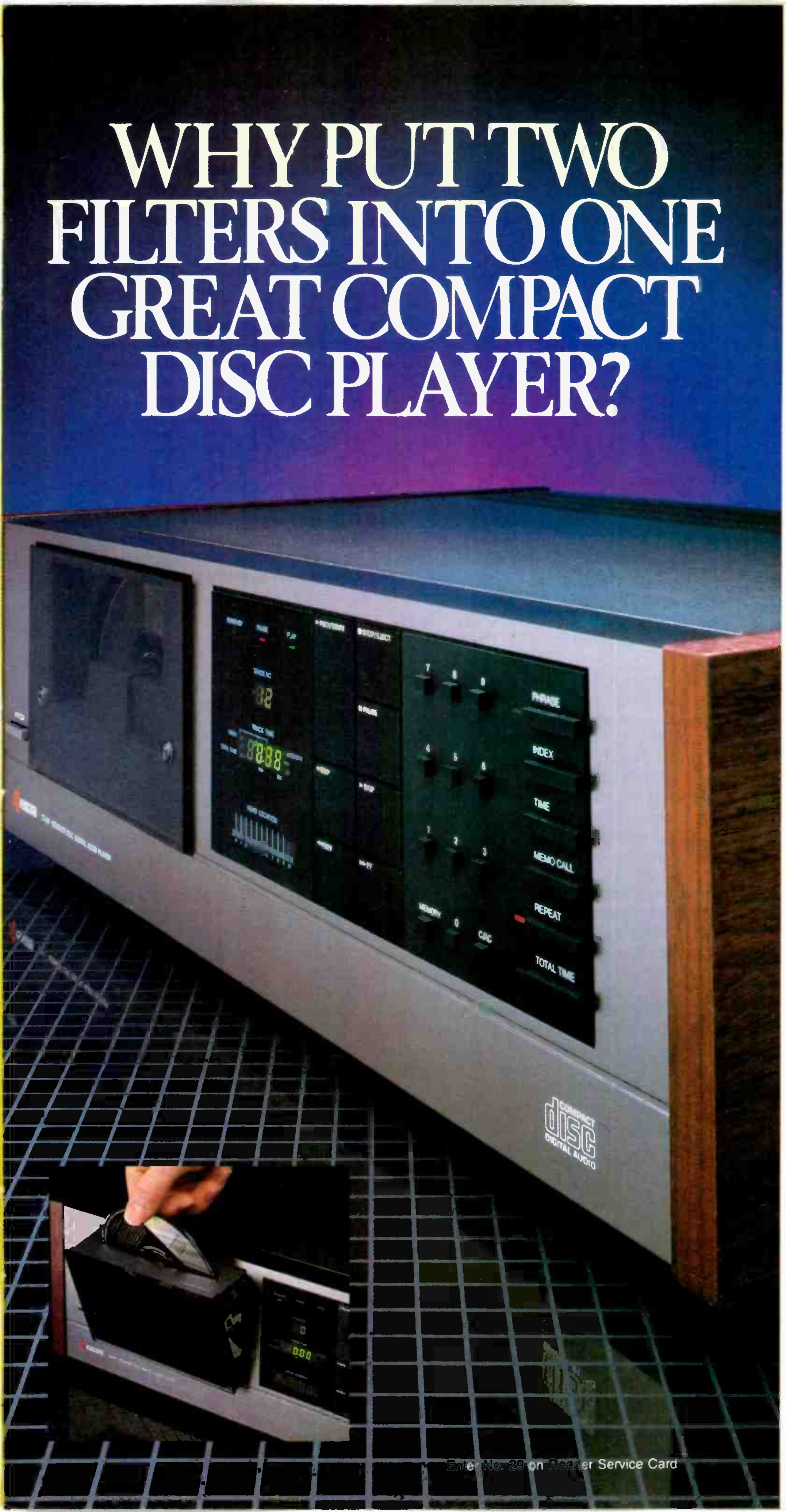
Output impedance of the phono function at tape output was about 1 kilohm. Output impedance at the main outputs was 840 ohms for the right channel and 965 ohms for the left. The AUX input impedance was about 59 kilohms shunted by 150 pF on low gain and 180 pF on high gain.

Amplifier Measurements

First thing done to the D-70 was to measure its bias and balance conditions. Output-tube idling current was about 60 mA for both channels. Both channels were set to 65 mA per Audio Research's recommendation. The d.c. balance of the front-end was close but was set right on.

I must say that setting output-tube bias by oneself is a bitch in this design. I had to measure the voltage drop across 1-ohm sampling resistors which have terminals on the p.c. board near the *hot* output tubes. Holding two meter probes on these terminals with one hand in order to have the other hand available to adjust the bias pot is a bit of a trick. Have someone else help with this if you can.

When attempting to set the a.c. balance controls for minimum second-harmonic distortion, I noticed that the second couldn't be eliminated on the 4-ohm taps but could be on the 16-ohm taps. The a.c. balance controls were set to null out the second harmonic at 10-watts output, 1-kHz, 16-ohm taps. Harmonic distortion plus noise was then measured as a function of frequency and power with 4-, 8-, and 16-ohm loads on their respective output taps. Harmonic distortion versus power at 1 kHz for 4-, 8-, and 16-ohm loads, and SMPTE and CCIF distortion with 8-ohm loads, are shown in Fig. 6. Harmonic distortion versus frequency for the 4-ohm tap is shown in Fig. 7. Note that distortion on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I recommend the SP-10 as "state of the available art"; on the D-70, go listen in as many situations as you can and judge for yourself.

the 8- and 16-ohm taps will be lower than shown in Fig. 7.

The reason for differences in distortion on different output taps is because the coupling in the output transformer between secondary windings is somewhat less than perfect. In a recent discussion, Bill Johnson of Audio Research said this phenomenon was less prominent in the higher power (and cost) D115 and D250 amplifiers, which implies better coupling in their output transformers. Some people have reported better sound from Audio Research tube power amps on the 16-ohm taps even though their speaker impedances were lower than 16 ohms. This may be related to better circuit balance affecting sound on the 16-ohm taps. Unfortunately, I didn't try this when listening to the D-70. (Postscript: As I was finishing typing this review, I started to listen to the D-70 on the 16-ohm tap with the Infinity RS IIa speakers and find that it sounds smoother and less offensive that way.)

Voltage gain of the D-70 on the 8-ohm taps loaded with 8 ohms was 25×, or 27.9 dB, which is close to "normal" power amp gain of 26 dB. IHF input sensitivity on the 16-ohm taps loaded with 16 ohms was 118 mV (channel 1) and 116 mV (channel 2).

Measured rise-time on the 16-ohm taps was about 4.5 μS at 5-V peak-to-peak output level. Running the amp up to clipping with a 10-kHz square wave yielded a large-signal rise-time of 5 μS. This is a good quality for an amp to have, approximately the same small- and large-signal rise-times.

Frequency response at the 1-watt output level and damping factor versus frequency are shown in Fig. 8. A 'scope photo illustrating square-wave responses is shown in Fig. 9. The top trace is 10 kHz into 16 ohms. (The nature and degree of ringing was not materially different on the other output taps.) The middle trace is with 2 μF across the 16-ohm load. Bottom trace is at 50 Hz and shows excellent low-frequency response. Finally, dynamic headroom measured out at about 0.16 dB with both channels operating into 16-ohm loads. Clipping headroom was about 0.32 dB.

