Audio®

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THE AUTHORITATIVE MAGAZINE ABOUT

AUGUST 1979

47425

Canby—TRIBUTE TO BBB

INFLUENCE OF *LISTENING ROOMS* ON LOUDSPEAKER SYSTEMS

A *QUICK-BUILD* SPEAKER IMPEDANCE CHECKER

Ed Long TESTS THE DECCA ARM & CARTRIDGE

AND IT'S WHAT GOES INTO HPM SPEAKERS THAT MAKES THEM SOUND GREAT ON EVERY PART OF THE MUSIC.

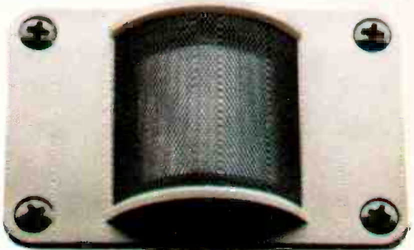
Most speaker companies try to impress you by describing the "wonderful" sound that comes out of their speakers.

At Pioneer, we think the most believable way to describe how good HPM speakers are is to tell you what went into them.

THE HPM SUPERTWEETER: SPEAKER TECHNOLOGY RISES TO NEW HIGHS.

In many speakers, you'll find that the upper end of the audio spectrum is reproduced by an ordinary tweeter.

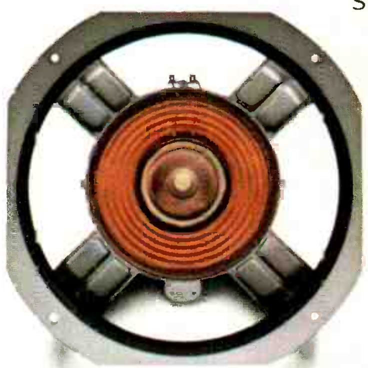
In HPM speakers, you'll find that the high frequencies are reproduced by a unique *super*tweeter.



The High Polymer Molecular Supertweeter. So incredible, we named a whole line of speakers after it.

It works by using a single piece of High Polymer Molecular film, (hence the name HPM) that converts electrical impulses into sound waves without a magnet, voice coil, cone, or dome.

And because the HPM supertweeter doesn't need any of these mechanical parts, it can reproduce highs with an accuracy and definition that surpasses even the finest conventional tweeter.



You'll never hear a sound out of these die cast aluminum speaker frames.

As an added advantage, the HPM film is curved for maximum sound dispersion. So unlike other speakers, you don't have to plant yourself in front of an HPM speaker to enjoy all the sound it can produce.

MID-RANGE THAT ISN'T MUDDLED.

For years, speaker manufacturers have labored over mid-range driver cones that are light enough to give you quick response, yet rigid enough not to distort.

Level controls that let you adjust the sound to your listening area.

Pioneer solved this problem by creating special cones that handle more power, and combine lower mass with greater rigidity. So our HPM drivers provide you with cleaner, and crisper mid-range. Which means you'll hear music, and not distortion.

WOOFERS THAT TOP EVERY OTHER BOTTOM.

Conventional woofers are still made with the same materials that were being used in 1945.

Every woofer in the HPM series, however, is made with a special carbon fiber blend that's allowed us to decrease the weight of the cone, yet increase the strength needed for clarity. So you'll hear the deepest notes exactly the way the musician recorded them.

And because every HPM woofer also has an oversized magnet and long throw voice coil, they can handle more power without distorting.

OTHER FEATURES YOU RARELY HEAR OF.

Every HPM speaker has cast aluminum frames, instead of the usual flimsy stamped out metal kind. So that even when you push our speakers to their limit, you only hear the music and never the frames. In fact, our competitors were so impressed, they started making what look like die cast frames, but aren't.

HPM speaker cabinets are made of specially compressed board that has better acoustic properties than ordinary wood.

Their speakers have level controls that let you adjust the sound of the music to your living room.

And these features are not just found in our most expensive HPM speaker, but in *every* speaker in the HPM series.

All of which begins to explain why, unlike speakers that sound great on only part of the music, HPM speakers sound great on all of it.

At this point, we suggest you take your favorite record into any Pioneer Dealer and audition a pair of HPM speakers in person.

If you think what went into them sounds impressive, wait till you hear what comes out of them.

PIONEER®
We bring it back alive.

WHAT COMES OUT OF A SPEAKER IS ONLY AS IMPRESSIVE AS WHAT GOES INTO IT.

August 1979 Vol. 63, No. 8

Audio

"Successor to RADIO, Est. 1917"

FEATURE ARTICLES

EQUIPMENT PROFILES

RECORD REVIEWS

AUDIO IN GENERAL

About the Cover: Conduct a loudspeaker? Not likely, but some speakers are almost "transparent" enough to "see" the orchestra — particularly if you follow the tips Roy Allison and M.J. Salvati have for you in this issue. Model: Charles Henry. Photo: Photographic Illustrations, Philadelphia.

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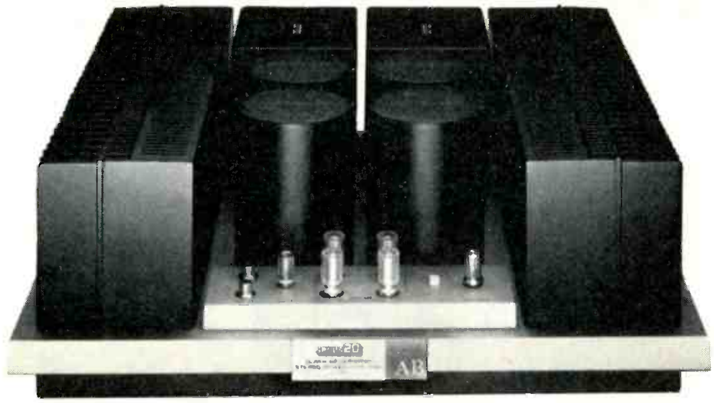

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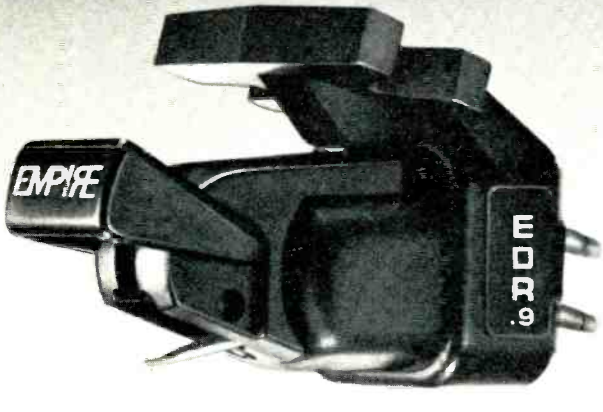


INTRODUCING THE EMPIRE EDR.9 PHONO CARTRIDGE. IT SOUNDS AS GOOD ON A RECORD AS IT DOES ON PAPER.

It was inevitable . . .

With all the rapid developments being made in today's high fidelity technology, the tremendous advance in audible performance in Empire's new EDR.9 phono cartridge was bound to happen. And bound to come from Empire, as we have been designing and manufacturing the finest phono cartridges for over 18 years.

Until now, all phono cartridges were designed in the lab to achieve certain engineering characteristics and requirements. These lab characteristics and requirements took priority over actual listening tests because it was considered more important that the cartridges "measure right" or "test right"—so almost everyone was satisfied.

Empire's EDR.9 (for Extended Dynamic Response) has broken with this tradition, and is the first phono cartridge that not only meets the highest technological and design specifications—but also our demanding listening tests—on an equal basis. In effect, it bridges the gap between the ideal blueprint and the actual sound.

The EDR.9 utilizes an L. A. C. (Large Area Contact) 0.9 stylus based upon—and named after—E. I. A. Standard RS-238B. This new design, resulting in a smaller radius and larger contact area, has a pressure index of 0.9, an improvement of almost six times the typical elliptical stylus and four times over the newest designs recently introduced by several other cartridge manufacturers. The result is that less pressure is applied to the vulnerable record groove, at the same time extending the bandwidth—including the important overtones and harmonic details.

In addition, Empire's exclusive, patented 3-Element Double Damped stylus assembly acts as an equalizer. This eliminates the high "Q" mechanical resonances typical of other stylus assemblies, producing a flatter response, and lessening wear and tear on the record groove.

We could go into more technical detail, describing pole rods that are laminated, rather than just one piece, so as to reduce losses in the magnetic structure, resulting in flatter high frequency response with less distortion. Or how the EDR.9 weighs one gram less than previous Empire phono cartridges, making it a perfect match for today's advance, low mass tonearms.

But more important, as the EDR.9 cartridge represents a new approach to cartridge design, we ask that you consider it in a slightly different way as well. Send for our free technical brochure on the EDR.9, and then visit your audio dealer and listen. Don't go by specs alone.

That's because the new Empire EDR.9 is the first phono cartridge that not only meets the highest technological and design specifications—but also our demanding listening tests.

Empire Scientific Corp.
Garden City, N.Y. 11530 EMPIRE

Enter No. 10 on Reader Service Card

Audioclinic

Joseph Giovanelli

A.C. Adaptors

Q. Can the a.c. adaptors, such as those sold for portable radios, calculators and recorders, be left plugged in for long periods of time when they are not being used?—James R. Henderson, Victoria, B.C., Canada

A. It is only in those instances where the adaptor serves something like an intercom, which must be ready for service at any time, that I recommend these adaptors be left plugged in when not actually in use.

These a.c. adaptors are actually complete power supplies and are comprised of a stepdown transformer, a rectifier system, and the necessary filter capacitor. When one of these devices is operated, there is some heat generated by the stepdown transformer which will not be significant unless the filter capacitor should short out. When this occurs, the transformer will run excessively hot and might cause problems.

Keep in mind that when the device is plugged in, but not feeding a suitable load, the voltage developed across the filter capacitors will be higher than the nominal output voltage of the a.c. adaptor. If the filters are made to operate at or close to their maximum ratings, this high voltage remaining across the capacitor for extended periods of time could cause a short circuit.

"Popping"

Q. My component system develops a "popping" noise in my speakers every five minutes or so. It sounds like a static discharge. It is heard whether my amplifier's mode switch is on FM, Tape, or Turntable.

What do you suggest that I try in the way of trouble-shooting? The people in the store where I bought my system said, "let it get worse, and then the technician has a better chance of finding the problem."—Tuck Krehbiel, Cincinnati, Ohio

A. It will be hard to locate your "popping" problem because of its intermittent character, and that is why your dealer was reluctant to attempt servicing the equipment until such time as the symptoms become more constant. This is probably to your advantage inasmuch as this kind of servicing can be expensive. Where a problem occurs more or less constantly, it is simpler to track down and, therefore, less costly to solve.

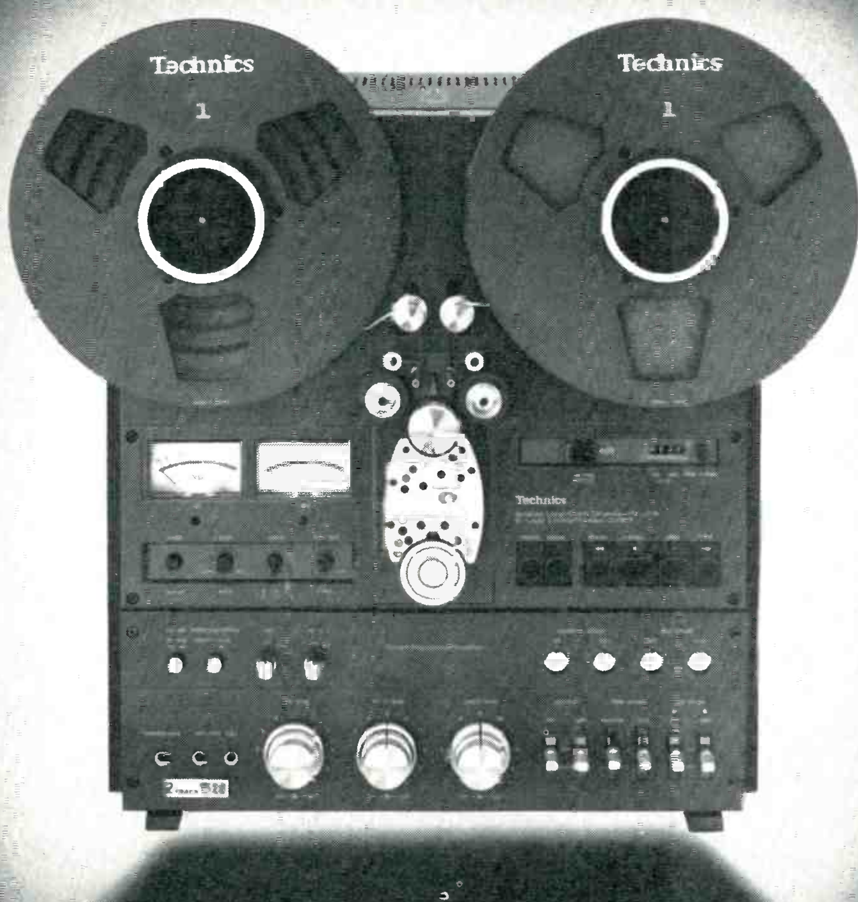
You do know something about this problem, however. For instance, you know that the problem is not located in the early phono stages of the equipment. You know this because it occurs even when these stages are switched out. It is located in stages common to the rest of the input functions. You did not state whether or not the condition exists in just one channel. If the condition exists in both, you know that the "popping" is the result of some common component, and power supply or decoupling elements would be suspect. This condition could also indicate that the "popping" is external to your system. Transient voltage changes on the power line often cause this condition. Various filters are available which can suppress such interference.

Poorly soldered connections or minute cracks in the circuit "lands" could also cause the problem. Resolder suspicious joints.

Try signal tracing. Use a second amplifier to enable you to listen to the output from various stages in the defective equipment. Feed the input of this second amplifier via a blocking capacitor. This will allow you to make direct connections to collectors where this is necessary. Work your way from the input selector switch to the output of the defective channel. When the "popping" is heard in both amplifiers, this means that you have reached the output of the defective stage. You can then investigate the components in that particular stage. The ultimate source of the problem can be anything from defective semiconductors to defective capacitors, resistors, or even solder or circuit foil problems.

If you have a problem or question about audio, write to Mr. Joseph Giovanelli at AUDIO Magazine, 401 North Broad Street, Philadelphia, PA 19108. All letters are answered. Please enclose a stamped, self-addressed envelope.

If Technics RS-1500 meets the high standards of A&M Records, why did we improve it?



After the music is recorded, and before it becomes a record, how do the top executives of A&M Records listen to Peter Frampton, Chuck Mangione, and their other stars? On the Technics RS-1500. Why? Because of its outstanding frequency response, constant tape speed and low wow and flutter. In fact they were so impressed, A&M Records bought seven more.

Now, with Technics RS-1520, you can have the same performance A&M Records has with the RS-1500, plus these extra features studios want. Like adjustable front panel bias and equalization controls. A 1kHz / 10kHz test-tone oscillator for accurate equipment checks. The precision of ASA standard VU meters with a −10dB sensitivity selector. A Cue/Edit switch for quick, safe edits. And balanced low-impedance, XLR-type output connectors to match other widely used broadcast and studio equipment.

Like all our open reel decks, the RS-1520 has Technics "Isolated Loop" tape transport system. By isolating the tape from external influences, our "Isolated Loop" minimized tape tension to a constant 80 grams. This not only provides extremely stable tape transport and low head wear, it also reduces modulation noise to the point where it's detectable only on sophisticated testing equipment.

Electronically the RS-1520 is equally sophisticated. And the reasons are as simple as IC full-logic controls. A highly accurate microphone amplifier. FET mixing amplifier. And separate 3-position bias/EQ selectors.

The RS-1520. It meets the high standards of A&M Records for the same reasons the RS-1500 does: FREQ. RESP.: 30-30,000Hz, ±3dB (−10dB rec. level) at 15ips. WOW & FLUTTER: 0.018% WRMS at 15ips. S/N RATIO: 60dB (NAB weighted) at 15ips. SEPARATION: 50dB. START-UP TIME: 0.7 secs. SPEED DEVIATION: ±0.[illegible]% with 1.0 or 1.5 mil tape at 15ips. SPEED FLUCTUATION: 0.05% with 1.0 or 1.5 mil tape at 15ips. PITCH CONTROL: ±5%. TRACK SYSTEM: 2-track, 2-channel recording, playback and erase. 4-track, 2-channel playback.

RS-1520. A rare combination of audio technology. A rare standard of audio excellence.

Technics
Professional Series

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European letter

Donald Aldous

Despite the gloomy forecasts of some hi-fi industry pollsters, British audiophiles are still spending considerable sums of money on their hobby. Certainly the success of the Spring Hi-Fi Exhibition, held at the end of April in London's Cunard International Hotel, served as a pointer to the sustained enthusiasm of the hi-fi devotees here in the United Kingdom.

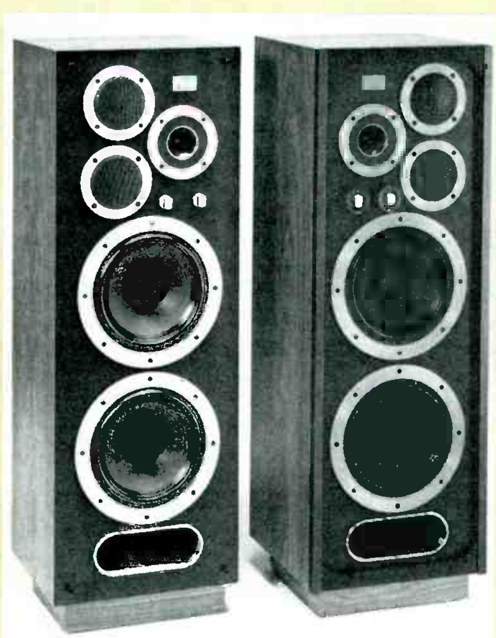
Let's take a look at several of the "top-of-the-market" loudspeakers revealed at this show. The first of a new series of B & W loudspeakers, Model 801, was seen in an early format at last winter's Consumer Electronics Show in Las Vegas. It has been designed as a professional monitor system produced using totally new facilities (such as laser interferometry and computer optimization) linked to the most comprehensive tests and quality control checks. In fact, each model manufactured will have factory documentation filed, based on tests in the company's new anechoic chamber at their Worthing, Sussex, factory. This chamber has cost some $100,000 and will be completed during September; in the meantime the firm's existing R & D anechoic chamber will be used for the tests.

"Professional Monitor" is a much-abused description, but John Bowers and his team have used a design brief that calls for a linear free-field amplitude response from 30 Hz to 20 kHz, with minimum deviation horizontally and vertically, to provide a uniform sound picture to a group of listeners. And, of course, such a monitor must have no coloration and be free from audible distortion. Another feature of the specification is an ability to handle sound levels of 106 dB in environments of up to 200 m^3 (that is, 7,000 ft.^{3}) capacity. Physical size was not laid down, other than a general requirement that the new 801 be large enough for studio work and yet remain attractive enough from a domestic furniture viewpoint.

The full design story is too lengthy for publication in this column, but the speakers involved are a bass driver of 270-mm diameter with a thermo-plastic, PVA-coated cone and 50-mm diameter voice-coil; a midrange driver with 100-mm diameter, aromatic polyamide-fiber matrix cone, and 25-mm, phenolic-bonded, aluminum-lined voice-coil, plus an HF driver with a 26-mm multifilament, polyester-weave domed diaphragm. The LF system is a closed-box acoustic suspension design with a resonance of 37 Hz and a system Q of 0.7 (i.e., -3 dB at the resonance frequency). Its power handling spec is a minimum of 50 watts into 8 ohms with no upper limit.

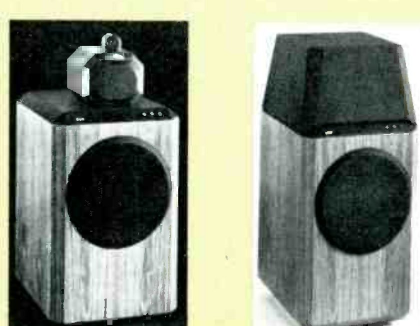
As we all know, unfortunately, with the growth of transistor amplifiers, the wattage and destructive power of amplifiers has rapidly increased. In fact, power outputs between 100 and 350 watts are not uncommon, and without some form of protection almost any loudspeaker can be destroyed by the simple act of, say, removing a phono plug with the preamplifier gain control advanced. Fuses are not a complete answer, but B & W's Steven Roe has developed an overload protection circuit that senses the peak voltage applied to each driver. It has individual adjustment for each such voltage, and the time constant at which the trip will operate is individually adjustable. If any of these predetermined parameters are exceeded, the trip circuit operates and the loudspeaker is disconnected from the audio supply. The reset button restores operation. Envi-

Continued on page 95

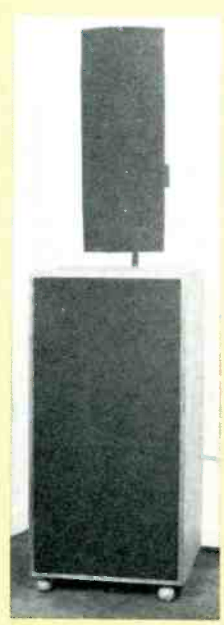


Wharfedale E90

KEF 101



B & W 801



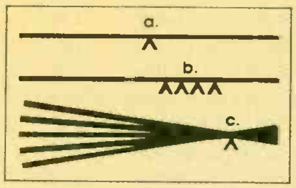
PWB Dyna-X 100

We found the optimum pivot point before the others even knew it was missing.