Use and Listening Tests

Equipment used in evaluating the SP-10 and D-70 included an Infinity air-bearing turntable and arm using a Koetsu EMC-1B cartridge; Fidelity Research XF-1 Type M moving-coil step-up transformer; Marantz Model 9, Dyna Stereo 35, and Acrosound 20-20 power amplifiers; Audio Research SP-3 and GC/BHK developmental tube reference preamp; Infinity RS II and RS IIa and Magneplanar loudspeakers, and always, Stax SRX Mk III headphones.

Early on, the SP-10 was compared to the tube reference preamp using Marantz 9s to drive the Stax headphones via the Stax SRD-7 power supply and step-up transformers. (Note: I used the FR transformer only with my tube reference preamp.) The sound of the SP-10 was, by comparison, not as spacious and airy by an appreciable margin. Spectral balance, harmonic structure, and revelation of detail were very good with the SP-10. One observer characterized the SP-10 as "spatially compressed" by comparison. Next, the D-70 was listened to in the same setup, using the reference preamp as the signal source. Compared to Marantz 9s, the D-70 sounded noticeably less open and spacious and was slightly hard and metallic-sounding in the upper midrange.

Another interesting listening experiment was to interpose one power amplifier in series with the other and then to reverse the order. More specifically, the reference preamp was fed via a dual 50-kilohm volume control into the input of the D-70. The output of the D-70 was loaded with 50 ohms on the 4-ohm output tap and then fed into the inputs of the Marantz 9s, which drove the Stax phones. The 50-kilohm level control was adjusted so that overall level, as adjusted with the M-9 input level controls, was the same as when the M-9s were used alone and with the M-9 level controls at the same degree of rotation. In effect, I was inserting the D-70 as a gain-of-one device and noting how the sound changed as a result of this insertion. The sound of this arrangement was less spacious and generally sounded more like the D-70 alone. Instrumental texture was good, and the hardness of the D-70 alone was less noticeable. The order was then reversed, with the Marantz 9s first, attenuated by the 50-kilohm level control and loaded with 50 ohms on the 4-ohm taps, and then the D-70 driving the Stax phones. Interestingly, the sound took on the character of the M-9s, being more open and spacious. This means that neither amplifier is perfect; otherwise, there would be no change in the sound wherever a perfect amplifier was inserted in series with an imperfect one.

I personally prefer the sound of the Marantz 9s to this particular D-70 sample, both in headphone listening and on the speakers I have used. Another observer, who uses Magneplanar speakers and Quicksilver tube amps, said of the D-70: "Punchy, very powerful-sounding for its rating, dimensionally flat, clear, metallic-sounding in upper ranges, less apparent low bass." I have heard very good reports about the D-70 in other situations from people whose listening ability I respect.

The SP-10 I find highly listenable and have used it extensively in my system and in other systems. I took it over to the house of the same friend who has the Magneplanars. On his system, the SP-10 produced excellent resolution and detail, with good spectral balance. We compared it to an old Audio Research SP-3, which sounded more spacious and three-dimensional, but the SP-10 was more textually honest.

A few caveats on the SP-10 and D-70. I can generally judge preamps' susceptibility to external r.f. interference by how much of a thump I get at playing levels on phono function when I turn my turntable on and off. The SP-10 makes a horrendous crack when I do this. I definitely have to mute it when turning on my turntable. Also, when my kitchen oven cycles on and off, I get a zap in my stereo when playing records with the SP-10. Other preamps, under the same conditions, produce less or no interference. The D-70 has a moderate turn-off thump, which is odd for a tube power amp.

In conclusion, I feel the Audio Research components reviewed here are both attractive and functional pieces. I would wholeheartedly recommend the SP-10 as a "state of the available or purchasable art" preamp. My less enthusiastic feelings about the D-70 may be related to my personal preferences and possibly a less than representative sample. On this count, I would have to say, go listen to the D-70 in as many situations as you can and judge for yourself.

Bascom H. King

INNOVATIVE TECHNIQUES ITC-1 SPEAKER

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Editor's Note: This is the first appearance of both a new column and a new reviewer, Anthony Cordesman. Though breaking our tradition of listening backed by thorough, careful measurements, we are adding the column in an attempt to discuss more of the truly worthwhile gear available, with less delay than a full-scale review might take. Mr. Cordesman intends to concentrate principally on "high-end" gear; other reviewers will probably also contribute to "Auricle." We must emphasize that we still believe in the ultimate worth of measurements; however, we have long felt the need in these pages for something in between a "New Products" mention and a complete "Equipment Profile." We invite your commentary on this column.—E.P.

It has been clear ever since the LS-3/5A that a speaker system could be small and still produce excellent high-end sound. While no speaker can defy the laws of physics regarding the amount of bass energy that can be produced from a small box, the LS-3/5A demonstrated that a small box could produce a great deal of apparent bass, high-quality midrange sound, and act as a near point-source radiator which provided excellent imaging and sound state.

The Innovative Techniques ITC-1 is an attempt to provide even higher quality sound in a very small box. Each speaker is only 7¼ in. W × 12¼ in. H × 8 in. D and is nicely packaged in high-quality veneer with matching wood stands. Despite its small size, the ITC-1 is a full three-way system, with a 5¼-inch woofer having a damped Bextrene cone and a magnet larger than the cone; a 1½-inch, soft-dome midrange, and a 1-inch soft-dome tweeter. The cost per pair, including equalizer, of the ITC-1 is $800 without stands or $900 with stands.

The ITC-1's frequency response is specified as being ±3 dB from 50 Hz to 18 kHz, with ±1.5 dB from 55 Hz to 17 kHz as typical. Its efficiency is specified at 86 dB SPL at 1 meter with 1-watt input, and it is said to be able to handle 150 watts. Crossover frequencies are at 1 and 7.5 kHz. The system is described as phase coherent and uses a first-order cascaded filter at the top end and a second-order crossover between the midrange and woofer. These high crossover frequencies are felt to increase speed and reduce distortion. There are separate treble and midrange gain controls.

An external active equalizer, used to improve bass response and protect the woofer by filtering very low bass frequencies, fits in a spare tape loop or between the preamp and amplifier. The equalizer is comparatively neutral, although it will add a slight transistor character to the sound if you are using tube equipment. This is reflected in a slight drying out of the sound and minor loss of transient life.

In most ways, however, all this technology pays off. The ITC-1 produces very good bass from about 60 Hz up, even at relatively loud playing levels, and the bass is tight and has good transient speed. It sounds flat and can handle a great deal of power. There are no major irregularities apparent in its performance. Unlike many small or miniature speakers, the ITC-1 provides the full audio spectrum, except for deep bass, without compensating rises or shifts in apparent frequency response.

Placed on its stand, and several feet from the side and back walls, the ITC-1 has outstanding imaging and very good depth. The manufacturer, incidentally, recommends placing the speaker 4 feet from the back wall to improve depth, but 2½ to 3 feet generally seemed adequate. The speaker does not present bass problems if it is placed closer to a rear wall, but it does lose some of its air and excellent sound stage. It also benefits from a wide spacing between the units and from having the speakers toed in towards the listener. This still leaves a wide listening area and produces the most realistic overall result.

The ITC-1 must be treated for what it is: A small "point source" designed to be kept in the open; it should not be hidden on a bookshelf.

In fact, few speakers at any price can provide a more natural and stable spread of instruments from left through center to right with natural size and height. There is no loss of center fill, nor any tendency to divide the sound of instruments and make it sound as if each group had somehow been bunched near each speaker. This is enhanced by a good range of controls that allow you to make slight adjustments in the frequency balance so that the treble energy reaching the listener seems natural to the sound stage. Many speakers with fixed controls tend to sound either too bright and close, or too soft and far away, for their apparent imaging.