Most manufacturers are content to determine tonearm pivot points by trial-and-error. And many tonearms are so susceptible to external vibrations that you have to tiptoe around the turntable.

With Sansui's Dyna-Optimum Balanced (DOB) tonearms, based on our Optimum Pivot Point principle, the transmission of vibrations is dramatically reduced to give you more freedom to enjoy your music. It's used in our new, fully automatic direct-drive FR-D4 and FR-Q5.

Here's how the DOB works: Put a pencil on a table. Wiggle one end back-and-forth. The other end will move; but a certain point will not. This is the Optimum Pivot Point.



a. Center of Mass. Starting point for conventional tonearm designs.

b. Typical trial-and-error pivot points, usually placed close to **a.** so that counterweight is not too heavy, tonearm not too long.

c. Sansui's Optimum Pivot Point. Calculated mathematically as a function of length and mass. The most stable point.

In our new DOB tonearm the arm is pivoted at this highly stable point. With no relative motion between the point and the arm support, effects from external forces are minimized. Friction is almost non-existent, so the stylus is free to trace every part of the groove. We also added a special decoupling device and a unique counterweight for optimum tracking.

A patent is pending on Sansui's brushless DC motor used in the FR-D4 and FR-Q5. And with the Quartz-PLL system of the FR-Q5 and the special speed-error detection/correction system of the FR-D4, wow and flutter, speed accuracy and signal-to-noise specifications are outstanding. All operations are computer-controlled using the latest LSIC technology. The computer even knows to shut off the motor if you forget to unlock the tonearm clip.

To make the FR-D4, FR-Q5, as well as the budget-priced direct-drive FR-D3 even more convenient, we put all the controls up-front, outside the dustcover.

Ask an authorized Sansui dealer to demonstrate our new turntables. Listen closely and you'll hear what the others are missing.

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Audio etc.

Edward Tatnall Canby

A great many Audio Engineering Society members last March were aware of the presence in Brussels, at the AES winter convention, of a man whose familiar initials were BBB. It was only the usual. As always, he was everywhere, indefatigable, seeing everybody, highly visible. And as usual he presented a paper — what AES convention has he ever missed, and did he ever *not* present a paper or two?

This one, though, was perhaps more than the usual. Somewhat as in Einstein's unified field theory, BBB here aimed to set forth an overall theoretical system for multichannel sound in both recording and broadcasting, in the taking down and the playing back, incorporating all the presently variable approaches towards an "en route" broadcast signal as presently designated — 4-4-4, 4-3-4, 4-2-4 — plus conventional mono and stereo and SCR and, of course, every aspect of the disc process. A huge theoretical package and, as the ultimate synthesis of this man's work over many years, it must have impressed even those who might not go along with the system itself by its sheer elegance and comprehensiveness.

BBB also received a new honor at Brussels this year, on top of many others. He became an honorary horseman. A *chevalier* of the ancient Order of the Knights of the Star of Peace, an organization founded in 1229 when knighthood was in flower and quadraphony quite unknown. This must have tickled him pink. Some horseman! Fortunately, there was no need to mount an actual horse.

As always, BBB came back home full of verve and immediately got to work preparing his Brussels paper for wider distribution, to the American audio press and to all other possibly interested parties including, of course, the most important party of all, the FCC in Washington, which has a few outstanding little matters to decide in this very same area. The FCC has been hearing regularly from BBB for perhaps a bit longer than some of its members might wish. Few engineering minds in the U.S. could match BBB's steely ability for careful, quiet, and logical argument — of the sort that one challenges at considerable risk. I do not think I would ever have wanted to be in the line of BBB's technical fire. Not even as an FCC member. Behind that courteous European politeness was a will of incredible intensity and the mind power to match. Was it diamond drill or bulldozer? A judicious bit of both.

The final BBB paper was ready for mailing only a week or so after the Brussels AES, more than 30 pages of closely reasoned text, diagrams, formulae with derivations, and reference listings. My own copy was sent out from BBB's "retirement" office, Audio-Metrics, Inc. (which consisted of his front living room plus facilities in his old nearby laboratory haunts in Stamford, Connecticut), on Wednesday, March 28, 1979. Enclosed was a signed, personal note from BBB. Page 5 of the paper was missing — the only indication of any haste, and surely not *his* haste. I got it later on. On that very day, Benjamin B. Bauer suffered his second and fatal heart attack. After a typically optimistic and even cheerful several days in the hospital, where he happily found himself in the charge of a personable physician, Ben Bauer died on Saturday, March 31. It was barely two weeks after the Brussels convention. So he made it — by a hair. He must have known the risk.

Patents by the Score

As most of us know, BBB was for many years out in the Midwest with Shure Brothers, doing major work on microphones, in our field, and later in phono pickups, predecessors of the present-day Shure line. There was that sensational "dart" arm and cartridge, a long, thin, tapering arm with an incredibly tiny cartridge in its drooping nose, independently sprung; the arm moved sidewise only, the tiny head moved up and down. (Well, if an arm can have a head, it can have a nose . . . .) There was a cybernetic problem with this arrangement. To raise the stylus, you pushed downwards on a button, a motion so unnatural for the human mind and fingers that most people just grabbed the arm itself and dragged the point sidewise over the grooves. No damage but an awful squawk. I doubt if this aspect was a BBB idea.

The most important of BBB's earlier inventions (he pulled down some 75 U.S. patents) was the original single-transducer, cardioid dynamic microphone, 'way back in 1937, making use of the phase-shift principle, or what I like to call re-entry, to cancel out signals coming from the sides. It is, of course, fundamental to the cardioid style of miking today and therefore fundamental to the art of recording and broadcasting. How directly prophetic of later Bauer developments along phase-shift lines! Culminating in the ultimate BBB consolidation, the 1979 Brussels paper.

In 1957 BBB came east to join CBS Laboratories and from thence onwards his activities spread and multiplied into the infrared and the ultraviolet.One never knew quite what he was up

Yamaha, the industry

When we set out to improve on our industry-acclaimed receivers, we knew we had a tough task ahead of us. How do you top being the first in such precedent-setting developments as built-in moving coil head amps, negative feedback MPX demodulators, pilot signal cancellation circuits, and the same amazingly low distortion throughout our entire line? After much continuing research, effort and unique care in design, we have the answer. It's called the CR-2040, the first in Yamaha's new line of receivers that does what only Yamaha could do. Outdo ourselves.

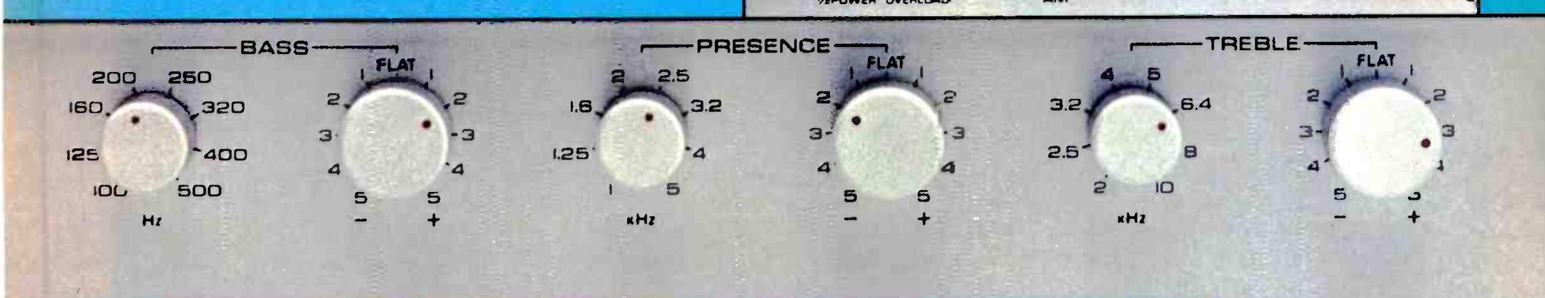
Unique continuously variable turnover tone controls. This unique Yamaha innovation gives you the tonal tailoring characteristics of both a parametric and a graphic equalizer. Without the added expense of having to purchase either. For instance, in addition to boosting or cutting the bass control ±10dB, you can also vary the turnover frequencies between 100 & 500 Hz to compensate for speaker deficiencies, room anomalies, etc., for unparalleled tonal tailoring flexibility.

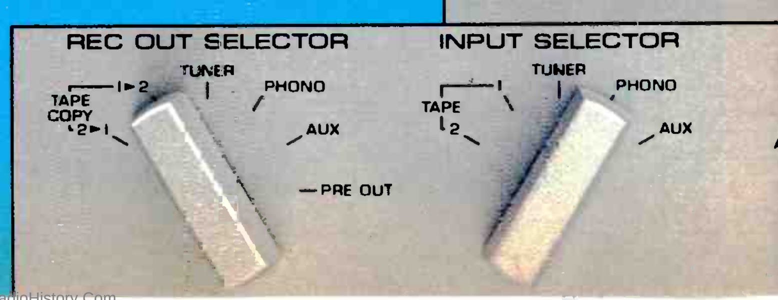
Built-in moving coil head amp. More and more listeners are discovering the beautiful experience of music reproduced with a moving coil cartridge, such as Yamaha's newly introduced MC-1X and MC-1S. Discover this exquisite pleasure for yourself with the CR-2040's built-in moving coil head amp. This ultra-low noise head amp provides an ultra-quiet 86dB S/N ratio to assure you of capturing all the high-end detail and imaging the MC experience affords. All you'll miss is the extra expense and added noise of an outboard head amp or step-up transformer.

Independent input and record out selectors. If you're a tape recording enthusiast, this feature is something you won't want to be without. It lets you select the signal from one program source to send to the REC OUT terminals for recording while you listen through your speakers to an entirely different program chosen on the INPUT selector. You can also dub from one tape to another even while listening to an entirely different program. It's another example of why Yamaha is the industry leader. We build in what the others can't even figure out.

Continuously variable loudness contour. This control compensates for the ear's decreased sensitivity to bass and treble tones at low volume levels. And you're not just limited to compensation at only one specific volume setting as with other manufacturers' on/off-type loudness switches. The Yamaha continuously variable loudness contour assures you of full, accurate fidelity at any volume setting you choose. Another Yamaha exclusive!

Automatic operation. Without a doubt, the Yamaha CR-2040 is one of the most automated receivers in audio history. Instead of fiddling with dials and meters, you can sit back and let the automatic circuits do the work. Or, if you choose, manually override the circuits. Take the AUTO-DX circuit, for instance. We developed IF bandwidth switching for our world-acclaimed CT-7000 tuner. Now we've gone even further by improving this circuit so the receiver automatically chooses the correct bandwidth (local or DX) for the least noise. Working with this circuit is the AUTO BLEND circuit which eliminates annoying FM hiss to make previously unlistenable stations more clearly audible. All without your lifting a finger. And Yamaha's exclusive OTS (Optimum Tuning System) automatically locks in and holds the desired station when you release the tuning knob.





leader...leads again!

Advanced circuitry. All these advanced features are backed by the most advanced internal circuitry imaginable. Like the auto tracking pilot signal canceller. Yamaha invented pilot signal cancellation and now we've improved it further. A special circuit not only senses the incoming 19kHz pilot signal (which is a part of FM broadcasts), it also automatically tracks any signal fluctuation which might occur. This assures you of complete pilot signal cancellation for interference-free FM listening. Yamaha does it again!

The all DC power amp section pours out a massive 120 watts per channel, both channels driven into 8 ohms, from 20Hz to 20kHz, with THD and I.M. an astronomically low 0.02%. That's a new low, even for Yamaha. And to keep tabs on all this pure power there's a twin LED power-monitoring system—green to indicate half power, red to indicate an overload condition.

The tuner section has a Yamaha-exclusive Direct Current-Negative Feedback—PLL MPX IC providing excellent phasing of the high frequencies for superb stereo separation and clearer sound. Our efforts to bring you the finest sound possible know no limits.

Human engineering. As incredibly advanced and complex as the CR-2040 is, it is incredibly simple to operate. The front panel is arranged in a clean and logical manner with the larger primary operational controls located on the central forward panel, and the smaller tone-tailoring controls located on the lower panel. It takes a minimum of effort to set up the CR-2040 for maximum listening pleasure.

The functionally beautiful front panel is complemented by the beautifully functional ebony grain veneer cabinet. The elegant appearance of ebony is the perfect finishing touch to the extraordinary CR-2040.

And the CR-2040 is just one of a whole new line of receivers from Yamaha. Each one offers, in its class, the ultimate in features, performance and pure musical pleasure. Visit your local Yamaha Audio Specialty Dealer and see and hear for yourself how we've outdone ourselves. He's listed in the Yellow Pages. Or write us: Yamaha, Audio Division, P.O. Box 6600, Buena Park, CA 90622.

From Yamaha, naturally.

YAMAHA

0.02% THD

to. I remember one notable occasion (for me) when I became a temporary Bauer guinea pig. Under Ben's benevolent direction I was taken to a local Stamford indoor swimming pool and immersed in about 12 feet of water, with headphones on. There was an athletic CBS guard, too, in case I conked out, which I didn't. I can still swim my 50 feet under water minus snorkel or aqualung. Down at the bottom of the pool I was fed headphone signals and asked to point to their apparent source. The signals had been processed in such a way as to simulate ordinary airborne acoustic signals. Inside the phones, there were air pockets for ordinary dry-land-type binaural hearing. This was merely a bit of fundamental research, the sort that must cover all bases, however obvious. Of course I heard the signals exactly as I would have on shore, but this had to be *proved*. So I vigorously pointed to the left and to the right, but not towards the front (!) and then came up for a hot shower. My normal binaural experience,if in an odd location.

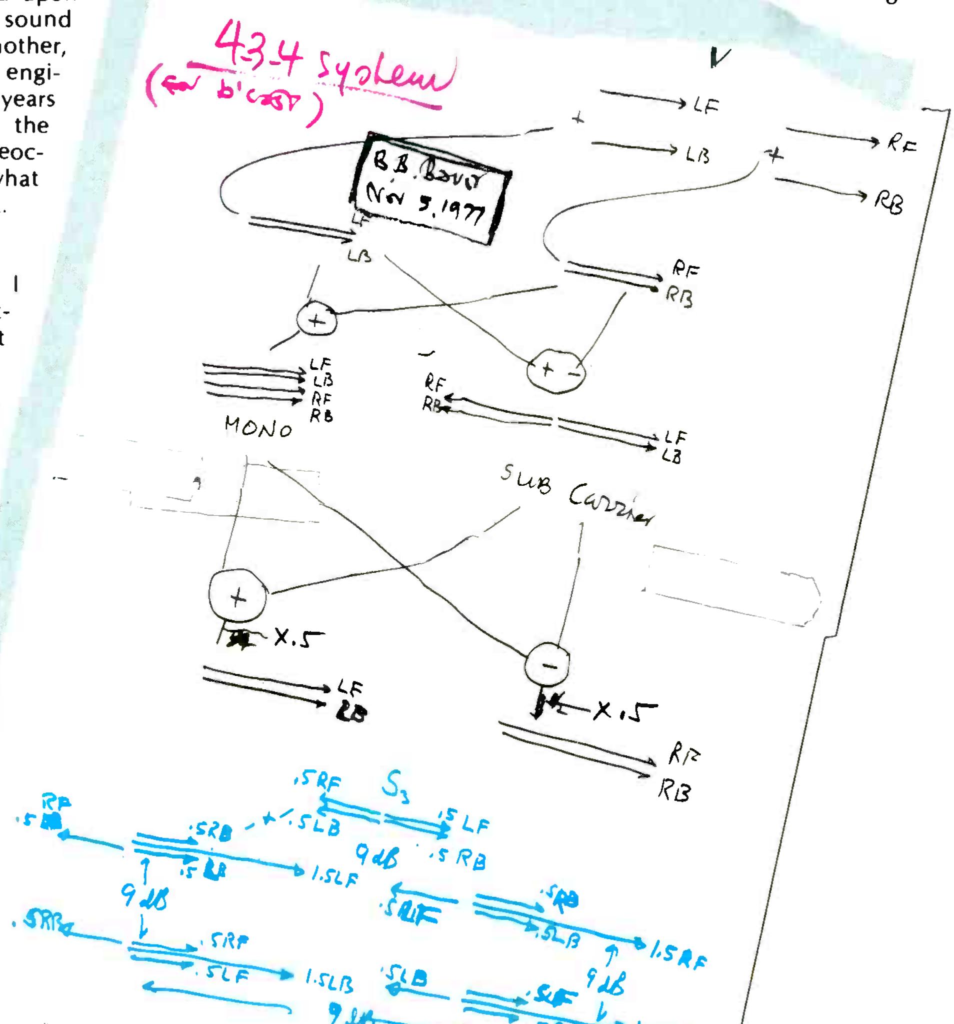
Note in passing that this, too, was based on timing differences as between two listening ears and upon directional selectivity in sound reproduction. One way or another, that was the focus of Bauer's engineering life over a span of 40 years and more. SQ was merely the late-late product of phase preoccupation, though it was what most of us will remember first.

Movers and Doers

With long-time friends, I have a curious habit of forgetfulness of the past. I have not the slightest recollection of my first meeting with BBB. Nor, for that matter, with that other and closely related (corporately) CBS leader, Dr. Peter Goldmark. Curious, too, in a larger scale of reference, that CBS, grand and omnipotent combine of communications corporality, should have taken on two such far-seeing and original engineering leaders of similar backgrounds. Both came out of Europe, Goldmark from Hungary, Bauer out of Russia via Cuba; both inherited an unmistakable degree of Old-World culture and manners and to the day of their respective deaths — so near in time — spoke with the faint remains of a European accent. Eventually, of course, they became more American than most Americans, joining a whole group of similar powerhouse types from the ancient lands who made their mark at the very top in American communications biz. (To give good credit to the CBS Opposition, we might mention Gen. Sarnoff of RCA.)

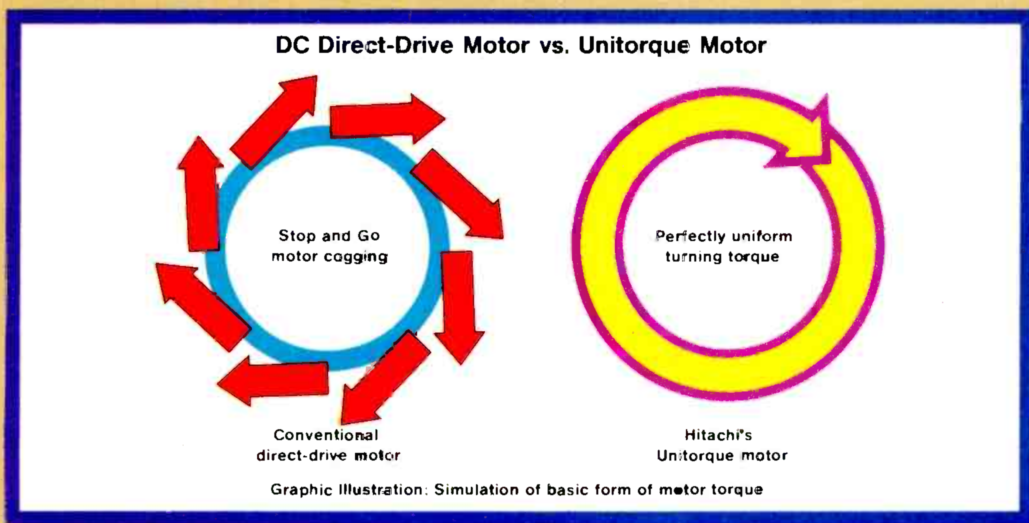
These men, as we always put it, were movers and doers. But in a higher sense they were also out of a background of culture, however distantly, that was totally unlike that of our native Edisons and Henry Fords. These were better, more meticulous engineers, if not greater geniuses, more rigorous in their science but also far wider in their range of view. It was no accident that so much of the audio-related work of both Goldmark and Bauer was based to a really surprising extent on the demands of European classical music in all the aspects of its reproduction — and this held true from the innovation of the Goldmark LP record and "360 degree" Columbia phonograph (anybody still remember that one?) right through to the final Bauer matrix configurations of SQ-with-logic, and that ultimate consolidation of this year at Brussels which he called USQ.