This combination of controls, and the small size and weight (16 pounds) of the ITC-1, also provide an unusually practical ability to vary the sound stage to suit the performance. The speakers are so small and light that you can easily reach the treble and midrange controls to change the apparent frequency balance to match your listening position. You can then alter the distance between the speakers so the imaging matches. Moving them closer together makes the imaging seem further back in the hall; moving them further apart makes the imaging seem closer to the stage.

This means, however, that you must treat the ITC-1 for what it is. It is not a small speaker designed to be hidden on a bookshelf. It is a small "point source" designed to be kept in the open with a clear line of sight to the listening area. It can always be put aside when it is not being used, but it ought to be well out in the room when the music is playing.

As for the competition, it may be unfair to judge the ITC-1s by their size, but the LS-3/5As, the Spica TC-50s and the Dayton-Wright LCM-1s do provide some good benchmarks in the small speaker arena. The LS-3As are less flat, more distorted, and can handle less power, but they have a slightly more natural transient life and very musical midrange. The Spicas have more speed or detail from the lower midrange up, although they have less extended and balanced bass. The Dayton-Wrights are more dynamic and have more air and imaging detail than the ITC-1s, although they are not the equal of the Spicas in this regard. The Dayton Wrights also have bass that seems as natural and more live than that of the ITC-1s, although the LCM-1s sound flatter.

This places the ITC-1s among several excellent speakers. Their strength is in coherence, smooth frequency response, and imaging. Their weakness is a slight lack of life and dynamic realism. They mate best with the faster moving-coil cartridges and the transistor or tube amplifiers having a great deal of low-level detail and transient speed. A good new entry in a tough old world. *Anthony H. Cordesman*

STAR BRIGHT

Illustration: Rick Tulka

Stardust: Willie Nelson
CBS CK 35305.

It's a strange and wonderful marriage: Country outlaw Willie Nelson, producer Booker T. Jones (once of Booker T and The MG's), and CD technology. This weird wedlock has brought forth one helluva gorgeous CD. *Stardust*, originally released in 1978, was Nelson's first full album of pop standards in what later became a growing family of such releases. Exquisitely engineered and produced at that time by analog means, this LP translates perfectly to the digital medium.

Jones' production and arrangements are marvels of subtle, intelligent music-making. Unlike far too many pop recordings, this one leaves no question about who the star is. Willie Nelson's warm, unique voice floats dead center, cushioned by a light layer of reverb. Each instrument complements or accents the main vocal line, never detracting from the old outlaw's superb vocals. Only on an instrumental bridge is his voice replaced center-stage, and then generally by a single instrument (either Jody Payne's masterful acoustic guitar or Mickey Raphael's soulful harmonica) which takes on the function of the main voice.

A special accolade to Bradley Hartman, Donivan Cowart, and Bernie Grundman, the unsung engineers of this outstanding recording. The sound is clean as a whistle and utterly transparent. There is absolutely no audible hiss from the original master tapes. The first few pristine acoustic-guitar notes of the title tune introduce the album and set up a standard of clarity that holds throughout the recording's 10 succeeding cuts. Following this guitar intro, Nelson's voice drifts in, buoyed by a touch of cymbal and a slight swell of organ so subtle, so keyed to his vocal quality, that the accompaniment almost goes unnoticed. Each of the other family heirlooms in this digital dowry—"Blue Skies," "All of Me," "Moonlight in Vermont" among them—is treated equally lovingly by all involved.

The only flaw here—and it is minor, though annoying—is in the album graphics, a simple copy of the original LP jacket reduced in size so as to give an inveterate credit-reader a major headache from perusing the teeny-tiny print. 'Nuff said on the negative side.

The musicians are among the best available, the technical packaging is, as mentioned, superb, and then there's Willie. If you're used to smooth, overly polished pop crooners, Willie Nelson's resiny voice and unique phrasing may take a moment to get used to, but not much more than that. Since *Stardust*'s release, Nelson has taken many other standards into the country fold. If old, leathery Willie continues along these lines, he may yet earn himself the title "Grandpop of Pop."

Paulette Weiss

Kind of Blue: Miles Davis
CBS CK 08163.

Sketches of Spain: Miles Davis
CBS CK 08271.

This is the original Miles Davis, the thinking person's man with a horn. Here is Miles pre *Bitches Brew,* his 1969 album credited with giving birth to the jazz fusion movement. For those of us who consider his earlier recordings among the greatest American music of the 20th century and are sorely disappointed in his current output, these two CDs, *Kind of Blue* and *Sketches of Spain,* are manna from jazz heaven.

If your original analog LPs are anything like mine, the grooves are worn into oblivion; at the very least, these CDs offer pristine surfaces to replace the mangled vinyl owned by Davis fans worldwide. Unfortunately, there's just so much a digital clean-up can effect with recordings made so long ago (1959 and 1960, respectively). A definite hiss remains from the original tapes; this is most noticeable in the contrast between the spaces which separate cuts (which are totally silent) and the initial portions of the cuts, when the hiss first raises its ugly head. It does so quite prominently in the first few moments of "So What" from *Kind of Blue,* for one instance.

Kind of Blue presents the instrumentalists—Davis on trumpet, Julian "Cannonball" Adderly on alto saxophone, the magnificent John Coltrane on tenor saxophone, Bill Evans and Wyn Kelly on piano (the latter appearing only on "Freddie Freeloader"), Paul Chambers on bass, and James Cobb on drums—firmly entrenched in the same aural location throughout the five selections: Piano and tenor sax on the left, drums,

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On *Sketches of Spain*, delicate accents stand out clear and defined, pulled from the murk of the original analog recording.

bass and alto on the right, and Davis' trumpet center stage. This presentation offers little sensation of depth, but the brilliance of the music makes up for any lack of technical recording flash.

Davis' horn both soars and strolls, both sets up a foundation for each tune and examines new cracks and open spaces. Under his leadership, these individually gifted jazz artists can be heard *thinking* together, exploring the musical terrain side by side. The lengthy (11½ minutes) "All Blues" is especially appealing.

Although there is no vast improvement in dynamic range, presence or clarity, this CD is worth having for its cleanliness and bècause it will last without suffering further deterioration.

Sketches of Spain, the classic collaboration of Davis and jazz arranger/conductor Gil Evans, presents Davis' moody, sensual trumpet against a full orchestral background. Although analog tape hiss is evident here as well, the improved sound of the CD version is marked. Delicate accents (the momentary metallic rattle of a tambourine, a scattering of high-pitched, plucked harp strings) stand out clear and defined, pulled from the murk of the original analog recording. The castanets used to impart the Spanish flavor Davis had begun to cook with on *Kind of Blue* ("Flamenco Sketches") click away in clean, crisp contrast to Davis' sometimes-sexy, sometimes-stately horn. This is the album that won Miles Davis many new fans, with its accessible sensuality and its beautiful melodies.

Sketches of Spain and *Kind of Blue* are both timeless recordings; what could be more appropriate than timeless music presented in a format that, theoretically, will preserve it for all time? One minor quibble, though. The lack of liner notes or even basic credits is sorely felt on classic recordings such as these. No indication is made of which musician plays what instrument on *Kind of Blue*; this seems the rock-bottom minimum of information to be supplied for those unfamiliar with a recording. That aside, these are splendid acquisitions. Thank you, CBS; thank you *very* much. *Paulette Weiss*

Beethoven: Violin Concerto. The Philharmonia Orchestra, Carlo Maria Giulini; Itzhak Perlman, violin.
EMI/Angel CDC 747002.

EMI/Angel, the last major record-company holdout, has finally entered into the production of Compact Disc recordings. The vast resources of their classical catalog will have considerable impact on the CD market.