If I may say so, I have often suspected that with these men CBS must have sometimes thought that it had bitten off a bit more than it could chew. No doubt of their leadership and we do not need to hold the CBS hand in sympathy for a few little monetary losses here and there. The overall balance was emphatically favorable. But, however corporate minded they became, in their work both remained the purest engineers and scientists and, if you will, artists. Goldmark was from a distinguished musical family. Ben Bauer studied classical violin, as I discovered one day when I heard some remarkable fi coming from his living room and went in to find the man tossing off advanced fiddle exercises "live" on his own instrument. This peculiar combination of far-seeing aesthetic,



"Teaching doodle" by B. B. Bauer
Derivation of the 4-3-4 system of four-channel broadcast

Absolutely even torque through a full 360°



Unitorque direct-drive turntable

Hitachi's HT-356 Semi-Automatic Turntable is the epitome of accuracy. Its patented Unitorque motor has two star-shaped stator coils arranged for precise balance, even torque distribution and low temperature rise. Brushless, coreless and slotless, it eliminates cogging and vibration. And this direct-drive marvel features quartz-locked control to keep platter speed free from deviation or drift, regardless of changes in load, temperature or line voltage.

Quartz is the most accurate frequency generating element known to man. Coupled with Unitorque's inherent smoothness, it leads to extremely low wow and flutter and virtually unmeasurable turntable rumble. 0.03% WRMS and a S/N ratio of 75 dB (DIN B).

This impressive performer also has front-mounted controls for full operation with the dust cover down.

The Hitachi HT-356. It's the accurate choice.

HT-356

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artistic, and scientific background with the doer-mover psychology meant that CBS as a whole was really rocked — pro and con — by these two, again and again; for both were, needless to say, consummate persuaders within the company, as well as outside it, and very much in that order. First, persuade the corporation execs to plank down X R & D millions; then persuade the public to buy the D via the press. Most of the press in our area can remember that relentless, if genteel, blizzard that came down upon us in favor of this or that CBS project from the Goldmark and Bauer offices, and of course from every subsidiary branch of CBS Public Relations right down to the bottom. I would suggest that Bauer's persuasiveness was even more potent than his engineering logic. And equally so with Goldmark.

Not that these men were remotely alike in personality. During the very early LP days I used to go visit CBS Labs, which then squeezed itself into a floor of the old New York CBS building, and Dr. G. would take me out to some plush, private dining room nearby, where I would be treated to unimaginably wonderful food, plus a soft, deft, endlessly interesting lecture on the latest Goldmarkian developments. In later years, BBB would do the same but here it was some happily expensive suburban steak house in Connecticut where Bauer knew all the waitresses by their first names; and with his wife, we three would consume whole lobsters while I would again be subject to tablecloth and torn-notebook diagrams on every aspect of SQ and plenty more — see illustration.

To Teach, Perchance to Learn

It was sheer education at its best, right from the top, a thing that could not ever be duplicated by an academic course, though that kind of organized study is equally important, obviously. I floundered (again — see illustration). But I learned.

I tried, I really tried, to ascribe ulterior motives. Yes indeed, both men were single minded about promoting their own wares. After all, I would very possibly "write them up." But to spend all those hours with a non-engineer tyro like myself who had no more to offer personally than a brain and a desperate interest to learn the impossible — this was beyond the call of duty. And public relations. They were natural teachers, these two, and as a matter of fact in his "off moments" (say a mere 8 hours a day) Bauer often taught courses in engineering. I learned with dismay, last year after his first and warning heart attack, of his pleasure in a strenuous 1978 summer course at Pennsylvania and the welcome request that he expand the project for the next summer — this one. Too much! He never stopped. And his satisfaction was clearly in seeing the advancement of others' knowledge and understanding. The very learning process itself. As is my own satisfaction, too, in a smaller way and in different areas. This, I may say, is the utter opposite of what I must call the "didn't you know?" attitude, which radiates disdain towards those who do not happen to know the same things as the radiator himself. What distinguishes the real teacher in every area is a respect for the *un-knowledge* of his students, of whatever sort, even including us reasonably intelligent souls in the hi-fi press. I have always cherished that sort of respect. And with it goes another, an equal respect for the things that one does happen to know — which was given to me unstintingly by Ben Bauer. We should realize by this time that leadership, greatness in this world, basically means humbleness of spirit.

Different personalities — yes. I never saw Bauer less than humble in the deepest meaning of that word. Gold-

A NEW PREAMP FOR THAT DISCERNING PERFECTIONIST WHO CAN APPRECIATE THE DIFFERENCE.

The new Phase 3000 Series Two was designed for that discerning music-lover who has a passion for accurate sound, an eye for elegant, yet functional design, a feel for craftsmanship, and an unfailing determination to maximize return on investment.

The Phase 3000 incorporates the latest technological advancements in preamp design. Transient overloading that plagues preamps has been virtually eliminated, whether amplitude, frequency, or slew induced. Now you can enjoy the flexibility, performance and features that are priced substantially higher in other equipment.

CMOS LOGIC MEMORY SYSTEM

Most preamps use dated mechanical switching devices that force signals to travel long, noisy, circuitous routes from the inputs, to the front panel, then back to the outputs. *Ours doesn't.* The Phase 3000 uses CMOS-digital logic to energize switching relays located where they belong, at the input jacks. This shortens critical signal paths. Noise, hum, and the "crosstalk" that's characteristic of mechanical switching is virtually eliminated.

WANT MORE?

A listening session with a pair of headphones will convince you just how much of a difference a true headphone amp makes. Turn the 3000 around, and see how easy it is to patch in your noise reduction unit.

Two complete taping circuits allow you to copy between decks while listening to another source.

But we've done enough talking. If you're serious about state-of-the-art performance it's time for you to do some listening. See your Phase dealer.

SPECIFICATIONS:

Distortion: less than 0.04% (20Hz-20kHz). Typically 0.005% @ 1kHz.
Signal/Noise (IHF "A"): Phono 1—Moving Magnet: greater than 90dB re: 10mV input. Phono 2—Moving Coil: greater than 78dB re: 1mV input
Frequency Response: Phono-1/Phono-2 deviation: ±0.3dB
Tone Controls: High & Low Frequency controls with switchable turnover points.
Volume Control: 22-position precision attenuator with plus or minus 0.5dB tracking.
Low Filter: 18dB/octave below 15Hz.

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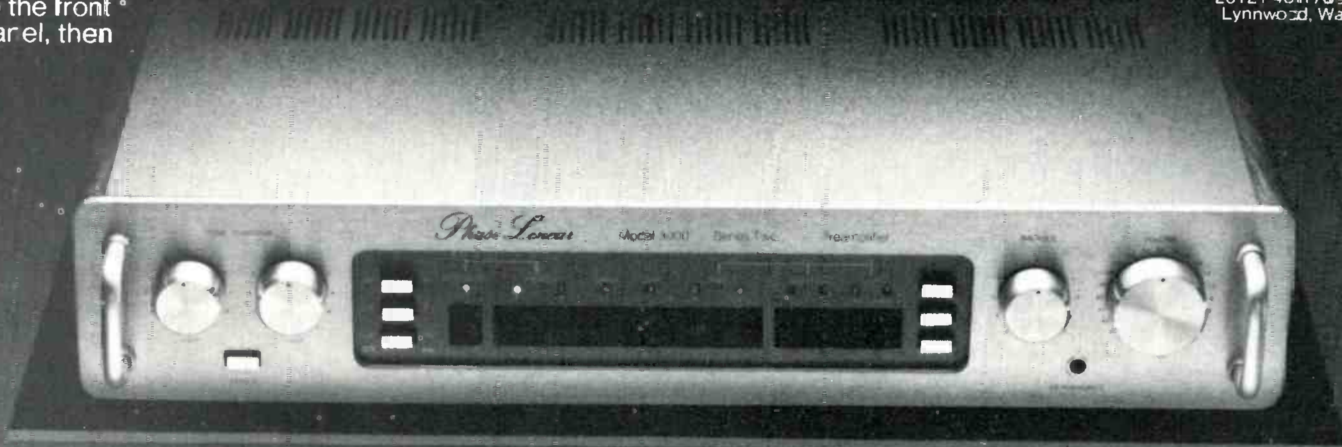

PHONO CARTRIDGE FLEXIBILITY

The two independent RIAA Phono Stages eliminate all low-level switching. As a result, noise is reduced to theoretical limits.

Phono 1 is designed for moving-magnet cartridges and has three selectable capacitance values.

Phono 2 is used with moving-coil cartridges and has three selectable resistance values. The expensive outboard head amp usually required for a moving-coil cartridge is already built into the 3000.

Phase Linear®

THE POWERFUL DIFFERENCE

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mark, at the glorious height of his fame, I thought rather enjoyed the perquisites and fringe benefits that come to the Big Boss. I will never forget the day when, happening to be at CBS for some other biz, I casually asked if I could stop by for a moment and see Dr. G., just for old times. It was at the apex of that glorious CBS development, EVR (TV recorded on film), and Dr. G. was IT. Braces of lowly minions took me in charge and I was granted the privilege of an INTERVIEW, maybe for five minutes. I walked in and gaped — there he was, the Great God himself in his CBS heaven, behind a monstrous white desk so covered with phones and pushbutton consoles I could hardly see him, Rajah of Rajahs, the Panjandrum! Believe it or not, I began to laugh. Never saw such a preposterous sight.

"I didn't even ASK for an interview," I sputtered, "I just wanted to say hello — and *look* at you!" For a moment a black thundercloud arose. Dr. Goldmark could be pretty formidable when he wanted to. But a twinkle quickly appeared and he suddenly laughed, too, almost apologetically. Those fancy trimmings really did look sort of silly. How could I be expected to take them seriously?

Before his last and somewhat pensive speech at an AES banquet, long after EVR, he came up to me of his own accord in the preliminary cocktail hour, this time with no conceivable public relations in mind — simply as a human being. I was moved. Not so long after, he was killed in a hideous car accident.

I am, of course, aware that from his position as an executive in a very large corporation Ben Bauer was able to wield great power in the long, frustrating war of the quadraphonic systems. I do not think he ever abused the engineering aspects of that power, and I know that he was always ready to meet arguments with the most detailed reasoning. I must say now that in private I did not myself necessarily go along with all aspects of the SQ system that I could judge and understand — that is, the audible, musical aspects. I did feel that there were other and reasonable premises and different values, if not always presented with the rigorous logic that was Bauer's. But now that he is gone, few of us are likely to challenge the sheer technical elegance of his conclusions. Enough! Even BBB's erstwhile foes are going to miss the excitement of the fight that is now over, for him.

Take a look at that Brussels paper — it'll soon be around. USQ by BBB.

The standard bearers.

The high bias standard.

In the past few years, these fine deck manufacturers have helped to push the cassette medium ever closer to the ultimate boundaries of high fidelity. Today, their best decks can produce results that are virtually indistinguishable from those of the best reel-to-reel machines.

Through all of their technical breakthroughs, they've had one thing in common. They all use TDK SA as their reference tape for the high bias position. These manufacturers wanted a tape that could extract every last drop of performance from their decks and they chose SA.

And to make sure that kind of performance is duplicated by each and every deck that comes off the assembly line, these manufacturers use SA to align their decks before they leave the factory.

Which makes SA the logical choice for home use; the best way to be sure you get all the sound you've paid for.

But sound isn't the only reason SA is the high bias standard. Its super-precision mechanism is the most advanced and reliable TDK has ever made—and we've been backing our cassettes with a full lifetime warranty* longer than anyone else in hi fi—more than 10 years.

So if you would like to raise your own recording standards, simply switch to the tape that's become a recording legend—TDK SA. TDK Electronics Corp., Garden City, NY 11530.

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The machine for your machine.

*In the unlikely event that any TDK cassette ever fails to perform due to a defect in materials or workmanship simply return it to your local dealer or to TDK for a free replacement.

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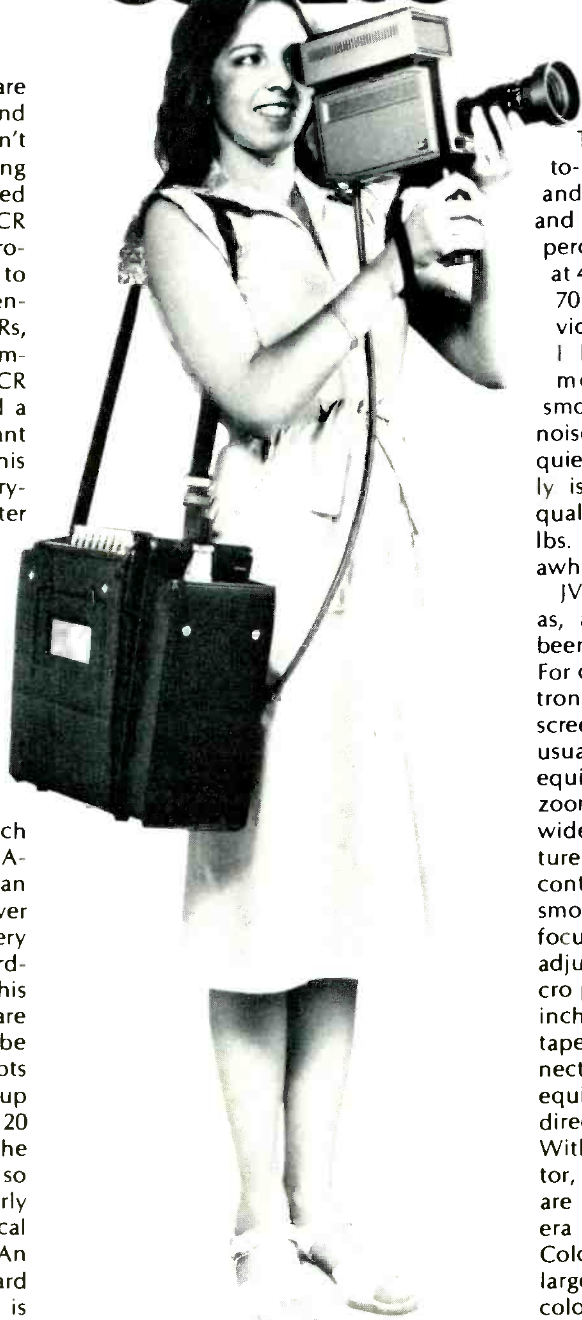
Video scenes

Bert Whyte

While video cassette recorders are still relatively new on the scene, and obviously the market for them hasn't even been scratched, it is amazing how many people have progressed through several generations of VCR units, adding the jazzy new programmable units or color cameras to their VCR set-ups. Now the latest enthusiasm is for the new portable VCRs, which with an appropriate color camera permits a vast broadening of VCR interests. With the ability to record a scene in full color and then get instant playback on your TV screen, this brings out the "ham" latent in everyone and "sells" the system far better than any salesperson.

For the past several months I have been enjoying using the nifty, new JVC VHS portable VCR and color camera. The system consists of the HR-4100 portable Vidstar VHS ½-in. video cassette recorder and the GC-3350 color camera with Color Control Unit (CCU). The HR-4100 weighs in at 21 lbs. with its battery pack. The PBP-1 battery pack is a nickel-cadmium type which is rechargeable overnight via the AA-P41 battery charger. There is also an a.c. adaptor which supplies d.c. power to the VCR. A fully charged battery provides about three hours of recording time. For those who really ride this hobby horse, you can carry a spare charged battery, which can be changed in minutes. The VCR accepts standard VHS cassettes and permits up to two hours of recording with the 120 cassette. Being a portable design, the HR-4100 has a gyroscopic capacity so that the unit can be subjected to fairly abrupt motion without mechanical damage or recording malfunction. An aid, too, is that during fast-forward and rewind modes, the videotape is *not* wound around the head drum. The VCR has low wow and flutter thanks to a capstan servo system. There are finger-type pushbuttons for *Play, Stop, Rewind, Fast Forward, Record, Pause, Audio Dub,* and *Eject.* On the front panel are a digital counter with search button and pilot lights showing battery condition and dew conditons. The latter is quite important, since quite often the VCR will be used outdoors. An automatic dew protector automatically shuts off the VCR when the external temperature drops below a predetermined threshold and there would be a threat of condensation. A tracking control is provided to correct picture distortion during playback. The HR-4100 has a built-in r.f. adaptor so that it can be played through any TV set on the usual channels, 3 or 4. This VCR uses the JVC rotary, slant-azimuth, two-head, helical-scan system to record the NTSC color signal. Tape speed is 1.31 ips, the signal-to-noise ratio is better than 45 dB, and color resolution is 240 lines. Wow and flutter is spec'ed at less than 0.5 percent rms. Audio S/N ratio is rated at 40 dB, with a frequency response of 70 Hz to 10 kHz. There are jacks provided for mike input and earphones. I have found the HR-4100 to be mechanically reliable, with smooth operating controls, and while noise is hardly a factor outdoors, it is a quiet-operating unit. This VCR certainly is a neat and tidy package, thus qualifying as a portable unit, but 21 lbs. gets to be a bit burdensome after awhile.



JVC's HR-4100 is portable but weighs a hefty 21 lbs.

JVC makes a number of color cameras, and the GC-3350 model I have been using has some deluxe features. For one thing, this camera has an electronic viewfinder (in essence a tiny TV screen) which is far better than the usual optical viewfinder. The camera is equipped with a high-quality, 6-to-1 zoom lens, ranging from 12.5-mm wide angle to 75-mm telephoto. Aperture is a fast f 1.8. A lever is used to control the zoom, and I found it very smooth working. There are the usual focusing and aperture rings. With an adjustment, the lens can be set to Macro position and focus as close as four inches. The start/stop switch activates tape motion when the camera is connected to the HR-4100. The camera is equipped with a fairly sensitive omnidirectional condenser microphone. With the built-in sync signal generator, needless to say, picture and sound are in perfect juxtaposition. The camera actually plugs into the external Color Control Unit. This 2-lb. unit is largely responsible for the excellent color produced by this camera. The CCU has a color compensating switch which selects between outdoor, indoor, morning/evening or a manual position which permits further fine tuning of red and blue elements. As you might expect, in bright sunshine with the color temperature at 6500 degrees Kelvin, color quality of the image is at optimum, with highly saturated, clean, clear colors. Red is particularly well reproduced. The color system used in the camera is NTSC frequency multiplex type and uses 2⅔ inch Vidicon tubes with electrostatic focus. The

What separates our separates from the boys.

Two things, actually.

Number one, Sherwood separates are the only separates designed to outperform our receivers. Because we don't make a laundry list of products, we can concentrate on creating the most practical, reliable and audible design improvements in our tuners and amplifiers.

Like our S-32 CP Stereo Tuner and S-702 CP Integrated Amplifier.

The Tuner offers 50 dB stereo quieting from less than 38 micro volts of signal. That's station monitor-quality performance.

There's a multiplex noise filter to eliminate noise in weak FM signals and an output level control so you can match the volume levels of broadcasts and records.

And more.

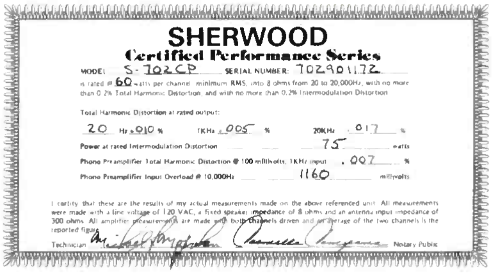
The Amp gives you pre-amplifier outputs and power amp inputs. You get a phono section with THD of .008% (or less), 92 dB signal-to-noise ratio and subsonic filter. It's DC coupled with fully complementary circuitry in the amplifier section.

After we put them together, we take them apart.

The second thing that sets our separates apart from our competitors is the fact that we're the only maker of audio components to certify and notarize their performance in writing.

After production, every Sherwood Amp and Tuner is individually checked and adjusted for maximum performance under the supervision of the engineers who originally designed the model.

With Sherwood Certified Performance™ Separates, what you see in writing is what you hear. Certifiably. The result? Distortion-free sound that's music to your ears.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Certified Performance Series
MODEL S-702CP SERIAL NUMBER: 702901172
is rated @ 60 watts per channel minimum RMS, into 8 ohms from 20 to 20,000Hz, with no more than 0.2% Total Harmonic Distortion, and with no more than 0.2% Intermodulation Distortion

Total Harmonic Distortion at rated output:
20 Hz .010 % 1KHz .005 % 20KHz .017 %
Power at rated Intermodulation Distortion 75 watts
Phono Preamplifier Total Harmonic Distortion @ 100 millivolts, 1KHz input .007 %
Phono Preamplifier Input Overload @ 10,000Hz 1160 millivolts

I certify that these are the results of my actual measurements made on the above referenced unit. All measurements were made with a line voltage of 120 VAC, a fixed speaker impedance of 8 ohms and an antenna input impedance of 300 ohms. All amplifier measurements are made with both channels driven and an average of the two channels is the reported figure.
Technician Notary Public

It all adds up to a sound deal.