One of their first offerings is this splendid recording of the Beethoven *Violin Concerto*, with the great Itzhak Perlman as soloist. Needless to say, in this early CD, I was keenly interested in the quality of the sound. EMI/Angel has a deservedly good reputation for the outstanding, high-quality sound of their

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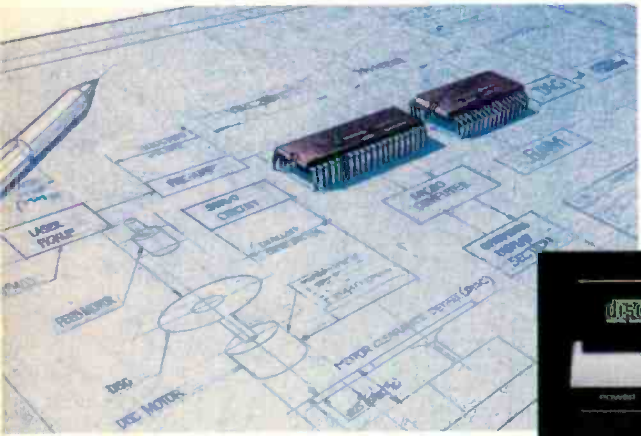

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Telarc's penchant for authenticity resulted in the digital recording of live cannon and musket fire for *Battle Music*.

vinyl recordings, and this CD release certainly is an encouraging beginning.

Perlman's characteristic tone is clean and sweet, completely articulate with no trace of edginess. The sound of his violin is just forward of the orchestra, nicely balanced and never too prominent. It goes without saying that Perlman's performance is superlative—highly expressive, lyrical, insightful, masterful.

Carlo Maria Giulini and the Philharmonia Orchestra furnish a knowledgeable accompaniment to Perlman. The orchestral sound has good internal balances, is clean and well detailed, and the high strings do not exhibit any stridency or wiriness. The hall acoustics had just about the right amount of reverberation to give a warm, fairly spacious ambience to the sound. The EMI/Angel engineers managed a fairly wide dynamic range in this recording, and, all in all, the sound of this CD must be judged a resounding success.

So, a hearty welcome to EMI/Angel CDs. There is great music in the offing.

Bert Whyte

Erich Kunzel

Battle Music of Beethoven & Liszt. The Cincinnati Symphony Orchestra, Erich Kunzel.
Telarc CD-80079.

Telarc's LP recording of Tchaikovsky's "1812 Overture" gained no small measure of fame by including the stylus-rattling sound of live cannon fire. Now, in this recording of Beethoven's *piece d'occasion*, "Wellington's Victory," the Telarc artillery has gone into action again.

In Beethoven's time and ever since, critics have not treated his salute to Wellington's victory in the Battle of Vitoria too kindly. It has always been overshadowed by Beethoven's Seventh Symphony, which premiered on the same program as the "Victory," December 13, 1813.

Telarc's penchant for authenticity resulted once again in the digital recording of live cannon and musket fire, provided by the North/South Skirmish As-

London's CD of Ravel's *Daphnis et Chloé* has an acoustic perspective of rare beauty, and it abounds with ambience.

sociation, and the battle sounds were incorporated into the score according to Beethoven's notations. While this Telarc recording carries a warning about the dynamic range of the artillery, in fact these battle sounds do not have the huge impact of the cannon fire in their recording of the "1812 Overture." The cannons do produce a considerable pulse and steep wavefronts, but the sound is more of a mid-bass, lower midrange crack rather than a low-frequency boom. In any case, it is a fun piece, with drums and brass fanfares, ruffles and flourishes, depicting the British forces on your left and the French forces on your right.

This CD also contains Liszt's "Battle of the Huns" and "Hungarian March to the Assault." As you might expect from the titles, these are rather overblown, fustian pieces, heavily orchestrated. In my view, there are more sonic fireworks in these pieces than in the "Victory." This is especially true in the finale of the "Huns," with the sound of very high-energy cymbals, huge brass fanfares and the counterpoint of great organ chords. All is recorded in a spacious acoustic perspective, with good internal orchestral balances and very clean, highly detailed sound of wide dynamic range. *Bert Whyte*

Ravel: Daphnis et Chloé (complete ballet). Choeur et Orchestre Symphonique de Montreal, Charles Dutoit.
London 400 055-2.

I direct the attention of all CD naysayers to this magnificent recording of Ravel's *Daphnis and Chloé*. It was recorded in St. Eustache Church in Montreal, Canada, one of the premier recording venues extant. The gorgeous acoustics combine an ideal reverberation period, great diffusion which makes for warmth and spaciousness, and a marvelous perception of depth. These qualities do not sublimate sonic focus and definition, which in this recording are of the highest order.

In short, this recording has an acoustic perspective of rare beauty, and it abounds with ambience. In no manner does the CD medium diminish, attenuate, truncate, or otherwise alter the ambient information on this digital recording; it is, rather, a vital part of the glorious sound of an exceptional performance.

Charles Dutoit is rapidly becoming the foremost conductor of French music, and his Montreal Symphony Orchestra is beginning to achieve world-class standards. Dutoit furnishes a wonderfully atmospheric interpretation of this masterpiece. He brings out every detail in Ravel's incredible orchestration, but never diminishes the sensual and mystical elements of the score.

The sumptuous, natural-sounding string tone in this digital recording of Ravel's *Daphnis and Chloé* should convince most people that the Compact Disc medium is capable of complete neutrality in its delineation of mu-

Tricycle offers some striking sounds, especially in the high-intensity, transient attack of the percussion.

sic. Overall orchestral definition and clarity are outstanding here, and the internal balances afford splendidly cohesive sound. The wordless chorus is placed and miked to accent the sense of depth without becoming amorphous. The dynamic range is very wide, ranging from ethereal pianissimos to awesome fortissimo outpourings from full orchestra and chorus.

This is the complete ballet music of *Daphnis and Chloé*, all 56 minutes of it. Hearing it without interruption enables a better understanding of the organic and dynamic structure of the exquisitely scored music. This recording should positively dispel any notion that the CD medium has inherent technical flaws that are in any way inimical to music. Don't miss it! *Bert Whyte*

Tricycle: Flim & The BB's
Digital Music Products CD 443, $20.00. (Digital Music Products, Rockefeller Center Station, P.O. Box 2317, New York, N.Y. 10185.)

This is another of those super Digital Music Products recordings engineered by Tom Jung.

Flim Johnson and the three other members of The BB's play a wide variety of acoustic and electronic instruments in 10 freewheeling numbers, all original works unknown to me. With the frequent use of soprano saxophone, the group often reminds me of Weather Report.

There are some striking sounds here, especially in the high-intensity, transient attack of the percussion. The impact of the kick drum is startling. All is super clean and has been masterfully recorded on Tom Jung's digital Mitsubishi X-80. This pure digital recording is a knockout! *Bert Whyte*

I'll Be a Song: Nancy Wilson
Denon 88C38-7061.

Performance: A+ Recording: A+
Source: Digital

The magnificent Miss Wilson delivers performances here that just about make these songs hers alone. God, she is fantastic. And here I thought that a chanteuse was not to be found. And as good as she is throughout, she outdoes herself in "Life Begins with You."

The recording, a classic multi-track, multi-mike production, is a paramount example of good taste and impeccable expertise. Some parts were recorded in Japan (it's not clear where Miss Wilson's vocals were recorded) and parts in New York. Surprisingly, the homogeneity of the final product is just unbelievable. To begin with, all the elements in the recording have been echo-chambered—but they sound cohesive, as if they all had been in the same hall (unlike most multi-tracks, where each section seems to have been recorded on a different planet). There is a superb roundness and air

Nancy Wilson's *I'll Be a Song* is a paramount example of a recording done with good taste and impeccable expertise.

Nancy Wilson

The recording is multiple-mike, mixed very well and with the ambience of a small club, making it superb for easy listening. The sweet, overall sound and sensitive mixing make you feel as if you were in the club, low ceilings and all (except for the highly audible transitions when the violin solo is part of the ensemble). The drum set is not taped, as is the custom nowadays, and the cymbals are real-sounding, although the overall top end is a little subdued. The bass viol is good and solid, and the piano is very well recorded, with none of the percussive clang we are always subjected to by around the instruments that is just lovable. The mixing is faultless; I have never heard a mix as superb as the one here. Even with evidences of multimike, this CD sounds as if it were true stereo—no doubt due to masterful panning.

An interesting note: The Japanese recordings appear superior to those made in the U.S., but the blend is so good, only microscopic listening will reveal it. The percussion is also superb, but I wonder what size the bass drum is in the first two selections, "Just the Way You Are" and "The Island," that can make the floor move up and down—an 8-foot bass drum?

On a slightly negative note, there is a minor microphone peak in the vocals (sibilants) which mars this otherwise perfect recording. This is, so far, the greatest CD in this genre I've heard. Everyone should have it.

C. Victor Campos

The Club New Yorker: The Great Jazz Trio
Denon 38C38-7072.

Performance: B+ Recording: B−
Source: Digital

This CD features some of New York's most popular cocktail-hour musical offerings. It really sounds as if you were in the Plaza's Palm Court. The only disappointment is Lewis Eley and his violin; God, I wish he weren't there. In fact, his selections are the only places where the audio mixing trips and falls. The real star and surprise of this recording is Eddie Gomez, who is just outstanding on bass.

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"For anyone starting a compact-disc collection, I can think of no better release with which to begin."
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Fanfare Magazine, September/October 1983

"This is one of the most exciting organ records ever made."
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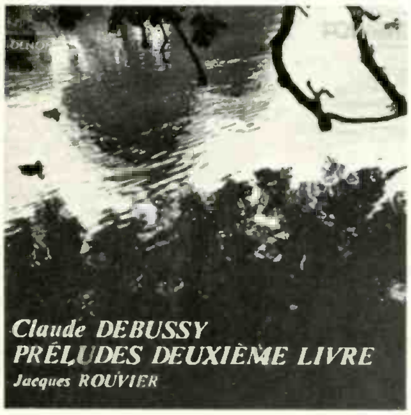
"A superb reading as a digital LP, the bass definition and general clarity are even greater on the CD, with no loss of warmth."
Ovation Magazine, November 1983



"...Jacques Rouvier is a superb technician, with tremendous power and solidity and remarkably precise fingers."
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Ovation Magazine, November 1983

NEW RELEASE!
Beethoven: Symphony No. 9 ("Choral")
Staatskapelle Berlin, Otmar Suitner, cond.

DENON IMAGINE WHAT WE'LL DO NEXT.

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Frederica von Stade has become a mezzo-soprano of increasing stature. Her voice is exceptionally clean, her articulation clear and precise.

Frederica von Stade

those who always know better. The notes are in Japanese and are no help, and the 43:22 timing shows another LP-formatted master.

C. Victor Campos

Handel: Messiah Highlights. Musica Sacra, Richard Westenburg; Judith Blegen, Katherine Ciesinski, John Aler and John Cheek, soloists.
RCA RCD1-4622.

Both chorus and orchestra number in the 30s, but the conductor's approach to this music is distinctly more modern than period. These are very competent performances, but they are somewhat inflexible. Only John Cheek rises above this difficulty for a quite spirited "Trumpet Shall Sound."

The recording, made in RCA's capacious Studio A in New York, is very well done. Soloists are ideally balanced with the orchestra, and the orchestral resources themselves are naturally arrayed on the stereo stage. Some artificial reverberation is added, and it is tastefully done, if not utterly natural.

John M. Eargle

Canteloube: Chants d'Auvergne, Vol. I. The Royal Philharmonic Orchestra, Antonio de Almeida; Frederica von Stade, soloist.
CBS MK 37299.

Frederica von Stade has become a mezzo-soprano of increasing stature. She really has a glorious voice, a fact readily apparent in this recording of Canteloube's "Songs of the Auvergne." Derived from French folk songs and colorfully orchestrated by Canteloube, they are an exquisitely lyrical vehicle for the lovely voice of Frederica von Stade.

Her voice is exceptionally clean, her articulation clear and precise. She is secure throughout her register, and the purity of her tonal palette is something at which to marvel. Her vocal production is so effortless and so richly expressive that she makes these lovely, colorfully scored songs newly attractive.

Antonio de Almeida conducts the Royal Philharmonic Orchestra and has a fine rapport with Ms. von Stade. Her voice is nicely positioned just in front of the orchestra. The felicitous acoustics add warmth to a most resplendent sound. The fine digital recording shows the quality of this beautiful voice, unsullied by noise. One of the best vocal recordings on CD.

Bert Whyte

MICHAEL TEARSON
JON & SALLY TIVEN

LEADING LADIES

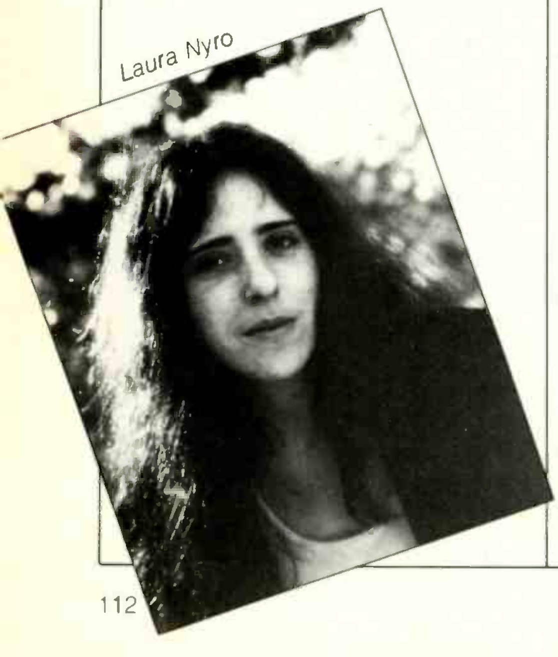
Mother's Spiritual: Laura Nyro
Columbia FC 39215.

Sound: B Performance: A

There isn't a female singer/songwriter of any worth whose work hasn't been affected by Laura Nyro. Although Carole King, Cynthia Weil, and Ellie Greenwich preceded her as premier pop tunesmiths—women in a world ruled by men—it was Laura Nyro who made the transition from a writer of contemporary tunes for pop singers to a singer/songwriter with a following all her own. Chrissie Hynde's vocal stylizations have more than a trace of Nyro to them, and Rickie Lee Jones has made a career out of slightly updating Laura's style. When she disappeared from public view in the early '70s, there were more than a few women inspired and ready to carry on in her tradition.

It is because of these circumstances that a new Laura Nyro record—as rare as snow in June—is always held up to the most scrupulous observation by critics and public alike. It is a wonder that a soul who has been so closely involved with the record/publishing industry can remain so untouched by that mire, but *Mother's Spiritual* is a fresh and original work. There is nothing here to suggest that Laura Nyro has listened to the radio, spoken with a record-company executive, or even thought about the competitive art process that goes along with being a member of the music industry. She still sounds like the unworldly, poetic individual who charmed everyone in the '60s with "Eli" and "Stoned Soul Picnic" when no one had a clue as to what those songs were about.

This is to say that this record will probably sell about 1/100th of what Michael Jackson's next will, but it really doesn't matter. Laura Nyro exists on the fringes of the music industry so that she can't be soiled by its irrelevant concerns. *Jon & Sally Tiven*


Laura Nyro

Christine McVie
Warner Bros. 25059, $8.98.