A fine-tuned Sherwood Tuner and Amp with specs you can believe. Together, they make the hi-fi heart of a superb audio system with all of the flexibility and performance only superior audio separates can provide. And it won't cost you an arm and a leg to own them.

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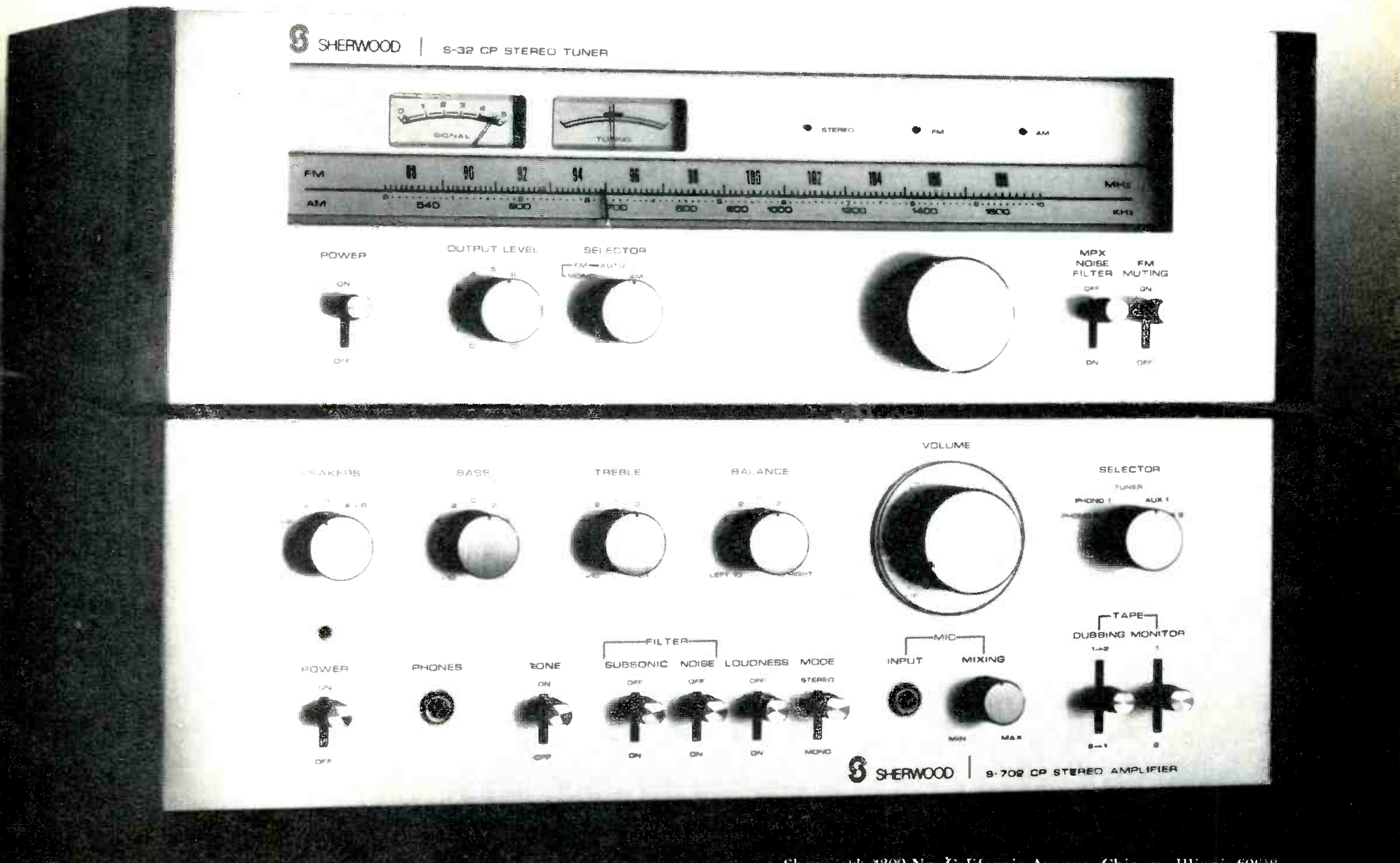

Sherwood, 4300 No. California Avenue, Chicago, Illinois 60618.

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scanning system is 525 lines, 2:1 interlaced. Horizontal resolution is better than 400 lines, and S/N ratio is better than 45 dB. There is a Sensitivity control switch on the CCU with *Normal* for regular lighting situations or *Up* for low light. Minimum practical illumination that will give a reasonably exposed picture is nine foot-candles. When you look through (more appropriately, at) the viewfinder, there is an aperture setting guide with plus or minus indications and a "proper" center mark. A white marker should be centered for proper exposure, which is

HR-4100, GC3350, and CCU.

accomplished by turning the aperture ring. Once you observe the contrast ratios of your image, and select that which you find pleasing, you are free of slavishly centering the aperture marker all the time. However, when you are zooming from the extremes of wide angle to telephoto and vice versa, unfortunately the camera does not have automatic iris control, and the aperture setting will vary with the focal length changes. The camera is really quite easy to use, and in conjunction with the HR-4100 produces outstanding, high-quality images on the videotape. Naturally, you are producing "direct" camera-to-VCR images, so there is none of the "hash," "snow" or picture granularity which often afflicts transmitted television pictures. What a pleasure to see such clean, steady, beautiful color images.

As to what you can do with a portable VCR set-up like this, the list is endless . . . photograph your golf swing or tennis form by using a sturdy tripod if there is no one around to capture your style . . . show your son his boo-boos or heroic efforts at his Little League game . . . make a production of your local theater group. You can never run out of subjects, and, best of all, it's available for instant playback. I have found this JVC portable set-up to be of excellent quality, endlessly fascinating, and, I assure you, definitely addictive! At list prices, the system will be around $2,700 . . . but think of the money you will save on film!

Perfection for the Professional

Drawing upon their unequalled 30 year leadership in magnetic recording technology, Tandberg's TD 20A open reel tape recorder extends their traditionally superior level of performance to even further limits—to even beyond the present capabilities of today's magnetic recording tape! This is due to Tandberg's exclusive ACTILINEAR Recording System, which not only provides up to 20 dB headroom margin over existing tape, but is specifically designed to be used with the new high coercivity tapes that will appear in the market in the near future—including the soon-to-be-available metal particle tapes. No other quality open reel tape recorder can make this obsolescent-proof claim today.

The ACTILINEAR Recording System's extremely linear frequency response ("ruler flat" according to some test reviewers) not only makes the TD 20A essentially immune to slew-rate limiting and transient intermodulation distortion (TIM), but also means better transient response and lower distortion overall.

Adding to the TD 20A's superior level of quality & performance is its unique PROM computer-controlled four-motor transport, as well as its many standard operating features that permit a degree of performance and control flexibility that you would expect only from Tandberg—the world leader in tape recorders.

Visit your authorized Tandberg dealer for a demonstration of the TD 20A. Check our *guaranteed minimum specifications* and rate them against any other manufacturer. Combined with the unsurpassed ease of operation & control, the TD 20A is probably more tape deck than you actually need. Isn't it the way things should be?

For your nearest dealer write:
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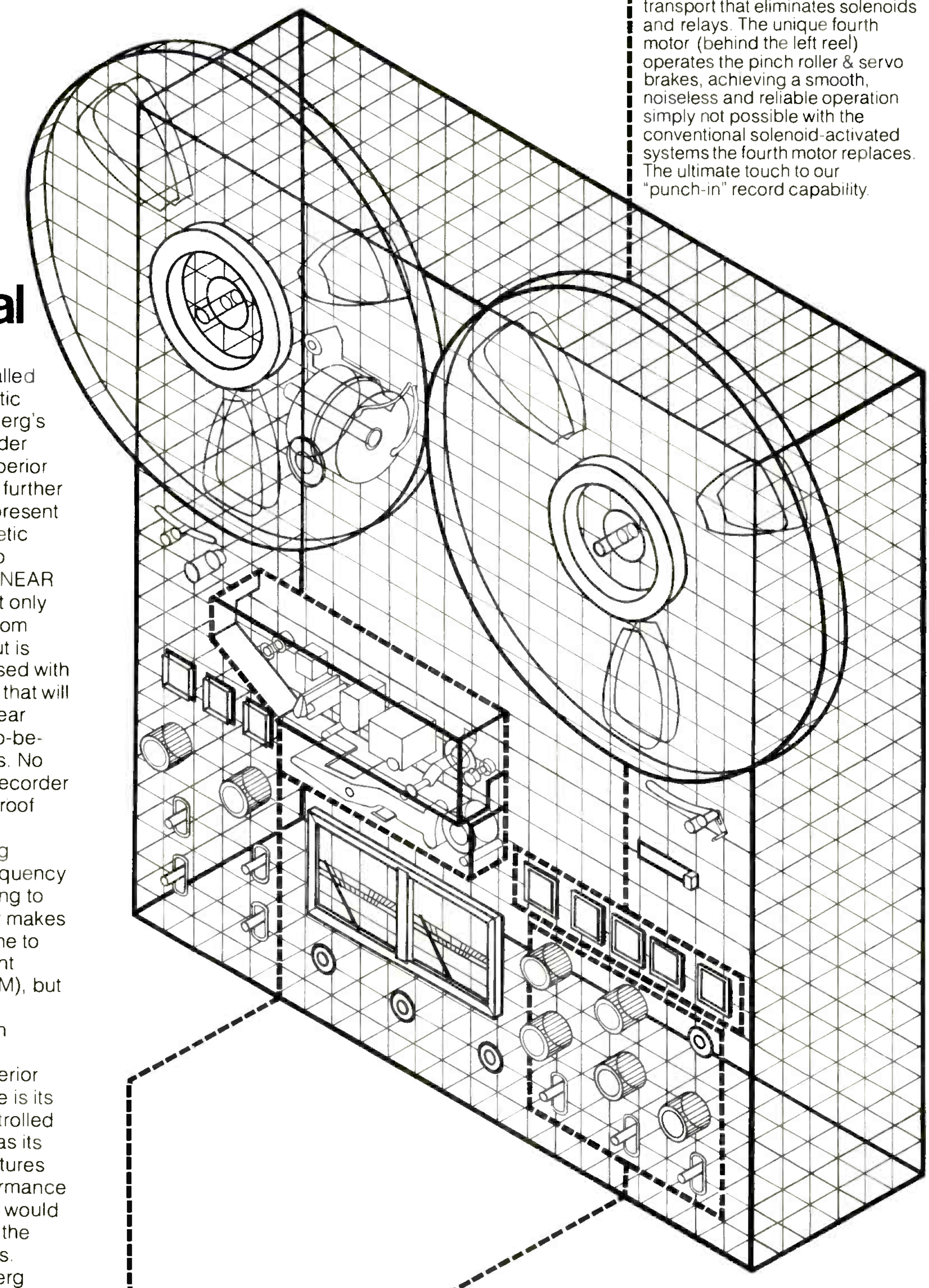
TANDBERG

Tandberg's exclusive PROM computer-controlled four-motor transport that eliminates solenoids and relays. The unique fourth motor (behind the left reel) operates the pinch roller & servo brakes, achieving a smooth, noiseless and reliable operation simply not possible with the conventional solenoid-activated systems the fourth motor replaces. The ultimate touch to our "punch-in" record capability.



Tandberg's unique ACTILINEAR Recording System, offering up to 20 dB headroom margin over *existing* tape. And easily adjustable for use with the new high coercivity tapes to come, so your TD 20A is obsolescent-proof!

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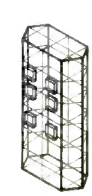

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Tape guide

Herman Burstein

Copying Dolby-Encoded Tapes

Q. What is the procedure when copying a Dolby-encoded tape to produce a Dolby-encoded copy?— David Rowland, Parlin, N.J.

A. There are two schools of thought on this. The first, and apparently preferred one, is that to obtain proper tracking (correct application of treble cut on low-level signals), you should play back through a Dolby decoder to restore a flat signal and then record through a Dolby encoder to make the dubbing. The second school of thought is that the less you tamper with an audio signal, the cleaner the final result will be. You would thus play the original tape *without* decoding, and copy this by recording *without* encoding. Accordingly, the copy will retain the original encoding.

I have tried both methods, and with my equipment and to my ears there is no obvious or consistent difference in results. With your equipment and *your* ears, however, there might be a difference.

External Dolby Hook-Up

Q. I am planning to buy an external Dolby unit. I'm wondering how to hook up this unit to decode FM Dolby broadcasts. Can the unit be put between my receiver and my open-reel tape deck, or would it be necessary to connect it between the preamp and amplifier sections of the receiver?— Scott MacGregor, Atlanta, Ga.

A. You apparently have two objectives: (1) To produce Dolbyized tape recordings for any signal source (FM, phono, etc.) and (2) to decode Dolbyized FM broadcasts. To meet the first objective, the Dolby unit must be placed between the receiver and the deck, utilizing the "tape-out" and "tape-in" jacks of the receiver. To meet the second objective, you need a switching arrangement that permits the decoding (playback) section of the Dolby unit to be connected to the FM signal. Quite possibly your deck provides such an arrangement, particularly if it is of the three-head type that permits simultaneous record and playback, as it will have a "tape-source" switch for monitoring. The switch can be set to the source position to accept the FM signal, and this can be processed through the decoding section of the Dolby unit. Altogether, the Dolbyized FM signal would be routed through the Dolby unit's recording section *but with Dolby encoding off,* through the tape deck (without otherwise operating the deck), through the Dolby unit's playback section *with Dolby decoding on,* and into your receiver via the "tape-in" jacks. In the case of non-Dolbyized FM broadcasts, you would play the FM signal straight through the receiver, without going through the above sequence.

Storing Tape Recordings

Q. I have been led to believe that tape recordings should be stored carefully away from electric motors and electronic equipment lest the recordings be damaged by stray magnetic fields. But I have also read an article with a different view. It summarizes a 3M Company report to the effect that, apart from a magnet placed directly on a reel of tape, no electrical or magnetic device in the home is likely to damage the magnetic impression on a tape. Has anyone confirmed 3M's research? — Everett Young, APO New York

A. The 3M Company is one of the primary authoritative sources on magnetic tape recording, and I am inclined to trust their findings. Studies by the National Bureau of Standards have confirmed the point that only an extremely powerful magnetic field very close to the tape (a matter of a very few inches) will endanger the tape. That danger is erasure.

My own experience is that a very powerful electromagnet (ordinarily used as a bulk eraser) brought as close as about four inches from a reel of tape has no audible effect on the recorded sound.

It seems, altogether, that a safe rule would be to keep tapes at least six inches away from possible sources of magnetic fields, such as those emanating from motors, speakers, etc. If you want to be extra, extra safe, change the rule to one foot.

If you have a problem or question on tape recording, write to Mr. Herman Burstein at AUDIO, 401 N. Broad Street, Philadelphia, PA 19108. All letters are answered. Please enclose a stamped, self-addressed envelope.

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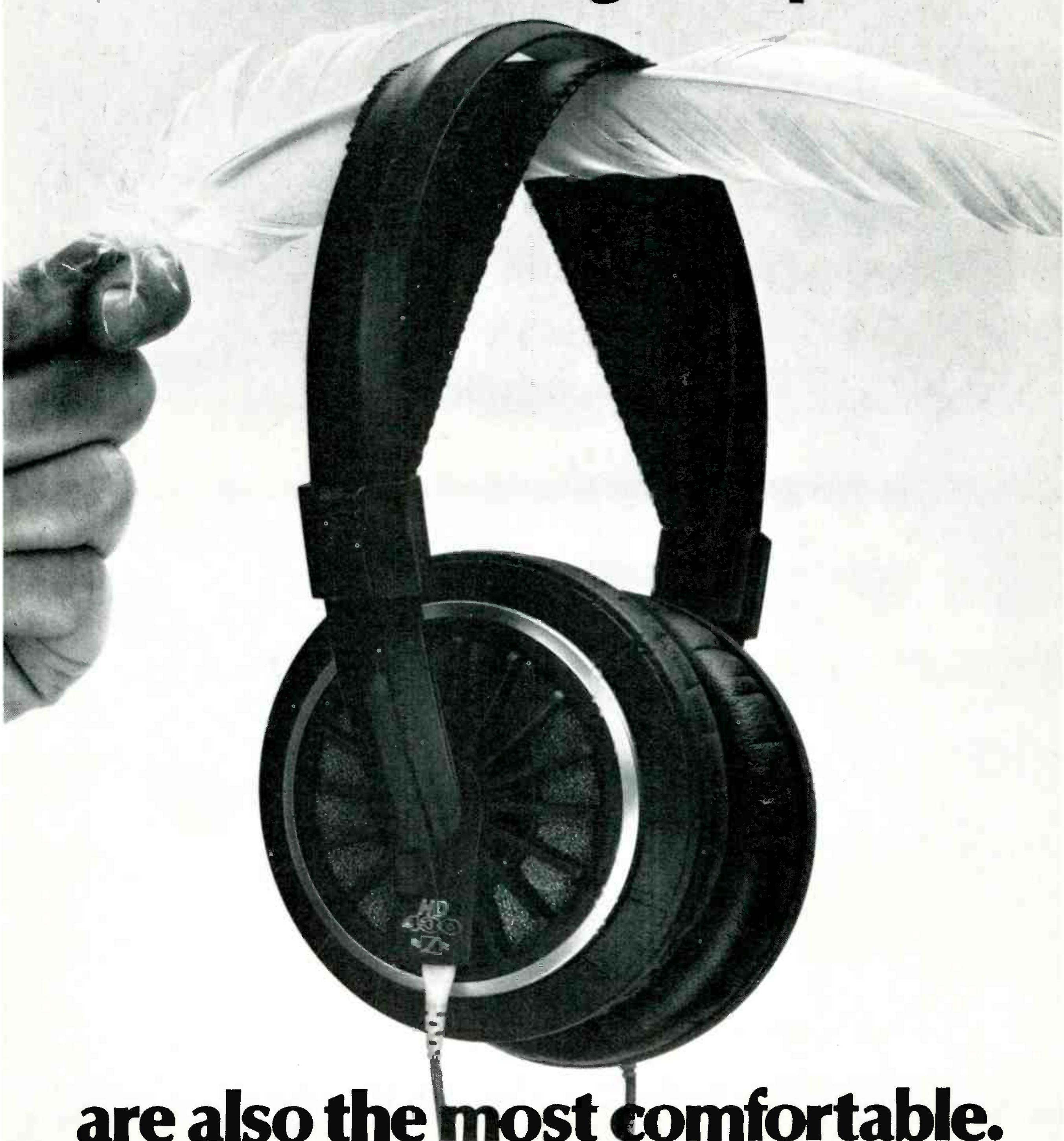

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Behind the scenes

Bert Whyte

The annual Los Angeles convention of the Audio Engineering Society was later than usual this year, May 15-18, and unfortunately coincided with the gasoline shortage hysteria that swept California. While the 63rd AES Convention was bigger than ever, and set new records for the number of exhibitors, the gasoline crunch kept the attendance at about the same level as last year.

Just prior to the convention, May 11-13, UCLA Extension, in cooperation with the AES and *Audio* magazine, presented a seminar on "The Revolution in Home Entertainment: New Technology's Impact on the Arts." Chaired by Martin Polon, Director of Audio-Visual Services at UCLA, who was also the Chairman of the 63rd AES Convention, this symposium suffered a reduction in attendance as a consequence of the gasoline problem. Nonetheless, there was quite a respectable turnout, with the attendees ranging from engineers of the audio manufacturers, salesmen from audio retailers, inquisitive audiophiles, and even Wall Street analysts. Everything from digital recording through direct disc to the latest developments in speakers, amplifiers, tape technology, all aspects of video, laser communication, and satellite broadcasting. Finally, "Visions of the Year 2000" was presented by a panel of speakers which included Dick Heyser; John Eargle; Bart Locanthi of Pioneer Development Laboratory; Stan Ricker of JVC Cutting Center; Emil Torick, former President of the AES and a Director of the CBS Technology Center; Jeffrey Krauss of the FCC; Bruce Apar, Editor of *Video* magazine; John Dykstra, supervisor of special effects for "Star Wars" and producer of "Battlestar Galactica," and yours truly. As the first effort in what apparently will be an ongoing series, the symposium had some organizational rough-spots and awkwardness in presentation, but most participants felt the event was worth their time and enjoyed the lively repartee with the panelists.