Sound: B Performance: A

In the crazy-quilt world of Fleetwood Mac, Stevie Nicks' spaceyness and Lindsey Buckingham's flash have dominated people's attention, but Christine McVie, with her warmth and earthiness, has been no less important to the group's massive success. She has composed a large share of their biggest hits, including, among others, "Warm Ways," "You Make Loving Fun" and "Hold Me."

Christine is the last of the three writers in the group to put out a solo album in this decade. (There was one solo effort, before she was in Fleetwood Mac, back at the beginning of the '70s under her maiden name of Christine Perfect.) She obviously has taken her time and expended great effort to deliver this one, a most classy album with not a single outright bad song to be found.

One thing about Christine's songs which makes them especially noteworthy is that she tends to write about love relationships which are working, not falling apart or one-sided. She writes much more about joy than pain; why more people don't do this is a good question. Perhaps when things are going right, most folks just don't take the time or get the inspiration to write about it. Fortunately, this is not so for Christine.

From the opening song, "Love Will Show Us How," *Christine McVie* is an album nearly all about how things can go right and what you have to go through to get there. Love may well be "The Challenge" she sings about, but she notes that it's worth it. She sings how she is "So Excited" to see her baby, what it is like to find that "One in a Million," and about "The Smile I Live For."


Christine McVie

Though this is a solo effort, it is not surprising to find some friends helping out in the course of the album. As it turns out, most of the guest appearances are front-loaded onto the first side which, as it goes, is one of the finest album sides I've heard in quite a while. A chief reason for the effervescence of "The Challenge" is the bubbly, liquid lead-guitar line Eric Clapton plays. Lindsey Buckingham happened through England when the album was being recorded, and he wound up on a clutch of songs, both singing and guitaring. A certified highlight is a duet with Steve Winwood on "One in a Million." Steve sticks around to take Christine's place at piano, adding his distinctive style to the song they wrote together, "Ask Anybody." This one also features the heavy downbeat of Mick Fleetwood's drumming.

The basic band heard on the album is very fine, playing with restraint and elegance. Ex-AWB drummer Steve Ferrone anchors the band with a lighter touch and more backbeat than Fleetwood. George Hawkins plays bass. Todd Sharpe not only collaborated with Christine, writing most songs, he plays guitar as well. Christine McVie plays her customary keyboards.

The album's production rests in Russ Titelman's very capable hands. With engineer David Richards, he has achieved uncommonly clear sound that lets you hear all the parts. You hear it all, soft or loud. *Christine McVie* is a fine example of how to use digital mixing and mastering.

Through her songs with Fleetwood Mac and now on her own, Christine McVie is that rare songwriter I can almost call a real friend without ever meeting, the kind you love to go out to the neighborhood pub with, to hoist a few pints. She seems to be unafraid of airing her feelings and talking straight. The really nice thing about this solo album is that I really feel I've gotten to know her better because of it.

Michael Tearson

Declaration: The Alarm
IRS SP 70608, $6.98.

Sound: B Performance: B+

In the ever-mounting British invasion, the Attack of the Killer Synthesizers seems to be subsiding. We Yanks should ready ourselves for the Battle of the Bagpipe Guitars. That chronic wail of the synths—supplied by ABC, The Human League, and a host of other pretentious twerps—has been supplanted by the air-guitar band best typified by U2 and Big Country. As a genre, this type of music is more rocking, less derivative of American R&B, and of a higher musical calibre than its predecessor. Part of the reason for this is that any fool can tap a digital synthesizer and make it sound like music, whereas an idiot playing a guitar will always sound like an idiot playing a guitar.

As for how The Alarm fits into this movement, the answer is quite snugly—right between U2 and The Clash. They are a capable bunch of songwriters, infused with enthusiasm and conviction, and this kind of energy makes for interesting records. Unfortunately, they are often blinded by their own fervor and come up with semi-preposterous lyrics. Like The Clash, they take the stand of being fierce moralists, but The Alarm chooses to make religion its

The Alarm

rock (The Clash tend to do the opposite). Musically, the group leans heavily upon acoustic guitars but still manages to produce a strong, rocking track.

This is one of those bands that happens to be at the right place at the right time—its sound is in vogue, its songs are compact and driving, and the

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guys' haircuts are pretty distinctive. However, one does get the feeling that the attention The Alarm is receiving has more to do with these superficialities than any intrinsic musical value, and its members will have to learn to survive the trend they currently are riding. *Jon & Sally Tiven*

The Everly Brothers Reunion Concert
Passport PB 11001, two discs.

Sound: B+ Performance: A

I was eight or nine when "Bye Bye Love" introduced The Everly Brothers to the world, and I was immediately hooked by that close sibling harmony which became their trademark sound. By the time "Wake Up Little Susie" followed, all doubt was long gone. Don and Phil went on to have a long, long string of hits well into the '60s. Beside all the rockers, the brothers sang some of the sweetest, most sincere love songs of the rock 'n' roll era, songs like "When Will I Be Loved," "I Wonder If I Care As Much," "So Sad (To Watch Good Love Go Bad)," "All I Have to Do Is Dream," "Devoted to You," "Cathy's Clown" and "Let It Be Me." They kept singing together until early in the '70s, when a severe falling out left them not only not singing together but not even talking for over a decade.

Following a long-hoped-for rapprochement comes this double album which documents their reunion concert at London's hallowed Albert Hall last autumn. For the occasion, they gathered a band of the best English musicians available, all guys who grew up on The Everly Brothers sound. There's

The Everly Brothers

The Everly Brothers start out a bit raggedly, but as they play on, the singing gets better and better, the harmonies tighter.

Pete Wingfield on piano and assorted keyboards, Graham Jarvis on drums, Mark Griffiths on bass, and Martin Jenner on guitar, plus England's best country guitarist, Albert Lee, too.

At the opening of the show you can almost hear and feel the brothers' nerves standing on end. They start out a bit raggedly, but as they play on, the singing gets better and better, the harmonies getting tighter all the while until they sound as great as ever, with a sublime, close meshing. The English audience is an active participant. They applaud many of the songs, greeting the openings as if they were long lost friends.

All the songs I mentioned above are included in the program, with many more, songs like "Bird Dog," "Claudette," "(Til) I Kissed You," "The Price of Love" and their Little Richard covers of "Lucille" and "Good Golly Miss Molly." It adds up to 28 in all and not a clunker among them.

The recording and mixdown were both done with digital technology, which results in a superb on-record sound that captures lots of sonic nuance, such as the feel of the flat pick on the acoustic-rhythm guitars the brothers play, really lively drums, and that wonderful interaction with the audience. A video of the concert has been shown a number of times on HBO, but since I live in a non-cable, non-HBO area I haven't seen it. I've only got the record to go on.

Hearing two of the heroes of my youth singing together again is a real thrill for me, but there's something else about this reunion that I'm really excited about. The trip was such a success that The Everly Brothers have announced plans to go in and make a new album. It is scheduled for release this summer.

Most albums like this one are dreary tasks to get through, as most of them sound like old folks trying desperately to sound young, a depressing effect. The Everly Brothers don't succumb to that fate. By the end of the show they are singing together sensationally in a style they defined—rock 'n' roll, close, two-part harmony. Without The Everlys, do you think that Simon and Garfunkel or The Beatles would have wound up sounding like they did?