As expected, some pretty "far out" ideas were in the scenario for home entertainment in the year 2000, with the consensus being that the home will have a central "media room," where at the punch-up of a program in a personal computer you command an incredible diversity of audio-visual sources, all presented in wall-sized three-dimensional holographs and 360-degree "live" sound. It was sort of ironic that this vision of the "brave new world" was being proposed in the midst of a gasoline crisis, since the energy requirements for this kind of installation and, indeed, many of the materials of the media complex itself are dependent on petroleum. It is obvious that, 21 years from now, we had better be operating on fusion power and have developed alternative materials for our "media rooms" or they will forever remain a fantasy. Martin Polon is to be commended for initiating this important new symposium and given a vote of appreciation as well for a smooth running AES convention.

As for the 63rd AES Convention, digital recording was as expected a prime topic, but rather surprisingly, not as dominant as in the past several conventions. Now I'm not saying that there is any diminution of interest in digital, merely that some of the manufacturers involved with digital equipment encountered problems which have delayed the debut of certain new digital products. For example, 3M's elaborate Inter-Technology Exchange (ITX, Ltd.) digital editing system evidently ran into a few "glitches," and it was deemed "not quite ready" for demonstration and subsequent production. Similarly, the long-anticipated debut of the Ampex digital recorder has been delayed. I believe they were quite close to its introduction, and, in view of this, perhaps we will see a special presentation of the recorder rather than endure the long wait until the November AES Convention at the Waldorf. However, counter to these unfortunate "no-shows" was the introduction of a new digital recorder from Technics; and an electronic editing console from Sony for its PCM-1600 digital recorder, an upgraded version of their original PCM-1 unit, now called the PCM-100, and a unique sampling rate converter, Model DSX-87.

The Technics open-reel digital recorder uses a closed-loop tape transport based on their by-now-familiar RS-1500. This system is a radical departure from anything previously shown by Technics and features an entirely new digital code format. Tape width is one-quarter inch, and tape speed is 15 ips. It is claimed that this will permit one hour continuous recording on a 10½-in. reel. This recorder (as yet undesignated as to model number) uses 16-bit linear quantization with a sampling rate of 50.4 kHz. The unit uses the unique thin-film magnetic head for recording and a magneto-resistive thin-film head for playback. These thin-film heads are made by photo-etching techniques similar to that employed in the manufacture of semiconductor devices. Because of this, uniformity of the heads is extremely high and costs comparatively low. This Technics recorder has four audio channels, but future formats would be 32 channels on one-inch tape and 48 channels on two-inch tape. Actually, there are 20 tracks on this quarter-inch tape . . . four audio channels, and four tracks to record each channel (three data and one parity), and four auxiliary tracks for such things as SMPTE time codes and analog tracks which would permit cut-and-splice editing techniques. This machine uses the data block system, and one data block of each track consists of one word of sync, 14 words of data, and one word of CRCC (cyclic redundancy check code). One word consists of 16 bits for data and CRCC and 12 bits for sync. All this adds up to complete parallel processing for bit-error detection and dropout countermeasures. Dynamic range of this digital recorder is rated at better than 90 dB, with THD less than 0.05 percent, and a frequency response of 20 Hz to 20 kHz plus or minus a mere half of a dB. With the SMPTE time code that is recorded on one of the auxiliary channels, electronic editing and assembly is possible, although at present no editing system is available. A great deal of interest was shown in this Technics digital recorder, especially when it was announced that the price of the unit is expected to be about $20,000, making it the least expensive 16-bit, fixed-head recorder thus far available. There, in fact, is the rub . . . production of this recorder is not slated until the fall of 1980.

The new Sony DEC-1000 editing controller is a very sophisticated electronic editing and assembly unit for use with their PCM-1600 digital audio processor and U-Matic VCR. This is a really slick unit, which actually permits edit points to be selected with a manual search dial and rotating the reels back and forth in the manner of present analog recorders. An auto search system is also provided. As with all present electronic editing systems, two VCR transports are necessary for editing lay-out and recording. In use, an approximate edit point within a six-second range is selected and stored in a memory. Then this six-second segment is scanned and searched for the exact edit point. Edits can be previewed, shifted in two millisecond steps over a 100-mS interval. Butt and crossfade edits are available, and edits are claimed to be accurate within 90.8 microseconds (equavalent to four 16-bit data words on the PCM-1600). Even level differences can be crossfaded over seven selectable fade times from 0.5 microsecond to 100 mS. Various LED indicators are used for editing functions, and an SMPTE time code generator and reader are available. Digital tape counters for the lay-out U-Matic VCR units are provided. This DEC-1000 electronic editing system is contained in a convenient desk-type console. No pricing information as yet.

Sony was also showing its interesting two-channel DSX-87 sampling rate converter. With its own internal clock, this unit can convert in real time the 44.056-kHz sampling rates common in video-type PCM units to the 50.4-kHz sampling rates used for fixed-head digital recorders, like the Sony 3224 24-channel model, and vice versa. With inputs for external clock systems, sampling rate changes up to 55 kHz can be accommodated. The big point with this converter is that sampling rate change can be accomplished without leaving the digital domain. Conversion errors are claimed to be held to one LSB (least significant bit) for input frequencies from d.c. to 20 kHz. Last, but not the least of the new digital products from Sony is their PCM-100, which is the successor to the original PCM-1 system. The PCM-100 is a two-channel unit which is the first to use the new Japanese standard 14-bit linear quantization system, although the sampling rate is still at 44.056 kHz. Sony claims much improved error detection and dropout correction in the PCM-100, using their Cyclic Redundancy Check Code, interleaving and interpolation up to 64 horizontal lines. With the PCM-100 and two VCR units, direct digital-to-digital dubbing can be performed with no signal degradation. Dynamic range of the PCM-100 is claimed to be better than 85 dB, with THD of less than 0.03 percent and a frequency response of less than plus or minus a half a dB from d.c. to 20 kHz. Here again no price information on this unit, but considering the ravages of inflation, it is unlikely to be less than the $4,000 tab for the PCM-1.

At the JVC demo room, they too had an updated PCM unit, this one using 14-bit linear encoding. It is claimed that the new PCM processor can handle either Beta or their own VHS format. JVC played a flamenco PCM recording through their new Super A amplifiers and some prototype Zero-9 speaker units which have new Dynaflat ribbon tweeters with a claimed response to 50 kHz and high power-handling capabilities. The sound was exceptionally clean with fine imaging, and the high energy transients of the flamenco foot-stomping were very sharp, with impressive impact.

Dr. Tom Stockham's Soundstream digital recording service is kept very busy these days (as reported in my last column), and he was demonstrating a wide variety of recordings through the new Infinity Reference 4.5 speakers, bi-amplified with the Infinity solid-state/tube hybrid amplifiers. While the analog LP record, which is the end product of the Soundstream digital mastering system, produces some impressive sounds, there simply is no contest when you hear the sound of the digital master itself through such a high-quality system. There is no question in my mind that digital recording will only make its full impact on the audiophile market felt when it is available in true digital format, either in prerecorded digital video-cassette tapes or on laser, VISC or capacitance-type digital discs.

While Ampex didn't turn up with their digital recorder, they did have an interesting new product based on digital technology. This was the ADD-1 Audio Digital Delay for disc mastering preview. Ampex was promoting this unit as part of what they termed "The Ampex Mastering System," which consists of an Ampex ATR-100 recorder equipped with their new two-channel head for *half-inch tape,* Ampex Grand Master tape that is, and the ADD-1 digital preview unit. I've had one of these new heads for some months now, and the increase in signal-to-noise ratio and higher head room makes a significant improvement in stereo recording. For the engineer, who is doing "purist" type simple mike setups for classical recording, this two-channel, half-inch approach is the way to go! As I am sure you know, when cutting a record, the dynamics of the recording are "previewed" by a magnetic head spaced a certain distance before the program playback head, with the time span dependent on the requirements of a particular model of the cutting lathe. The preview signal is fed into the computer system of the lathe, and from this signal the pitch and depth of the grooves is automatically controlled, before the program signal reaches the cutting amplifier. Typical delay is 1 to 1.3 seconds, with the information from the preview head continuously updating the computer. With the Ampex ADD-1, the preview head is eliminated, and instead, digital delay feeds the dynamic information to the lathe computer before the arrival of the program signal. The ADD-1 offers preset pushbutton selection of delay times up to 5.12 seconds and variable delays in 5-mS increments up to the 5.12 maximum. The ADD-1 is a 16-bit system with sampling rate up to 50 kHz for a full 20-kHz bandwidth. An optional 100-kHz sampling rate is available for ultra wide-band recording, with a maximum delay of 2.56 seconds at this rate. The unit allows up to 30-ips mastering speed, can be used for half-speed mastering, and, of course, since there is no preview head, the wow-and-flutter performance of the tape playback machine is not degraded. The system has a dynamic range of 90 dB, which obviously will handle digital inputs. A most fascinating feature is that it can be used (on the actual recording session, of course) to preview direct-disc recordings and presumably permit more time to be recorded on a side. Ampex claims that with the combination of the ATR-100 and the two-channel, half-inch head, plus the Grand Master tape and the ADD-1 delay, an 80-dB signal-to-noise ratio can be delivered to the cutting amplifier. The Ampex ADD-1 digital delay unit with 1.3 seconds of delay costs $14,500, with additional increments of delay available in optional modules at extra cost.

Before we leave the digital arena, I should mention that at the convention, news came of the digital recorder developed by the Central Research Laboratory of EMI in England. Unlike the helical-scan system of Decca, they apparently use a fixed-head open-reel unit at a speed of 30 ips in yet another new digital format. No information as to sampling rate, but one presumes it will in the 50-kHz area in a 16-bit system. Reportedly, EMI released a 12-in. single of a jazz/fusion band . . ." Morrissey/Mullen" cut from their digital master. They are also said to be continuing developmental work on their editing system.

That is just about the extent of digital news from the 63rd AES Convention. Meanwhile, back at the analog ranch . . . there was the usual proliferation of new audio gear, and I will report on some of these items next month, as well as bring you a review on the Calrec "sound field" microphone and ambiphonic "surround sound," which was finally demonstrated in this country and deserves special mention. **A**

QUICK-BUILD

Build A Speaker Impedance Checker

M.J. Salvati

Often an audiophile buys a quality speaker system together with a quality receiver or amplifier and runs into trouble. He finds that the sound cuts in and out or stops entirely, even at moderate sound levels, due to the operation of the amplifier's protective circuitry. When asked, the speaker manufacturer claims the amplifier is defective and the amplifier manufacturer claims the speakers are defective. In truth, both components may be performing up to spec, but the cause of the trouble is that the two are incompatible. A number of modern amplifiers have elaborate protection circuitry which mutes the amplifier if the load impedance drops below two or three ohms. Unfortunately, speaker impedance ratings are merely nominal values, and the actual impedances vary greatly with frequency. At some frequencies, impedances drop far below the nominal rating. The result is that speakers nominally rated at four ohms will cause such an amplifier to mute when the program material has significant power at a frequency where the speaker impedance dips, even though the total sound power is at a moderate level.

The simple device shown allows you to quickly check a speaker's impedance vs. frequency characteristics, using just your power amplifier, an audio oscillator, and an a.c. voltmeter. Figure 1 shows how. The device is just a box fitted with connectors and containing a 150-ohm, 4-watt resistor. This high-value resistor converts your transistor power amplifier into an a.c. constant-current source. The a.c. voltage appearing across the speaker terminal is therefore proportional to speaker impedance. By setting the oscillator and amplifier level controls for 15.8 V a.c. output from the power amplifier, the resulting output current results in speaker voltage at the rate of 0.1 volt per ohm. This relationship is most accurate when the speaker impedance is around 8 ohms, and it is accurate enough (±5 percent error) over an impedance range of 0-16 ohms for this check.

Construction

The 150-ohm resistor must be non-inductive and rated at least 3 watts. This rules out readily available wirewound power resistors and any single carbon-composition resistor. Instead, buy two 300-ohm, 2-watt, 5 percent tolerance carbon-composition resistors. These are more readily available than the more exotic types suitable for this application. If even these are hard to find, you can purchase five 750-ohm, 1-watt or ten 1500-ohm, ½-watt resistors, also of 5 percent tolerance. Either way, connect the resistors in parallel to produce a 150-ohm, 5 percent tolerance non-inductive resistor rated at least 4 watts.

If you are the "informal" type, the test setup of Fig. 1 can be assembled with clip leads. If you like things "neat," mount the resistor in a box fitted with 5-way binding posts, as I did.

Use

Oscillators most suitable for this procedure have a constant sinewave output-level vs. frequency characteristic and continuously variable frequency control. A lab-grade sinewave oscillator, like the Krohn-Hite 4200 or any decent function generator, is ideal. However, a service-grade audio oscillator equipped with an output voltmeter, such as the Heath SG-5218 or Eico 378, will also work well at the cost of some speed and convenience.

The audio amplifier's power rating must be *at least* 30 watts rms into an 8-ohm load. For maximum convenience, the amplifier must be capable of being set for a flat frequency response from 200 Hz-20 kHz. This is possible with quality amplifiers by simply setting the tone controls to "neutral" or "off" and setting the loudness and high- and low-filter switches to "off."

To measure speaker impedance, proceed as follows:

1. Connect the checker between the amplifier and the speaker being checked.
2. Connect an a.c. voltmeter across the *AMPL* terminals, and adjust the oscillator and amplifier level controls for 15.8 V a.c. at 200 Hz.
3. Transfer the a.c. voltmeter to the *SPKR* terminals. Record the voltage measured here.
4. Slowly vary the oscillator frequency in suitable increments from 200 Hz to 20 kHz, recording the voltmeter reading (at the *SPKR* terminals) at each frequency. If your oscillator and power amplifier are not perfectly flat, you must check and reset the input voltage at each frequency.
5. Plot the results of your impedance vs. frequency measurements on semilog graph paper, as I did in Fig. 2. Wherever you find a dip in the curve, make additional measurements at frequencies in that range to pinpoint the frequency of lowest impedance and severity of the dip.

Analyzing The Results

The effect of a big dip below the nominal impedance value depends on several things: Speaker efficiency, the power output characteristics of your power amplifier, and the amplifier's method of connecting multiple speakers. If you have high-efficiency speakers or like soft music, you are unlikely to run into trouble. If the speakers involved are low efficiency and you really try to "use" all those watts you paid for, you should pay particular attention to the following general precautions regarding amplifier/speaker combinations. Note, however, that modern equipment is so diverse that many exceptions do exist.

1. If the amplifier has an 8-ohm power rating, but no 4-ohm rating, it usually means its 4-ohm power capability is *less* than the 8-ohm rating. This means that 4-ohm speakers should not be used, not even a single pair. Parallel simultaneous (A & B) operation of two pairs of 8-ohm speakers (main and remote) is similarly not recommended; doing this with 4-ohm speakers is out of the question. However, simultaneous operation of two identical pairs of 4- or 8-ohm speakers is perfectly OK if the amplifier uses a series connection to do this.

2. If the amplifier has a respectable 4-ohm power rating, simultaneous parallel operation of two pairs of 4-ohm speakers *might* be a problem. If the impedance curves dip greatly (3 ohms or so) at some frequencies, this means the amplifier is burdened with a 1½-ohm load impedance at those frequencies! As above, simultaneous operation of series-connected 4-ohm speakers is fine.

3. If two (or more) sets of 4-ohm speakers are to be simultaneously driven, use an amplifier specifically designed for driving very low impedance loads. These are usually separate component power amplifiers whose output stage consists of banks of parallel-connected output transistors.

4. An amplifier having electronic overcurrent sensing and/or load impedance sensing is *generally* less suitable for driving low-impedance loads than is a similarly rated amplifier without this type of protection circuity. The exceptions are sophisticated circuits, like the one in the Crown M600, which allow higher current levels for low-impedance loads.

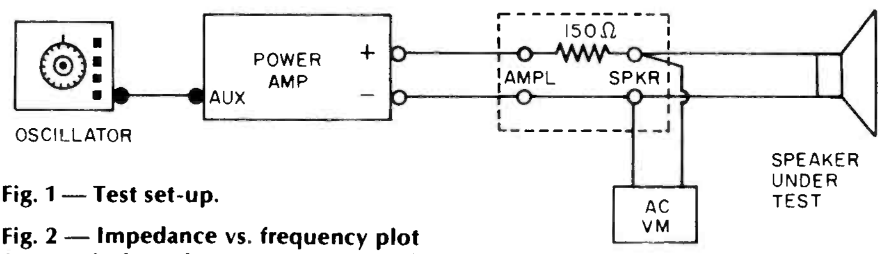
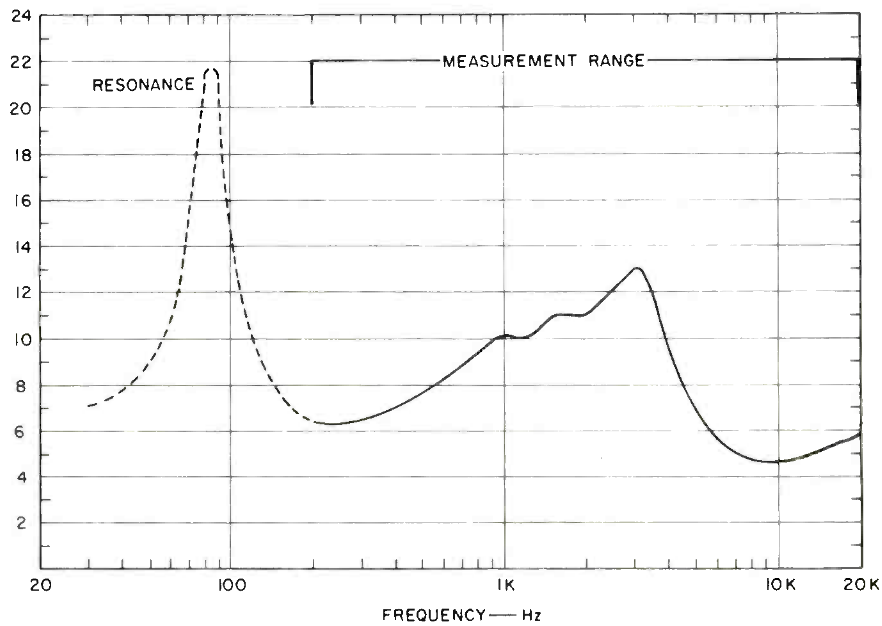


Fig. 1 — Test set-up.

Fig. 2 — Impedance vs. frequency plot for a typical speaker.



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Influence of Listening Rooms On Loudspeaker Systems

Roy F. Allison
President,
Allison Acoustics, Inc.
Natick, Mass. 01760

The work of Thiele and Small in recent years has changed the procedure by which loudspeaker systems are designed. They did not extend the inherent limits of performance of low-frequency loudspeakers, but they did define those limits. They quantified the interrelationships among cabinet size, system efficiency, and low-frequency response range, and they developed systematic synthesis techniques which enormously simplified design procedure.

It is certainly true that this has resulted in an improvement in the average quality of loudspeaker systems, because it is now easier for manufacturers to optimize their designs. Indeed, several manufacturers emphasize in advertisements that their products have been designed by computers programmed with the Thiele/Small synthesis formulas.

Unfortunately, consumers can enjoy the benefits of this improvement only to a very limited degree. It is traditional to design loudspeakers for flat frequency response in an anechoic test chamber. The Thiele/Small design formulas assume that kind of reflection-free environment. But people do not use loudspeakers in anechoic chambers; they use them in domestic living rooms. Normal rooms react on loudspeakers in the bass range, and this can change their power output significantly.

We can understand why this is so if we look at the formula for reference sound pressure from a loudspeaker at low frequencies. This is derived by Beranek [1] as follows:

$$|U_c| = \frac{e_g Bl}{S_D(R_g + R_E)\sqrt{R_A^2 + [\omega M_A - (1/\omega C_A)]^2}} \quad (1)$$

where $|U_c|$ = volume velocity of diaphragm; e_g = open-circuit amplifier voltage; B = magnetic flux density in air gap; l = length of voice-coil wire in air gap; S_D = area of the diaphragm; R_g = output impedance (resistive component) of the amplifier; R_E = voice-coil wire resistance; R_A = sum of electrical, mechanical, and acoustic resistive elements; $\omega = 2\pi f$ = radian frequency; M_A = sum of the acoustic masses, including diaphragm and voice coil, and C_A = total acoustic compliance of suspension and box. All elements are transformed to acoustic impedances and expressed in mks units.

Above the resonance frequency but within the piston band, and on the reasonable assumption that R_A^2 is small relative to $\omega^2 M_A^2$, (1) can be simplified to

$$|U_c|_c = \frac{e_g Bl}{(R_g + R_E)\omega M_A S_D} \quad (2)$$

and this is called the *reference* volume velocity.

Also, a loudspeaker system in this frequency region is a small source, that is, its radiation is essentially omnidirectional. For such a source the sound pressure is related to the volume velocity by

$$|p| \doteq \frac{f \rho_0 |U_c|}{2r}, \quad (3)$$

where $|p|$ = sound pressure at a distance r from the loudspeaker, f = frequency in Hertz, and ρ_0 = density of air. If we combine (2) and (3), we obtain the formula for reference sound pressure:

$$|p|_c = \frac{e_g Bl \rho_0}{(R_g + R_E) M_A 4\pi r S_D} \quad (4)$$

Most of the terms in this formula do not change with the loudspeaker system's environment, but two of them do change. One is the numerical factor, 4π, in the denominator. This denotes the solid angle (the three-dimensional space) into which the woofer radiates sound energy. The solid angle is measured in steradians; 4π steradians represents full space, which is the radiation angle that would be seen by the woofer if the system were suspended in mid-air high above the ground. Because low-frequency sound is radiated omnidirectionally, the woofer in such an environment would propagate sound equally in all directions and the sound energy would continue outward without encountering any nearby reflecting boundaries. An anechoic chamber simulates such an environment.

Now if the loudspeaker system were to be mounted in the middle of a very large wall, so that the woofer diaphragm were flush with the surface of this boundary, the radiation angle would be halved. The woofer would be operating in a half-space environment, a solid angle of 2π steradians. The radiation formula tells us that the reference sound pressure will be doubled, and experiment shows this to be true. We do find a 6-dB increase. An increase of 3 dB is obtained because we have confined all the radiated power to half the space it occupied before. This 3 dB is of no importance because it involves no change in power output. But a second increase of 3 dB is the result of an actual doubling of power radiated by the woofer. It is twice as efficient in 2π space as it is in 4π space.

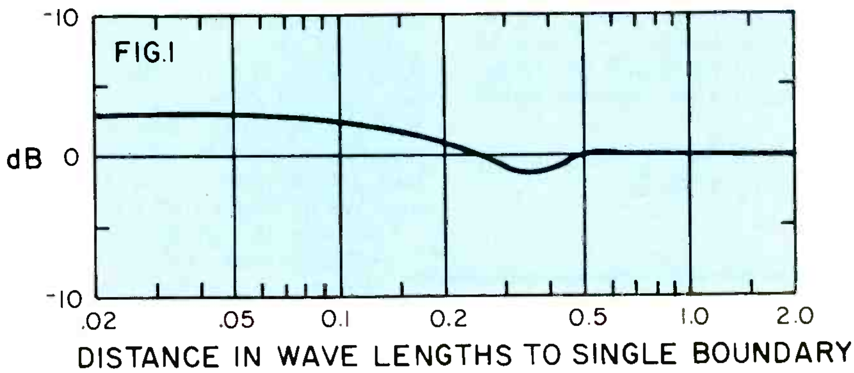
Let us further suppose that we are able to position the woofer at the intersection of two mutually perpendicular walls. Again the radiation angle is halved, this time to π steradians; again the power output of the woofer is doubled. Still another reduction in radiation angle, to $\pi/2$ steradians, is often found in real living rooms when a loudspeaker system is placed in a corner with the woofer close to the floor. Its power output is increased another 3 dB at low frequencies, for a total increase of 9 dB above the power radiated into full space.

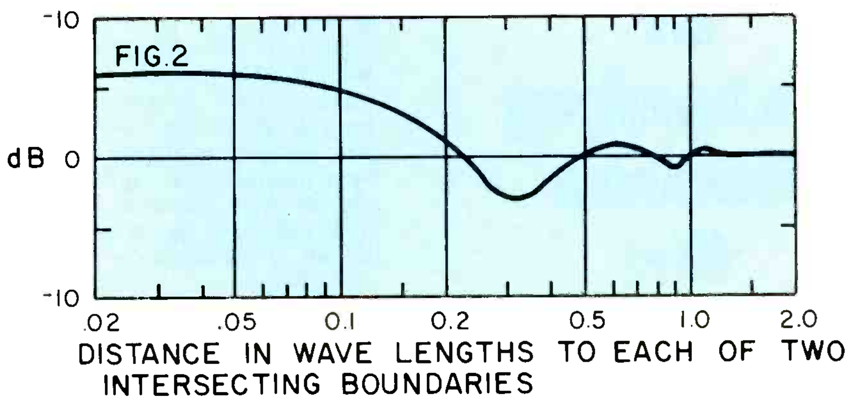
It should be emphasized that these theoretical increases in radiated power with decreasing radiation angle are obtained *only* when the driver is close to the boundaries. In an acoustical sense, drivers are never "close" to room surfaces at frequencies above 500 Hz or so. Therefore, real rooms — by changing a loudspeaker system's power output in one frequency region only, in an amount determined by where the user places the cabinet in the room — completely alter the original balance of the system as it was in the anechoic chamber. And because such room effects cannot be avoided, it follows that loudspeaker systems designed for flat response in anechoic chambers cannot produce a flat power response in real rooms.

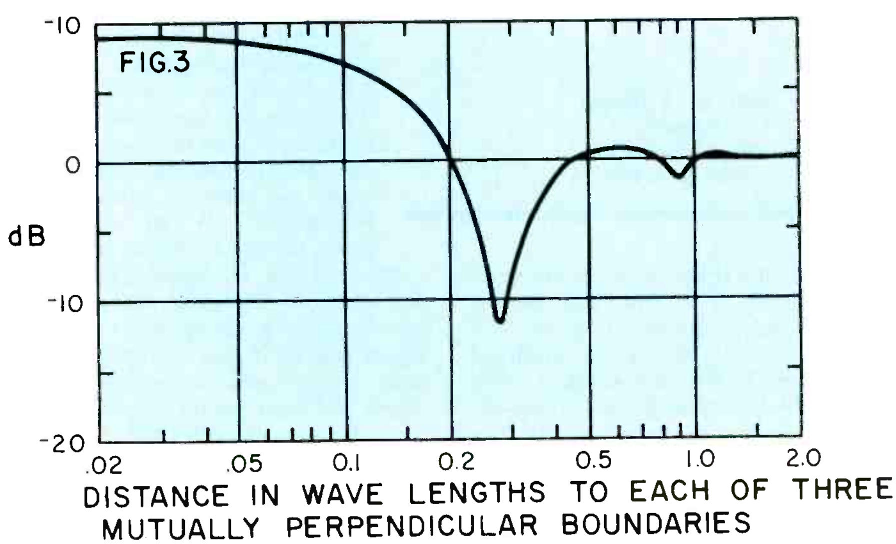
We have said that a driver must be close to a room boundary in order to be affected by it. A discussion of what "close" means brings us to the other term in our formula which changes when the loudspeaker system is brought out of the anechoic chamber and into the listening room. That term is ρ_0, the air density.

Of course, the *average* density varies only in accordance with changes in barometric pressure. But instantaneous density is proportional to instantaneous pressure, and sound itself is the result of variations in air pressure which occur at an audible rate. In the anechoic chamber, a loudspeaker driver creates audio-frequency changes in pressure which travel to the chamber walls and are absorbed there. In a living room, conversely, sound energy reaching the walls is reflected back to the driver where it either adds to or subtracts from the instantaneous pressure on the driver diaphragm, depending on the phase relationships. If a boundary is "close," the reflected pressure is strong enough to change the instantaneous pressure at the diaphragm surface significantly and to increase or decrease the acoustic power radiated.

Figs. 1-3 — Power output of small acoustic source close to one, two, and three boundaries relative to power output in 4π space.







Closeness of a driver to a boundary is dependent not on the absolute distance between them, but upon the distance in units of wave length. Therefore, a driver may be acoustically close to a boundary at low frequencies, for which sound waves are long, and not close at higher frequencies which have shorter wave lengths.

This relationship is quantified in Figs. 1 through 3. The power output of a direct-radiator driver in its nondirective frequency range is shown (relative to its output in an anechoic chamber) when it is put near a single boundary (Fig. 1); when it is equidistant from two boundaries intersecting at a right angle (Fig. 2), and when it is equidistant from three mutually perpendicular boundaries (Fig. 3). In each case the horizontal scale is in fractional parts of a wave length.

We can learn much from a careful examination of these curves. For example, it is obvious that the augmentations of power output predicted for reductions in radiation angle (+3, +6, and +9 dB for 2π, π, and π/2 steradians, respectively) are obtained only when the woofer is placed a small fraction of a wave length from the boundaries. At a distance of 1/10 wave length, the three-boundary augmentation has already decreased from 9 dB to 7 dB. A typical distance of the woofer from the three nearest walls in a real living room might be 50 cm, and 50 cm is 1/10 wave length at 69 Hz. At higher frequencies, the augmentation decreases rapidly, because 50 cm becomes a larger fraction of a wave length as frequency increases.

Eventually, as we continue to increase the frequency of the sound signal, the reflected pressure from the nearby walls no longer arrives back at the woofer diaphragm in phase with the driving signal, and at that frequency or above it the driver is no more

Inside, most speakers look pretty much the same. Drivers, baffle board and enclosure. Which is why some manufacturers make so much noise when they come up with anything new.

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2. Cross-over coil positioning. We found that two coils next to each other on a crossover network can cause signal leakage from the midrange to the woofer. By isolating the coils away from each other, we eliminated cross-talk and muddy midrange.

3. Thermal/shock cone construction. We manufacture our own wood-pulp cones by applying our exclusive heat/shock treatment. This creates a cone that is more rigid than the usual pressed type for low distortion, yet light enough to deliver much better efficiency.

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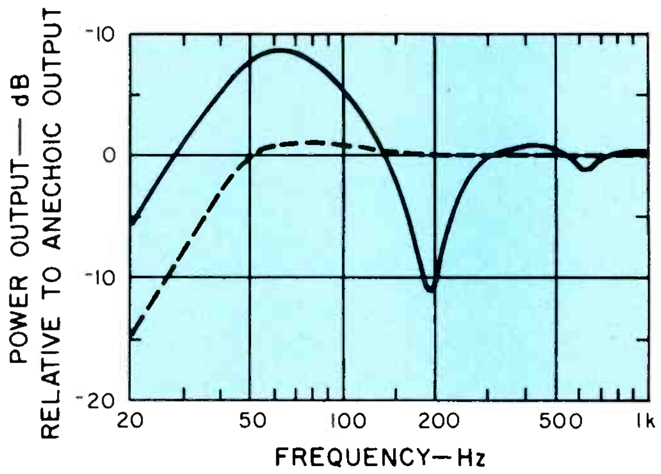

Fig. 4 — Output of a typical high-quality loudspeaker system in anechoic test chamber (dashed line), and power output of same system with woofer 50 cm from three mutually perpendicular room surfaces (solid line).

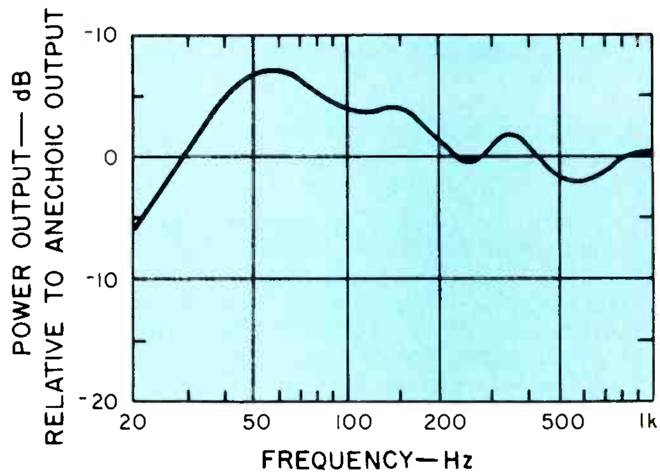

Fig. 5 — Power output of same system as Fig. 4, but with woofer located 20 cm above floor, 51 cm from one wall, and 122 cm from other nearest wall.

efficient than it is in full 4π steradian space. This limiting frequency is that for which the distance to the walls is 1/4 to 1/5 wave length, depending on the number of boundaries involved. In our hypothetical example, with a woofer located 50 cm from each surface in a three-boundary intersection, that frequency is approximately 140 Hz.

At still higher frequencies (200 Hz in our example) the woofer is about 3/10 wave length from the walls. Then the reflected pressure is in opposite phase with the motion of the diaphragm. As the woofer attempts to create a compression, the reflections cause a rarefaction, and vice versa. The woofer believes that it is working in a partial vacuum; its power output is correspondingly reduced. But the amount of power reduction is not in neat alignment with the number of reflecting boundaries. As Fig. 1 shows, an out-of-phase reflection from one boundary has a minimal effect, with only 1-dB reduction at the worst frequency. Equidistant reflections from two boundaries are considerably more effective, causing a 3-dB drop below full-space output in the critical frequency band. But reflections from three equidistant boundaries cause a deep reduction, more than 11 dB, below reference level. The total variation (including the 9-dB boost at very low frequencies) is about 20 dB from a speaker system that measured flat in an anechoic chamber! Figure 4 shows the power output vs. frequency for such a system, assuming a system resonance frequency of 50 Hz with a Q of 1 and 50-cm distance to each of three room surfaces.

The curves also show that, beyond 5/10 wave length distance, the boundaries have insignificant effect on loudspeaker performance. In our example, a 50-cm distance is 5/10 wave length at 345 Hz.

Figures 1 through 3 make it apparent that the effect of multiple out-of-phase reflections is more than simply additive. It follows that one should attempt to place the woofer of a conventional speaker system so that its distances to nearby room surfaces are as different as possible, and thereby place the out-of-phase reflections at widely different frequencies. When this can be done, it is very helpful in smoothing the system's low-frequency output. Power output vs. frequency is shown in Fig. 5 for our reference system when the woofer is placed 20 cm above the floor, 51 cm from one wall, and 122 cm from the other nearest wall.

Another way to deal with the effects of room boundaries is to place the woofer far away from them all. If there is at least 1.25 meters from the woofer to the nearest room boundary, all the major effects of the boundaries will occur well below 100 Hz, where they will be less audible than they are normally. Of course, this would not be convenient in most living rooms.

Both of these stratagems are defensive maneuvers. They limit the damage but do not prevent it entirely. A frontal attack is preferable in this case. It consists of designing loudspeaker systems to work in conjunction with the room boundaries, taking full advantage of their ability to increase efficiency at low frequencies and also avoiding the out-of-phase reflection problem altogether. These are serveral ways in which this plan can be implemented, but all have these steps in common:

1. Decide whether the system is to be used in proximity with one, two, or three mutually perpendicular room surfaces. The balance must be set differently for each kind of system because, as we have seen, the woofer's efficiency changes with its radiation angle.

2. Design the cabinet to locate the woofer (or woofers) as close as possible to the room surfaces.

3. Set the crossover frequency so that the operating range of the woofer is limited to well below the "notch" frequency. Then the reflected pressure will always be in phase with, and will reinforce, the direct output of the woofer. The woofer's power output can then be flat. Note that in practice this requires a three-way or four-way loudspeaker system, because even with placement of the woofers very close to the boundaries a low crossover frequency (400 Hz or lower) must be used.

4. Finally, locate the mid-range driver in the cabinet far enough away from the boundary intersection so that it is at least one-half wave length distant at the crossover frequency and above. Then the output of the mid-range driver (and of the tweeter) can be made flat and unaffected by the room surfaces.

Some loudspeaker systems designed in accordance with these principles are now available. I feel certain that others will soon follow.

Reference

1. L. L. Beranek, *Acoustics* (McGraw-Hill, New York, 1954), chapter 8.

LUX PD-277

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Of course, the resulting player lacked an automatic tonearm lift, set-down or return. The stylus had to be manually—and very carefully—placed in the lead-in groove. And at the end of every disc, there was a mad rush to lift the arm as it ground its way round and round the run-out groove. But these inconveniences were the price many audiophiles were willing to pay for the quality they sought.

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All essential functions of the PD-277 are electronically controlled. For example, a separate motor operates the tonearm, instead of conventional noisy, drag-producing mechanical arrangement. And the end-of-record lift is triggered by a photo-electric sensing system. And, of course, the arm motor completely disengages when not in use.

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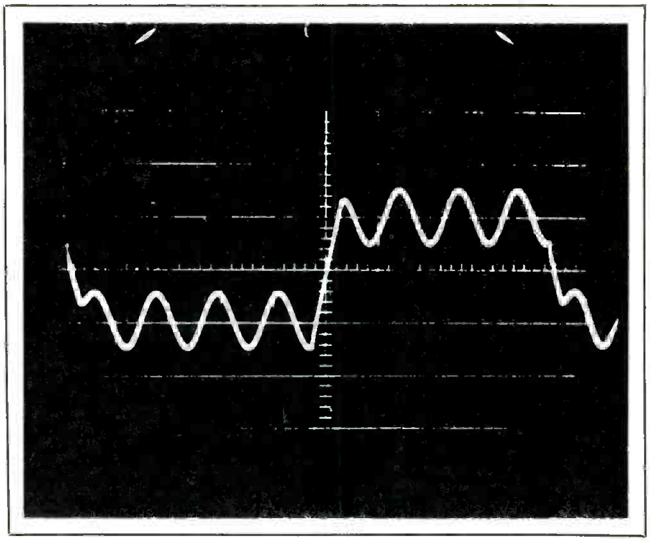
An Overview Of SID and TIM

Walter G. Jung, Mark L. Stephens, and Craig C. Todd

Part III — Analysis and Design of Amplifiers for Minimum SID



Calculation of Slew Induced Distortion

Thus far, little has been said in the literature about how to calculate slew induced or transient intermodulation distortion. This is, no doubt, due to the complexity of the problem, especially handling the frequency dependence of the amplifier stages and the incorporation of feedback. There is, however, a straightforward technique that can be used to find closed-form expressions for every possible harmonic or intermodulation distortion component. The technique involves forming a Volterra series to characterize the output as a function of some input variable [57]. The coefficients of the Volterra series can then be used to find the magnitude and phase of all distortion products. This technique has been widely used to predict distortion in radio frequency circuits with a high degree of accuracy.

Unfortunately, it takes more time and space to explain the technique itself than it does its application to a given problem. For this reason, we have not included a full analysis within the article and direct the interested reader to the reference cited. However, with appropriate assumptions and simplifications, many useful features of the Volterra series technique can be used to find approximate expressions for SID. These are conceptually easier to understand and are quite accurate for relatively small distortion conditions.

Consider a 741-type operational amplifier, which can be broken down into two basic stages, an input transconductance amplifier and an integrating amplifier. These are shown in Fig. 27. The transconductance stage is assumed to be the dominant nonlinearity and consists of a symmetrical saturating-type characteristic which is independent of frequency. The nonlinear characteristic (formed by a double differential pair) is modeled as a current source output Δi, for an input differential voltage ΔV, and can be represented by

$$\Delta i = I_K \tanh\left[\frac{\Delta V}{4V_T}\right] \qquad (21)$$

Portions of this article are adapted from "Slewing Induced Distortion in Audio Amplifiers" by the authors in *The Audio Amateur*, Feb., 1977 (P.O. Box 176, Peterborough, N.H. 03458), part of an article series which is available in book form. Portions were also adapted from the authors' article "Slewing Induced Distortion — Its Effect on Audio Amplifier Performance, with Correlated Listening Results," Audio Engineering Society Preprint No. 1252 from the May, 1977, convention. (See bibliography references nos. 33 and 34.)

where $V_T = KT/q$ or approximately 26 mV at 300° K and I_K = the bias current of the stage. The graph of equation (21) is shown in Fig. 28.

Equation 21 and Fig. 28 differ from equation 13 and Fig. 6b in our previous example of Part I, because the 741 input stage has a *pair* of transistors on each side. Equation (21) in its present form will not allow closed-form expressions for distortion. It must be expressed as a truncated power series with variable ΔV to complete the calculations, and this is shown in equation (22).

$$\tanh x = x - \frac{x^3}{3} + \dots + \dots \qquad (22)$$

Thus combining (21) and (22) we have

$$\Delta i = I_k \tanh\left[\frac{\Delta V}{4V_T}\right] \cong I_K\left[\left(\frac{\Delta V}{4V_T}\right) - \left(\frac{\Delta V}{4V_T}\right)^3\frac{1}{3} + \dots\right]. \qquad (23)$$

The first term in the power series is the desired linear component, and the cubic term (and other higher order terms) form undesirable distortion products. Distortion will eventually be calculated from (23) after making some additional necessary assumptions.

The second stage in the 741, the integrator, is assumed to be ideal and has a gain characteristic G(f) which is proportional to 1/f. This is expressed by

$$G(f) = K_2/f. \qquad (24)$$

There is a $\pi/2$ phase shift in (24) which has been neglected. The reason for this will become evident as the calculation progresses.