Michael Tearson

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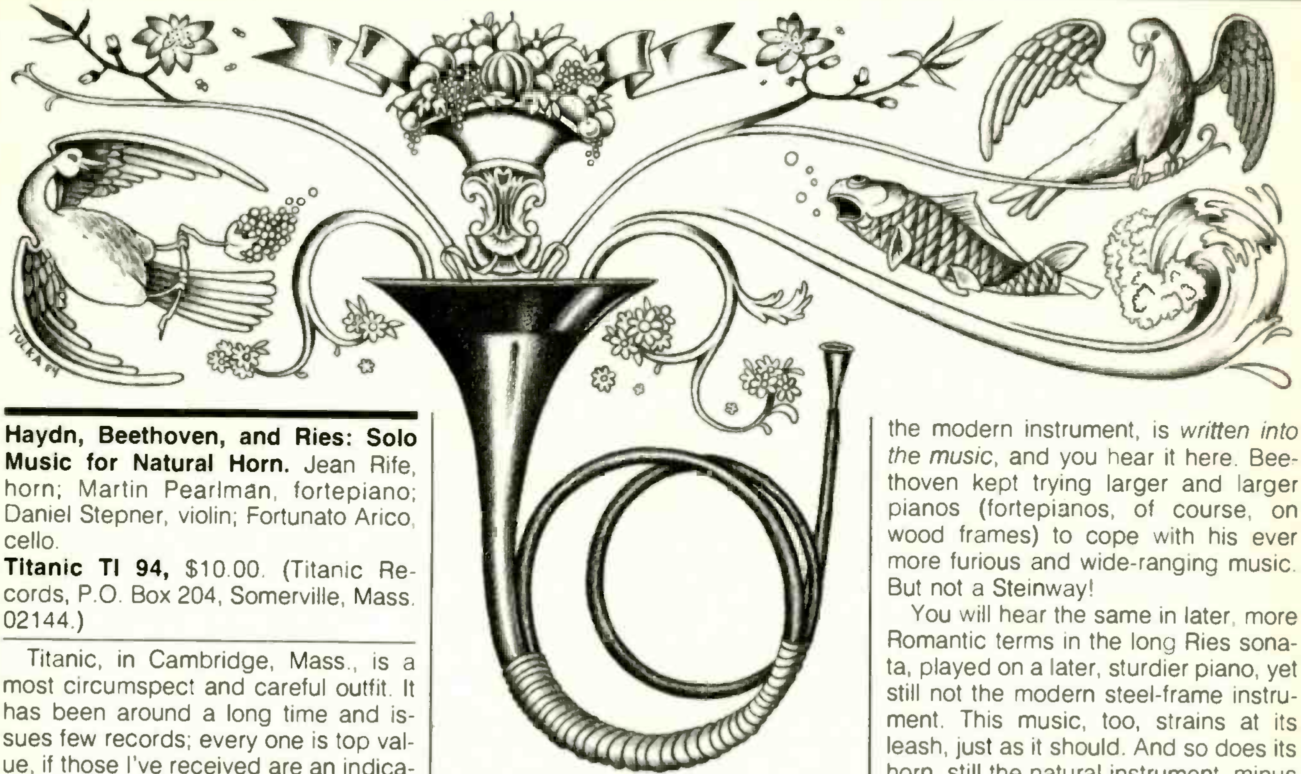

Illustration: Rick Tulka

Haydn, Beethoven, and Ries: Solo Music for Natural Horn. Jean Rife, horn; Martin Pearlman, fortepiano; Daniel Stepner, violin; Fortunato Arico, cello.
Titanic TI 94, $10.00. (Titanic Records, P.O. Box 204, Somerville, Mass. 02144.)

Titanic, in Cambridge, Mass., is a most circumspect and careful outfit. It has been around a long time and issues few records; every one is top value, if those I've received are an indication. This one is a musical landmark in my life. I have heard nothing like it, though no doubt there are other performances of the sort these days. And so beautifully recorded! Analog, of course.

Yes, this is one of those "authentic instrument" jobs. Music critics don't much like the idea, nor does the music establishment. Very, *very* narrow viewpoint, both on the grounds that performers are not good enough (the implication—all wrong—is that they never can be) and that our ears can't really enjoy the music as it was in the original. Poppycock! All it takes on our part is a bit of open-minded imagination. And on the musicians' part some really first-quality performing. That's what we have here, and I couldn't care less if *The Times* may disapprove.

Natural horn! Since the mid-19th century it has been considered unplayable. No valves, just the lips. Like a simple bugle at a Boy Scout camp. Yet Beethoven wrote for it, Mozart, Haydn, and even the Romantics, including the little-known and very juicy Ries, who was a student of Beethoven. All such music is played as a matter of course nowadays on the fancy, valved French horn. I don't suppose one hornist in thousands has even dared perform on a natural horn. Well—here is one who did. And the astonishing thing is that her music is in every way superb—always in tune, fluent, expressive, easy (less clumsy than many a valved performance I have heard). Intellectually, I knew it could be done, *was* done. I still was unprepared for the fact.

Fact is, these lost talents miraculously reappear, given the right interest in the instruments. Take the fortepiano, two different models here, also used for what seem to me splendid and idiomatic performances, notably in the Beethoven. Not only is the horn unbelievable in the Beethoven (even the stopped notes, tuned via hand in the bell, sound easy and musical), but the fortepiano, as played by Martin Pearlman, throws a whole new light on this familiar early piece, making it sound, oddly, much later, more "modern" than the usual effect with modern piano and valved horn. The sound almost rages at times, notably in the very active piano part—no wonder the man was famous for breaking strings! That strained sound, absolutely missing in the modern instrument, is *written into the music*, and you hear it here. Beethoven kept trying larger and larger pianos (fortepianos, of course, on wood frames) to cope with his ever more furious and wide-ranging music. But not a Steinway!

You will hear the same in later, more Romantic terms in the long Ries sonata, played on a later, sturdier piano, yet still not the modern steel-frame instrument. This music, too, strains at its leash, just as it should. And so does its horn, still the natural instrument, minus valves.

All this and hi-fi too. That's the way a fine recording should be.

Moore's Irish Melodies (1808). Lucy Sheldon, Jan de Gaetani, Martin Kelly, and William Sharp; Igor Kipnis, 1808 Broadwood fortepiano.
Nonesuch 79059, digital, $11.98.

You'll surely know some of these old tunes—you couldn't help it. Throughout the 19th century and well into ours, they were incredibly famous, largely as home-based do-it-yourself entertainment before the phonograph changed all that. Are they folk music? As much so as, say, Stephen Foster and maybe later balladeers like Cole Porter or even Dylan. These were adapted, at least, from various unspecified old tunes and given the "classical" treatment of the day, plus new and elegant words fit for the educated ear. All popular tunes were so treated. Beethoven and Haydn did scads of them (for pay) in the same style. For your ear, they are classical.

And yet, it says, when this Tom Moore opened his mouth and sang, "Women fainted and grown men

[redacted]

cried," he was a sensation. Like Dylan himself? Not so far removed! Dear me, how times change. Imagine fainting (or crying, you guys) over "The Last Rose of Summer" or "Believe Me If All Those Endearing Young Charms"! Well, they did. But you won't.

Nonesuch was ingenious in acquiring, out of a museum (Metropolitan, of course), an authentic Broadwood fortepiano of exactly the same time as the first publication of Moore's famous songs. Unfortunately, they could not match this with a brace of authentic 1808 voices. Instead, we have first-rate, modern professional singers, excellent musicians but simply not trained for this kind of music. They are too fussy in tone and diction, full of elaborate vibrato, blasting out the higher notes—which should be light. It's the operatic style of today and this is *not* opera! The sense is there, but you will have to work a bit to get hold of it. Some parts are lovely. Even old John McCormack (d. 1945), that invincibly sentimental Irish tenor of so many early discs, did this sort of music with a much more suitable simplicity.