The constant K_2 is determined by the overall gain of the composite amplifier, which must be approximately unity at a frequency of 1 MHz to make our circuit model represent the performance of a real 741-type op amp.

The actual gain characteristic of a 741 op amp is summarized by the Bode plot in Fig. 29. For most audio-frequency calculations, it is convenient to neglect the low frequency pole at 10 Hz and to assume infinite d.c. gain and a constant, gain-bandwidth product. This has a negligible effect on calculations, since it will be shown that the distortion is determined by the available loop gain at high frequencies.

The open loop gain for this approximation is specified by

$$\text{open loop gain} = \frac{V_{out}}{\Delta V} = \frac{10^6}{f}. \qquad (25)$$

By combining equations (23), (24) and (25), the constant K_2 can be expressed in more familiar terms. At a frequency of 1 MHz we have:

$$Vout/\Delta V = 1 = \left[\begin{array}{l}\text{gain of}\\ \text{transconductance}\\ \text{stage}\end{array}\right]\left[\begin{array}{l}\text{gain of}\\ \text{integrator}\end{array}\right]$$

$$1 = \frac{I_k}{4V_T}\left[\frac{K_2}{10^6}\right] \qquad (26)$$

$$K_2 = \frac{4V_T}{I_K} \times 10^6. \qquad (27)$$

$$\text{And thus } G(f) = \frac{4V_T \times 10^6}{I_K} \times \frac{1}{f}. \qquad (28)$$

The 741-type op amp that has been developed thus far is now placed in an inverting gain configuration with resistive feedback components. The feedback network is assumed to be linear and independent of frequency. The circuit used for distortion calculations is modeled in Fig. 30. In this circuit, a feedback factor ß can be specified as a function of R_1 and R_2

$$ß = R_1/(R_1+R_2). \qquad (29)$$

Since the closed loop gain G is equal to R_2/R_1, we have

$$ß = \frac{R_1}{(R_1+R_2)} = \frac{1}{(1+|G|)}. \qquad (30)$$

For inverting gains of 1, 10, and 100 the factor ß is 1/2, 1/11 and 1/101, respectively.

Additional assumptions that must be made to simplify calculations are:

1) Small distortion conditions exist (<1%). This enables a power series expansion of the transconductance nonlinearity.

2) The distortion consists of only odd-order products because of symmetry, and, because of 1), the distortion is dominated by third-order terms.

3) The distortion is reduced by the magnitude of the factor (1 + loop gain), at the frequency of the distortion product. It is further assumed that loop gain is much greater than 1, so that distortion is reduced by approximately the magnitude of the loop gain. Any phase shift in the loop gain can therefore be neglected.

A harmonic distortion analysis will be developed here to compare with measured data, although an intermodulation analysis could also have been pursued. The final result will solve for harmonic distortion (which is dominated by the third harmonic) as a function of output voltage level, frequency, and feedback factor (or closed loop gain).

The following method will be used to solve for harmonic distortion. First, an output level V_o and frequency f will be specified. Then using (25), ΔV will be calculated and used in (23) to find open-loop distortion. Finally the loop gain will be computed and used to predict the closed-loop distortion.

For a sinusoidal output voltage of $V_o \cos 2\pi ft$, we can compute ΔV from (25)

$$\Delta V = \frac{[Vo \cos(2\pi f)t]}{(10^6/f)} \qquad (31)$$

If this ΔV is substituted into (23) and simplified, the resulting equation will show an open-loop distortion ratio of:

$$\frac{\text{magnitude of 3rd harmonic}}{\text{magnitude of fundamental}} = \frac{\left(\frac{\Delta V}{4V_T}\right)^2}{12} =$$

$$\begin{array}{l}\text{Distortion}\\ \text{(open loop)}\end{array} = 1/12\left(\frac{Vo\,f}{4V_T \times 10^6}\right)^2 \qquad (32)$$

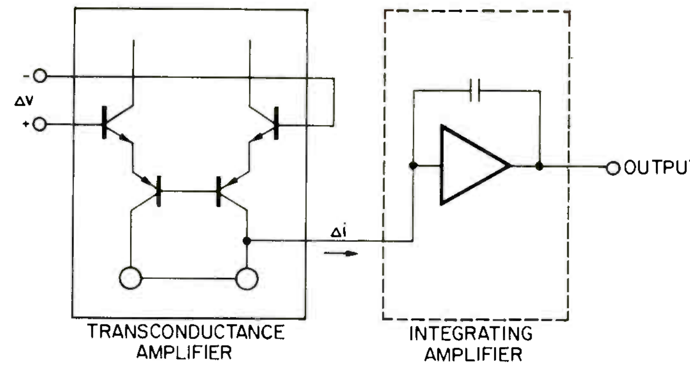


Fig. 27 — Two-stage model of an op amp.

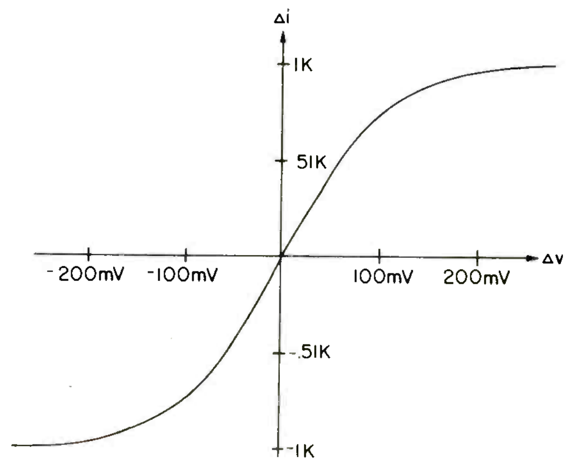


Fig. 28 — Transfer characteristics of a transconductance amplifier.

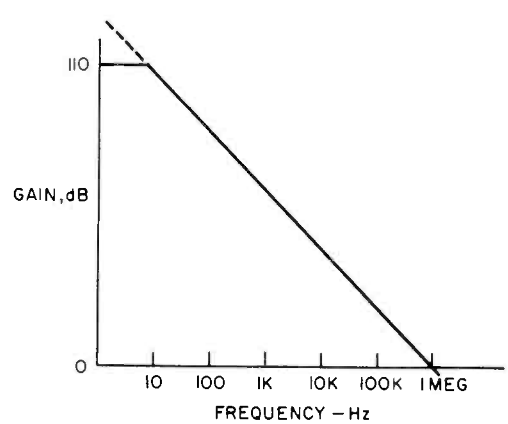


Fig. 29 — Gain-frequency characteristics for a 741 op amp.

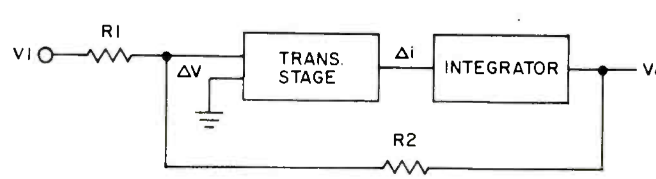


Fig. 30 — Model amplifier with feedback applied.

The open-loop distortion is reduced by the loop gain at the third harmonic frequency, 3f, and by the integrator frequency response which attenuates the third harmonic by a factor of 3. The loop gain at frequency 3f is

$$\text{loop gain} = \left(\frac{I_K}{4V_T}\right) \times \left(\frac{4V_T \times 10^6}{I_K\, 3f}\right) \times ß = \frac{10^6}{3f}\, ß. \qquad (33)$$

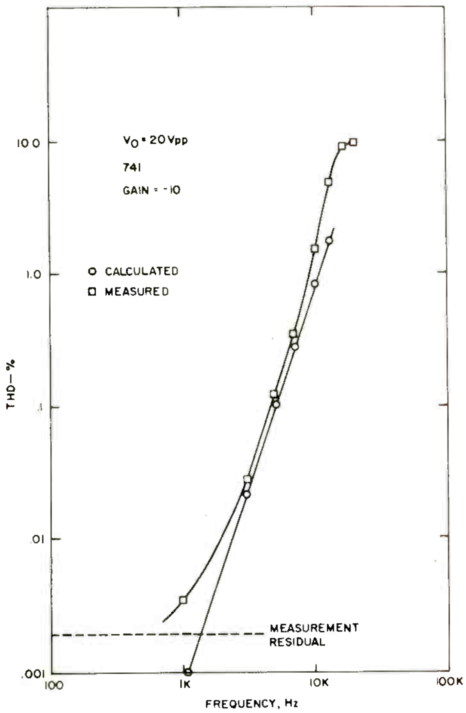


Fig. 31 — Calculated and measured distortion vs. frequency for a 741 at a gain of -1.

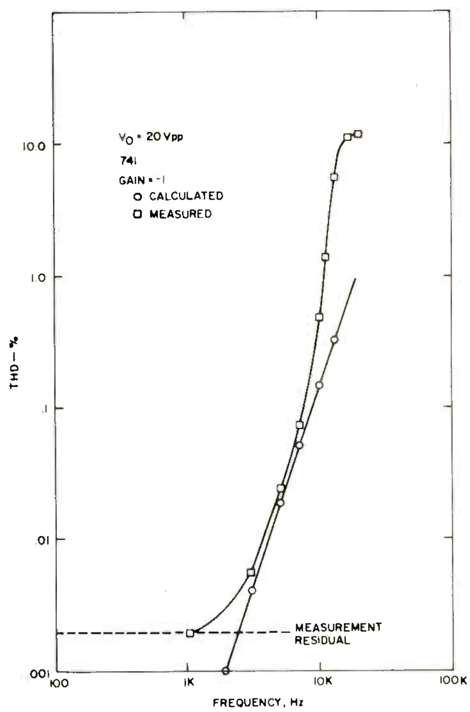


Fig. 32 — Calculated and measured distortion vs. frequency for a 741 at a gain of -10.

Therefore the closed loop distortion is

$$\begin{array}{c}\text{distortion} \\ \text{(closed loop)}\end{array} = \frac{\text{distortion (open loop)}}{\text{loop gain}} =$$

$$= \frac{1}{3}\left[\frac{\frac{1}{12}\left(\frac{V_o f}{4V_T \times 10^6}\right)^2}{\left(\frac{10^6 ß}{3f}\right)}\right] \qquad (34)$$

$$\text{THD(3rd)} = \frac{V_o^2 f^3}{12(4V_T)^2 ß \times 10^{18}} = \frac{V_o^2 f^3}{1.29 \times 10^{17} ß}. \qquad (35)$$

Equation (35) shows that harmonic distortion should vary directly with the cube of the input frequency, directly with the square of output voltage, and inversely with the feedback factor, ß. In order to test the accuracy of this equation, calculated data for distortion was compared directly with measured THD data from a 741 amplifier. Figures 31, 32 and 33 compare calculated and measured distortion for a constant-amplitude, swept-frequency test condition for three values of feedback factor, ß. Figure 34 compares calculated and measured distortion for a constant-frequency, swept-amplitude test condition, also for three values of feedback factor. The agreement is generally good and is excellent for the swept frequency tests. At lower distortion levels, the agreement deteriorates due to the noise floor of the distortion analyzer.

At higher distortion levels, the agreement deteriorates due to large distortion conditions, that is, the fundamental assumptions in developing the calculation are violated. The anomalous behavior of the G = 100 test results is due to the loop gain falling below unity at 10 kHz, which also violates a basic assumption of the calculation. Figure 34 indicates an additional crossover type of distortion that dominates at low signal levels and masks the true distortion characteristics. It should be clear from all the figures that increasing feedback *reduces* distortion.

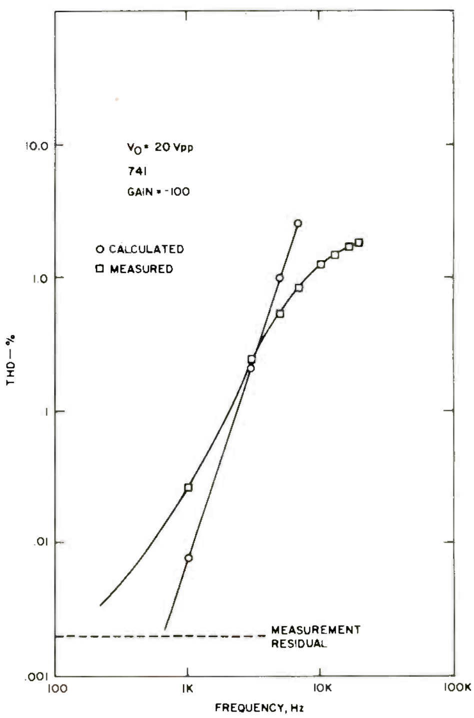


Fig. 33 — Calculated and measured distortion vs. frequency for a 741 at a gain of -100.

Equation (35) was developed specifically for the 741 op amp, which has a unity gain frequency (f_T) equal to approximately 1 MHz and a differential input stage consisting of four bipolar devices. A more generalized equation can also be developed which allows f_T to be a variable and which permits the number of input devices (n) to vary. This equation is

$$HD\ (3rd) = \frac{Vo^2}{12[n \cdot V_T]^2 ß} \left[\frac{f}{f_T}\right]^3 \quad (36)$$

where n = number of bipolar devices (2, 4, 6, . . .), V_T = KT/q = 26 mV at 300° K, ß = feedback factor, f_T = unity-gain frequency, Vo = output voltage, and f = frequency of fundamental.

Equation (36) reveals some characteristics of SID which were not evident from equation (35). First, it can be seen that increasing n reduces the distortion. This is due to a reduction in the curvature of the input transconductance curve (i.e. less change in g_m for the same current change) as n increases. Unfortunately, practical limitations usually require n to be 2 or 4 at most, so increasing n has a limited usefulness in reducing SID. Second, equation (36) shows the strong effect of the unity gain frequency on SID. Increasing f_T by a factor of 3 results in a distortion reduction of almost 30 dB! Clearly, f_T is a highly important parameter in improving SID. However, it is important to make the close connection between f_T and the SR limit. As pointed out by Solomon [21, 24] and others, for the 741-type circuit topology with bipolar input devices, f_T is proportional to the SR limit. This relationship is shown below

$$SR = 2\pi f_T (4V_T). \quad (37)$$

Therefore, improving f_T produces a proportionate improvement in the SR limit, which reduces SID.

Results of SID Calculation And Comparison with Measurements

The demonstrated accuracy of (35) and the generalized form in (36) in predicting harmonic distortion in a 741 amplifier leads to some useful conclusions concerning slew induced distortion.

1) It means that slew induced distortion can be modeled and calculated with closed-form expressions, based on Volterra series principles.

2) It shows that slew induced distortion is increased by the input signal slope (SS) and the sharpness of the transconductance curve. It also shows that SID is decreased by more feedback and by a higher gain-bandwidth product.

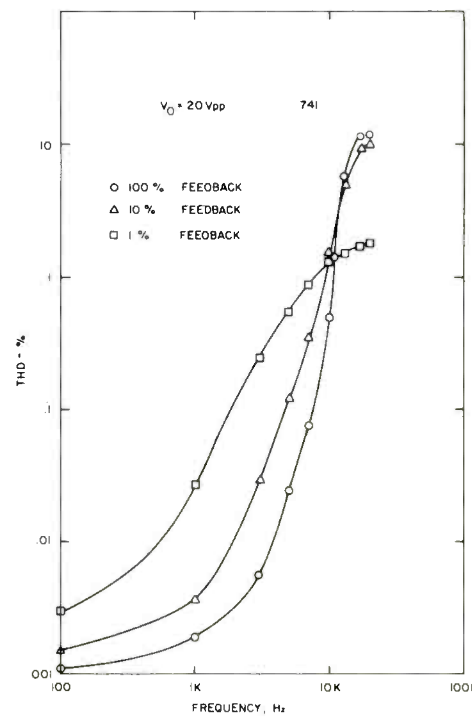


Fig. 35 — Distortion vs. frequency for a 741 at various feedback conditions.

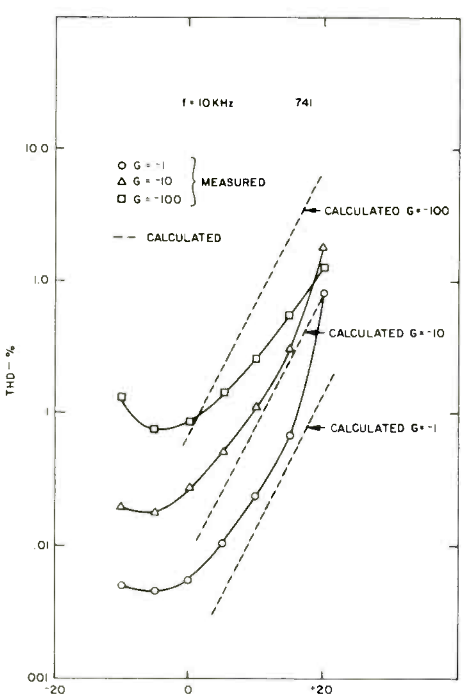


Fig. 34 — Distortion vs. output level for a 741 at various gain levels.

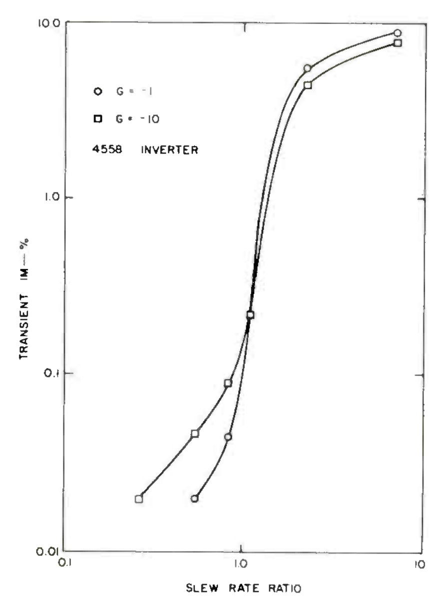


Fig. 36 — Transient intermodulation distortion vs. slew rate ratio for a 4558, operated inverting at two gain levels.

Stan Getz listened to us.

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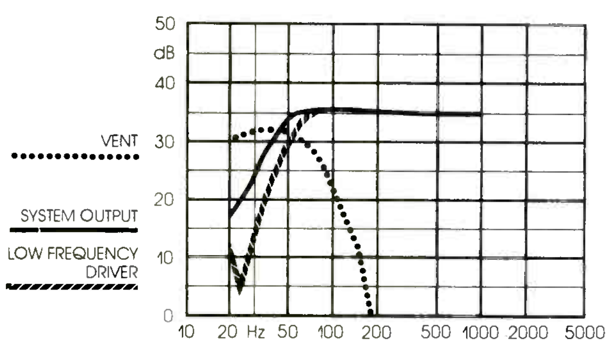

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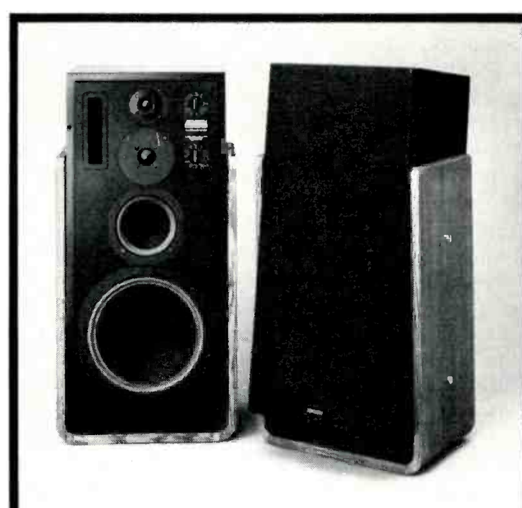

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3) It demonstrates that since the slope of a constant amplitude sine wave is proportional to its frequency, that SID (or DIM, as in the sine-square test) should vary as the *cube* of the input SS. This is confirmed by the data in Figs. 20 and 24 that show the variation of DIM with SS is a cubic relationship.

4) It shows that increasing a device's slew capability, without adding additional nonlinearities (like slew enhancement), will reduce slew induced distortion.

The Effect of Feedback for SS>SR

Present TIM theory suggests that feedback increases distortion. Our measurements and calculations show that, at least for signal conditions *below* the slew rate limit (SR ratio <1), that feedback reduces distortion. The overall effect of feedback on distortion (for a constant slew rate capability) is shown by our data to depend on whether the SS is less than or greater than the SR limit. For SS<SR, increasing feedback reduces distortion. For SS>SR, increasing feedback increases distortion. There is a crossover point around SS=SR where feedback has a minor effect on distortion. These trends are evident in the THD plot of Fig. 35 and the sine-square (TIM) plot of Fig. 36. It should be remembered, however, that for distortion-free performance the SS must be less than the SR, and if this criterion is met, feedback can generally be relied on for distortion reduction. Operating an amplifier with the SS>SR is simply not a realistic consideration for high-fidelity reproduction. Some discussion and experiments of the next section will clarify these points further.