Ravel: Ma Mère L'Oye (complete ballet), Valses nobles et sentimentales, La Valse. The Dallas Symphony Orchestra, Eduardo Mata.
RCA ARC1 4815, digital, $12.98.

A splendid sound here—I wish I could understand why so many good digital sounds emanate from Soundstream! Even when the good Dr. S. is not in attendance for the miking. This is no plug; it is simply an observation.

The music here isn't that positive. It's interesting but, shall I say, aberrant, departing from the established but undeclared traditions of this Ravel music in the way that it is performed.

To get back to the sound—it is not only big and full (including music for reduced orchestra) but has also an extraordinary clarity in the detail. I particularly noted the marvelous impact of the low strings here and there, sometimes solo, sometimes the whole body of cellos/basses. How to describe? It is resonantly stringy. What else can I say? All too often in the past, the bass line in the music has been simply that, a low pitch which supports the harmonies, without much color in itself. This

Mata's tempi and phrasing, his sense of line, are flatfooted, especially in the waltz. He does not feel the pacing.

Eduardo Mata

is an artifact of the recording process, not the sound of music alive. Digital seems to have made a definite new contribution in this unexpected area.

Beyond that, I must note that there is much more to digital than observed dynamic range and new silence, even though these are the touted features. Much appears equally well in the old LP system, by force of comparison with analog originals. I would not actually want to hear the full dynamic range of this Ravel in my living room; the mild LP compromise is plenty for me and in no way at all interferes with the musical sense. (And very quiet LP surfaces effectively enlarge that range beyond most earlier LPs.) What is more important than dynamic range is the new clarity in loud portions of the music, the big climaxes.

No question about it, digital—even via LP—has by its very nature made an often audible difference here. The 78 electrical recording accustomed our ears to inevitable distortion as volume increased, notably in the harsh, squealing string sounds and especially at the inner grooves. We took this in stride as a part of recording.

With LP, there was a big improvement, and that improvement has continued ever since. Yet the tendency towards distortion under high-level strain—potent signals, jaggedly complex wave forms—was *inherent* in the analog process, and severally in its many components. By improving all of these components, we have improved the sum output. The inherent tendency we cannot remove.

At last, then, digital recording can. And so even in an LP like this, though we make use of many of the analog elements out of the past, the digital master recording removes a major area of that inherent distortion—and you can hear it. Other things being equal (or excellent, as here!), there is a sense of relaxed clarity, a lack of strain in all the severely taxing climaxes of Ravel's music. This, to my judgment, is a basically new, satisfying experience, even via the old LP. It does not take a CD to bring it to usefulness.

For those who know a bit of Ravel—and a bit of waltz—these are curious performances. Details are beautifully rendered, with care and obvious dedication, if occasionally a bit underrehearsed for such tricky music. But Mata's tempi and phrasing, his sense of line, as the musicians put it, are flatfooted. He does not feel the pacing, the lift and shape of ideas, the rhythmic impact and springiness which make dance out of mere locomotion. Especially in the waltz—such a stylized tradition, with all its elegant hesitations!

Thus, the "Noble and Sentimental Waltzes" suffer the most; they simply do not waltz. You'd never know. (And they *can*, believe me.) The other works are better, but even so the music is full of clumsy overspeeding, too-great slowings-down, ungainly pauses that fall flat. Bad timing! Still, it's an enjoyable LP for many other virtues, and so it is recommended.

Scintillations, Music for Harp by Carlos Salzedo. Heidi Lehwalder, harp. **Nonesuch 79049,** digital, $11.98.

Digital recording is not really significant to the listening of this all-solo-harp record. There is little in the rather special musical palette here that could not be reproduced as well by current top-analog recording, to sell at a lower price. Other aspects of the disc are more important than its digitality.

First, of course, is that large bald head on the cover, attached to a body playing a big harp. It isn't the performer—she has hair. It's the composer. Double take. I would think that Ms. Lehwalder might be a bit put out. With SALZEDO so prominently displayed in large letters, one might casually suppose that *he* was the player, not she.

The confusion is, in a way, legitimate. Salzedo, who died in 1961, was an absolutely extraordinary harp genius. I once sat very close to him in a private recital which I will not forget. He was much more than just a virtuoso harpist. He magically lifted his medium far, far beyond its normal confines, not merely in technique but in a sort of universal expression; one forgets the instrument and hears only the music. A rare thing, especially in the harp.

Like most such outstanding performers in this century, Salzedo was also a composer but not, alas, with much genius. These are nice little virtuoso pieces, some in a sort of turn-of-the-century style, though composed much later, some of a more exotic and Impressionist-mystical sort, as of the pre-WW I period, all of them basically derivative and without much individuality. Nice, harpy sound and not much more.

As for the performer, her technique is tops all right but in this sound, at least, she is not too convincing. The effect seems more watery than most, the melodic lines aren't really sharp and defined, as they surely can be,

Heidi Lehwalder

and the upper strings are persistently out of tune. (A standard harp weakness that should never appear on records!) Recording technique? Marc Aubort surely knows how to get the best of what there is into his mikes, whether fed to analog or digital. I suspect we are hearing what the lady is playing in terms of music. She's good but she definitely is not Salzedo.

Chopin: Songs, Op. 74. Teresa Zylis-Gara, soprano; Halina Czerny-Stefanska, piano.
Erato STU 71527, $10.98.

Did you know Chopin composed songs? Few people do. These were written at various times throughout his short life, published together only after his death—hence the high opus number. It would be hard to tell which are early and which came later; they go together remarkably well.

If you will listen to the piano introductions, before the singer begins, you will hear a familiar Chopin sound. But, curiously, once she sings, the piano becomes super modest and not at all Chopinesque. Remarkable restraint for a piano composer! The songs themselves fall into an unfamiliar idiom, for Chopin, sounding to our ears vaguely Russian and rather folkish—not what you might expect from the composer. This is perhaps understandable considering that, for all their tragic interferences, the Russians and Poles have similar languages and an overlap in cultural terms. In fact, much of the Polish territory has often technically been a part of Russia, including the infamous era when Poland was divided up and disappeared entirely from the map.

A small galaxy of Polish female names here! The two ladies are indeed from Poland, though, like Chopin himself, they operate from France. The songs are beautifully performed by a large operatic voice, well controlled if rather too loud for the living room in the higher notes. The songs are sung, I assume, in Polish—it sounds like Russian to my uneducated ear. Polish, in any case, is much nicer on the ear than it looks on paper, with all those clumps of consonants. By all means add this disc to your Chopin collection if you incline in that direction.

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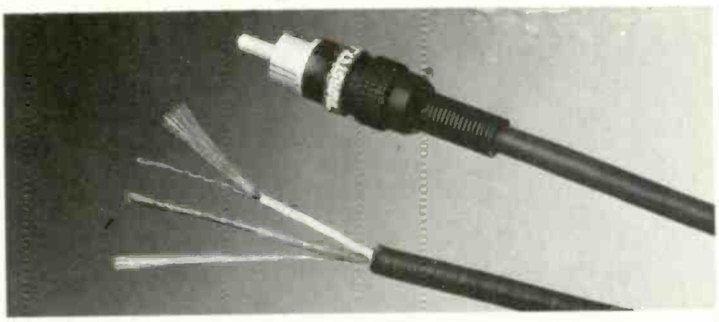

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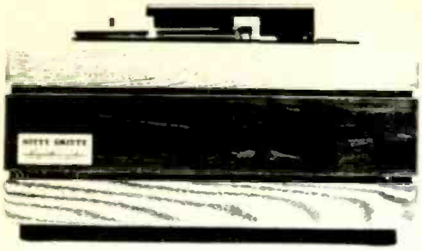

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