Designing for Minimal SID or TIM

We have now reached a point where the factors which govern the behavior of the SID mechanism have been discussed in principle. However, the discussion thus far has been largely focused on behavior as viewed from outside an amplifier or how to characterize it in terms of SID.

Perhaps more important is how to design an amplifier from the ground up for minimum susceptibility to SID or TIM. This section focuses on these aspects of the situation and develops techniques which can be used to predictably model circuit performance.

We will begin the discussion by returning to a two-stage amplifier model, shown in Fig. 37, which is similar in many regards to Fig. 5a of Part I or to Fig. 27 above. This two-stage circuit will now be used to develop a general topology which can be used to model amplifier performance and also dramatically illustrate the TIM and SID phenomenon.

A circuit topology similar to Fig. 37 was described 10 years ago in a classic paper by Solomon [24] et al. This paper contained a number of defining behavioral relations, which are not only historically important, but are also applicable to amplifiers of this type in general [47, 64].

A basic point which should be appreciated with regard to this two-stage amplifier is that one can actually design it to yield a given overall gain-bandwidth for an *infinite* set of combinations of stage 1 and stage 2 gains. The key question is, does it matter whether stage 1 or stage 2 furnishes the bulk of the gain? For herein lies the answer to the entire TIM and SID problem. In other words, how should the gain be partitioned between the two stages for best overall performance? Before we plunge into the equations which govern this, perhaps some discussion would be helpful towards insight.

We have already established by (14) that the SR which will be seen at Vo is set by I_K and C1. However, we also know that to increase SR we cannot just arbitrarily increase I_K or decrease C1, because of stability reasons. We must also decrease g_m simultaneously with either of these measures to maintain stability. In general, a lower g_m implies less gain in stage 1, i.e. the stage can accept greater input error signals ΔV before the saturation which results in TIM and/or SID is reached. Thus, it can be said that *to maximize SR in a given bandwidth, the stage preceding the integrator of a two-stage amplifier design such as this must have a low g_m and high I_K.*

Solomon expressed this as a *low* g_m/I_k ratio in [24] and [21], and it has also been expressed as a *high* I_k/g_m ratio by Gray and Meyer in [22]. The latter form allows an expression to be written which directly describes the amplifier's maximum input-voltage capability or dynamic range. This is the voltage which, when exceeded, will result in slewing. It is simply

$$Vth = \frac{I_K}{g_m}. \qquad (38)$$

Others have termed this the input-voltage dynamic range [50]; however, the meaning is similar.

A greater application for how these relationships function may be obtained by examining two representative IC amplifiers with dissimilar Vth's. These types are used as examples because they are externally compensated and readily available. This allows convenient experimental duplication. A 301A amplifier (or 741, as noted above) has a g_m of

$$g_m = \frac{I_K}{4V_T}. \qquad (39)$$

This equation can be expressed in terms of I_K/g_m or Vth, as

$$V_{th(301A)} = \frac{I_K}{g_m} = 4V_T. \qquad (40)$$

Since V_T = 26 mV at room temperature, a useful approximation of (40) is

$$V_{th(301A)} \cong 0.104\ V. \qquad (41)$$

Thus, a peak input voltage of 104 mV to a 301A (or 741) will cause it to slew.

To turn to another amplifier type, a representative FET input device is the TL070 (or TL080) which has a g_m of approximately

$$g_{m(070)} \cong 1.5\ I_K. \qquad (42)$$

If this relation is expressed in terms of Vth, it becomes

$$V_{th(070)} = \frac{I_k}{g_m} = 0.67\ V. \qquad (43)$$

As can be noted by comparison of (41) and (43), the TL070 FET achieves a Vth more than six times that of the 301A bipolar for similar conditions, This, for a comparable bandwidth, produces a higher SR. For example, for a 1 MHz bandwidth condition, the TL070 has a 4.3 V/ μS SR (Cc = 47 pF), while the 301A is only 0.67 V/ μS (Cc = 30 pF) [31].

For the amplifier model under discussion, a relationship can also be drawn between Vth, SR, and gain-bandwidth product (GBP) similar to that expressed in [24]. We use the more general GBP, rather than f_T, since GBP can often exceed f_T. Also, f_T is usually taken to mean the unity-gain crossover frequency and implies unity-gain stability. This is not always a requisite. An expression for SR in these terms is

$$SR = \frac{(V_{th}\ 2\pi\ GBP)}{10^6} \qquad (44)$$

where SR is in V/ μS, Vth in volts, and GPB is the gain-bandwidth product (Hz) *at audio frequencies.* (The relevance of this equation to the subject of TIM and SID is fundamental. Although first described by Solomon and others [24], the authors would like to document that this relationship's importance to *audio amplifier* performance has been previously noted in letters to the A.E.S. by R. Cordell of Bell Labs, 9/77, and B. Olsson of Xelex AB, 11/77 and 2/79.)

This relationship clearly demonstrates that SR is directly proportional to Vth and GBP for this model. However, the caution should be extended that it does not apply universally. Two particular exceptions are some feed-forward amplifiers and slew-enhanced circuits such as IC type 531. In the case of a feed-forward type, such as the 5534, Vth is not

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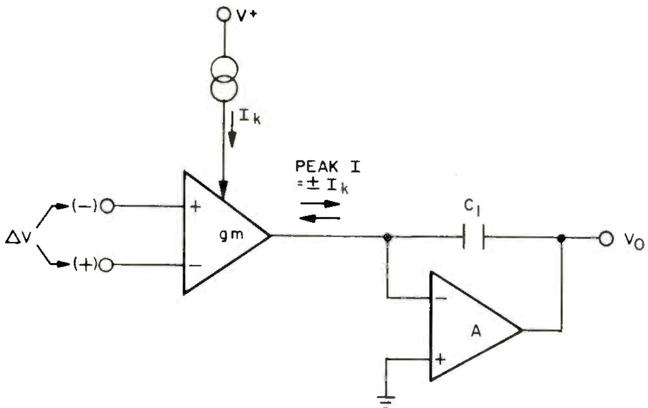
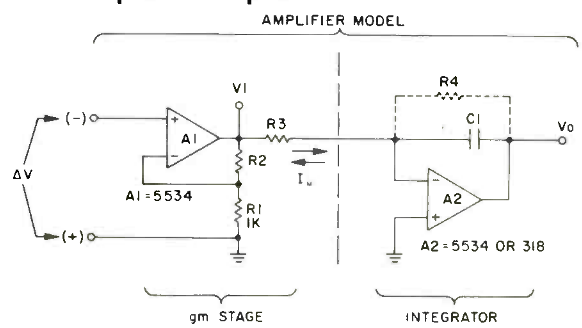


Fig. 37 — Two-stage transconductance-integrator model of a practical amplifier.



$$gm = \frac{\Delta I}{\Delta V} = \left(\frac{RI+R2}{RI}\right)\left(\frac{I}{R3}\right) \quad (45)$$

$$I_u = \frac{VI(max)}{R3} \quad (46)$$

$$Vth = \left(VI(max)\right)\left(\frac{RI}{RI+R2}\right) \quad (47)$$

$$SR = \frac{I_u}{CI} = \frac{VI(max)}{R3\ CI} \quad (48)$$

$$fp = \frac{SR}{2\pi\ Vop} = \left(\frac{VI(max)}{R3\ CI}\right)\left(\frac{I}{2\pi\ Vop}\right) \quad (49)$$

$$GBP = \frac{gm}{2\pi CI} \ (50) = \left(\frac{RI+R2}{RI}\right)\left(\frac{I}{R3}\right)\left(\frac{I}{2\pi CI}\right) \quad (51)$$

$$fo = \frac{I}{2\pi R4\ CI} \quad (52)$$

Fig. 38 — Synthesized two-stage amplifier model.

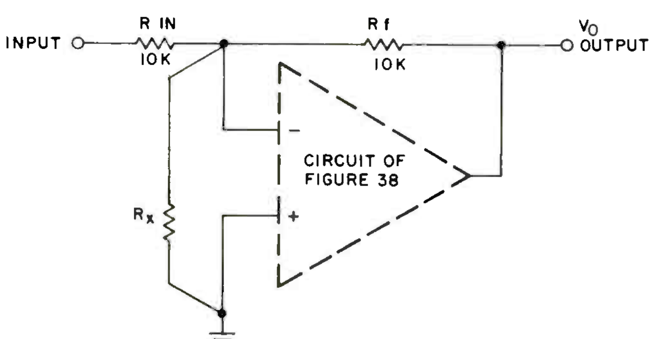


Fig. 39 — Test circuit for synthesized model.

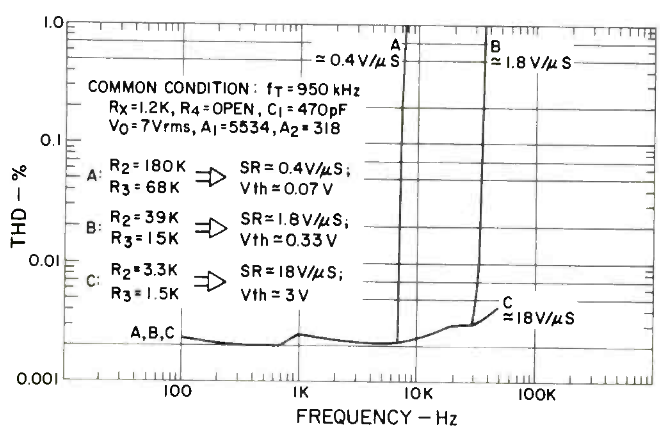


Fig. 40 — THD vs. frequency of the synthesized 741 op-amp model for various rate slew conditions (Test 1).

50

altogether a straightforward predictor of SR, as its Vth of 52mV and f_T = 10 MHz predicts only a 3 V/ μS SR. However, the GBP of this device is actually 22 MHz at audio frequencies — if this figure is used in (44), the SR predicted is 7 V/ μS, which agrees reasonably well. An important point is also that one must *not* be misled into the belief that slew-enhanced devices, which can show large voltages for Vth, lead directly to quality results. As has been shown previously, such amplifiers must be treated individually, as their dynamic input nonlinearities makes them special cases.

The relationship described by (44), while certainly an important one, can be erroneously misinterpreted. For example, it should not be interpreted to mean that *only* a very high Vth is fundamentally the route to high SR and thus low TIM. As (44) clearly shows, raising GBP (where allowable) achieves a similar result, and a practical example is the amplifier compensated for a higher noise gain (and thus GBP), such as the 301A of Fig. 11 (Part II). Such an example illustrates a *low* Vth device (the 301A) achieving a *high* SR. Another example is the 5534, a high GBP device, but with a very low Vth, only 52 mV! And, it should be noted, sufficient GBP must be present to result in a useful final closed-loop bandwidth.

The important thing to be remembered for this relationship is not totally Vth or GBP in absolute terms, but their *interrelationship,* which in many cases can be manipulated to achieve a high SR. The concept of a high Vth is, of course, most important when one is attempting to maximize SR *with a given GBP,* for as (44) shows, it is the only way it can be done with this type of circuit topology.

Experiments Which Demonstrate The Principle

A very cogent demonstration of the just described relationships can be made by synthesizing a two-stage amplifier model and subjecting it to various feedback and open-loop performance combination.

The circuit used for a series of these experiments is shown in Fig. 38 and is actually composed of two local-feedback IC op amps, which together comprise the model. A1 performs the function of a g_m input stage, converting the input voltage ΔV into a proportional current in R3. A2 performs the function of the integrator. Actual devices used for the experiments to be described were the 5534 for A1 and either a 5534 or 318 for A2. The devices used must, of course, have an inherent SR in excess of that which will be demanded by the model's operating conditions, as well as low distortion. These factors, combined with the local feedback, yield an amplifier with virtually ideal characteristics (even without overall feedback) as any nonlinearities are strongly suppressed.

A series of performance defining equations are included in the figure, and these can be manipulated with a great degree of freedom (another reason for using a model such as this, in fact). Some comment on these relations is in order before they are put to use, though.

Transconductance of the A1 stage is defined as

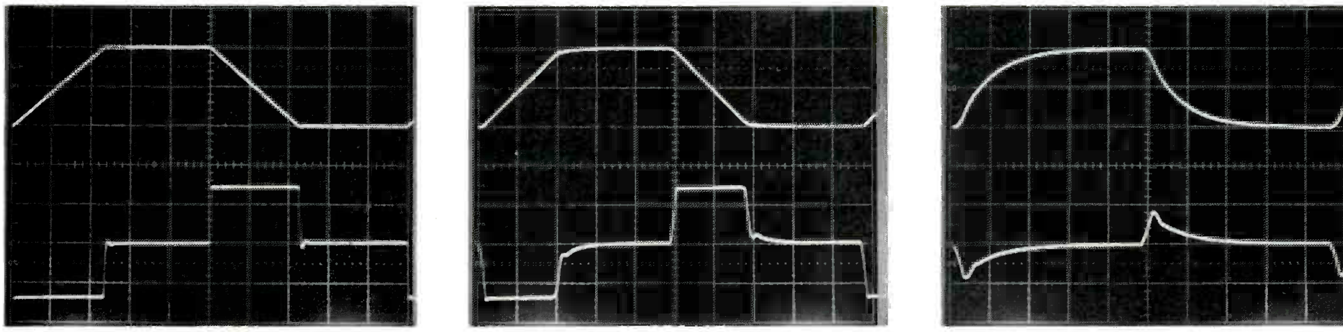
$$g_m = \left(\frac{R_1+R_2}{R_1}\right)\left(\frac{1}{R_3}\right) \quad (45)$$

Maximum output current, (I_m), is defined simply by the clipping voltage limit of A1, V1 (max) divided by R3, or

$$I_m = \frac{V_{1(max)}}{R_3}. \quad (46)$$

I_m, the peak output circuit, is analogous to I_K of Fig. 37, in that it sets the SR. It is slightly different in this case, due to more design freedom.

It is important to note that these two relationships are not exactly equivalent to those associated with Fig. 37. For example, the g_m of Fig. 38 can be set independent of I_m (if desired), and I_m can be set independent of g_m (if desired). This extra flexibility and the use of a voltage amplifier to produce V1



A B C

Fig. 41 — Transient performance of synthesized op-amp model with various slew rates to a 20-V p-p square wave of various frequencies. Top traces are outputs, bottom traces error voltages. A, SR = 0.4 V/ μS, 5 kHz; B, SR = 1.8 V/ μS, 20 kHz; C, SR = 18 V/ μS, 50 kHz. (Scales: All, 10 V/cm; A, 20 μS/cm; B,5 μS/cm; C, 2 μS/cm.)

yields a direct monitor of the conditions in the input stage. A standard g_m input stage does not allow voltage monitoring of error signals.

Because of the above, Vth in this circuit is simply

$$Vth = V_{1(max)} \frac{R_1}{R_1+R_2}. \quad (47)$$

As this expression shows, Vth is simply the output overload voltage of A1, divided by the gain set by R1-R2.

The remaining performance equations are simply derived from combinations of others; as the figure shows

$$SR = \frac{V_{1(max)}}{R_3C_1} \quad (48)$$

$$fp = \left(\frac{V_{1(max)}}{R_3C_1}\right) \left(\frac{1}{2\pi V_{op}}\right). \quad (49)$$

Gain bandwidth product (GBP) follows from (8)

$$GBP = \frac{g_m}{2\pi C_1}. \quad (50)$$

Substituting g_m as described by (45), this becomes

$$GBP = \left(\frac{R_1+R_2}{R_1}\right) \left(\frac{1}{R_3}\right) \left(\frac{1}{2\pi C_1}\right). \quad (51)$$

Open loop bandwidth (in the presence of R4) is

$$fo = \frac{1}{2\pi R_4C_1}. \quad (52)$$

Without R4, it is reasonable to regard A2 as a near-ideal integrator, in which case fo is well below the audio range for practical values of C1, and the gain-bandwidth product is constant throughout the audio range, as set by (51).

Test Results

The first test (Test 1) performed on the model was to synthesize a standard 741 op amp in terms of GBP and manipulate it for differing SR. The results should show very linear behavior up to fp, and a hard limit or sudden distortion rise as slew limiting is reached. Conditions were set up for a unity signal gain inverter, with a noise gain of 20 dB, using the test circuit of Fig. 39.

Figure 40 shows the results of Test 1 for a THD swept-frequency test, at an output of 7V rms. Conditions A, B, and C are approximately 0.4, 1.8, and 18 V/μ S respectively. The different circuit conditions to yield these SR are noted. As should be noted, since GBP and the feedback conditions are identical for all three of these tests, the only variables are SR and Vth.

As can be noted from the A and B curves, these conditions produce a sudden distortion increase when the SS of the test signal equals the amplifier SR. The high SR of condition C prevents the limit from being reached, for any test condition. Note that Vth increases, going from A to C, in the same proportion as SR.

For a case of transient signal condition, the photos of Fig. 41 show how this same amplifier behaves for the three conditions set down in Fig. 40, but with a different method of measurement.

Figure 41A shows waveforms for the "A" test condition (SR = 0.4 V/ μS) for a signal condition of a 5-kHz, 20-V p-p square-wave input. The top trace shows the Vo waveform, which clearly resembles a 741 – type response (31, 38), changing 20 V in over 40 μS. Inside the loop, the error voltage V1 is shown at the bottom. Here it is seen that V1 saturates negative, then positive, for the corresponding (+) and (-) slew intervals, respectively. It is clear from this photo that the slewing evident in Vo is a result of saturation in V1.

Figure 41B shows waveforms for the "B" test condition (SR = 1.8 V/ μS), with a 20-kHz, 20-V p-p square-wave input. At the top, the Vo waveform shows that slewing is present, as is evident by the linear (+) and (-) slopes. This is confirmed by the V1 waveform, which again indicates saturation of the 1st stage for these corresponding times. This is similar to Fig. 41A, but the difference is that for this higher SR condition, the slewing intervals are simply shorter (note scale factor differences — do not be misled by same *general* waveshape).

Figure 41C is very interesting, because it demonstrates that a sufficiently high SR and Vth can completely prevent saturation of the first stage and maintain operation within the small signal region entirely. Conditions of these photos are an SR of 18 V/ μS. However, the feedback conditions described above in conjunction with the 20-dB noise gain result in an amplifier closed-loop, small-signal bandwidth of 95 kHz. This in turn is equivalent to a single-pole, low-pass filter with a time constant of 1.7 μS. For a 20-V p-p output from this filter (the amplifier), the maximum signal slope is 12 V/ μS.

For Fig. 41C, the signal input is a 20-V p-p 50-kHz square wave, and it can be noted that there is no slewing evident in Vo. The waveform is exponential in shape with a risetime of about 4 μS — consistent with the small signal relationships.

That slewing is not present is also confirmed by V1, which shows that the error voltage remains below the clipping level. Note that the highest amplitudes of V1 occur at the peak SS of Vo or at the transition points of the square wave.

This particular test confirms in another way the point made in Part I of this series, that slewing can be prevented by maintaining the amplifier small-signal bandwidth at a lower frequency than the power bandwidth. In 41C, fc is 95 kHz, but fp is 290 kHz, and no slewing is evident.

With this same model, experiments were also conducted to examine the sensitivity of the amplifier to open-loop bandwidth (fo). Test two conditions were commonly set up as described in Fig. 42, which resulted in an SR of 1.3 V/ μS and an f_T of 540 kHz. For this test circuit with R4 present at

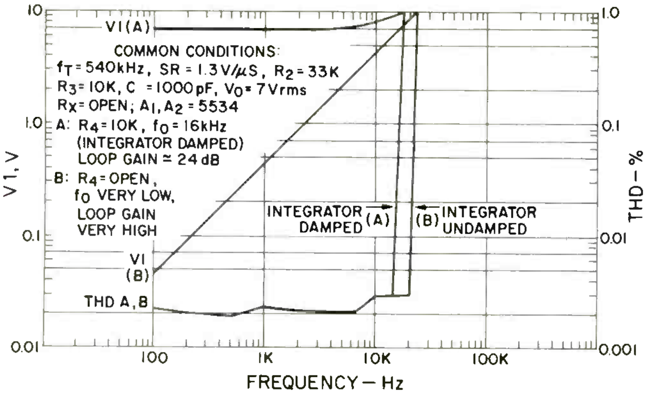


Fig. 42 — THD and error voltage vs. frequency of the synthesized 741 op amp model for different open-loop gain conditions (Test 2).

10K, fo becomes 16 kHz and the open-loop gain is 30 dB. With Rx open, the feedback is then 24 dB. With R4 open, the circuit becomes a classic op amp, with a very high open-loop gain and fo very low. Note, however, that *GBP remains unchanged for either condition.*

For condition A, where R4 is 10K, THD curve A indicates that slew limiting is reached at 18 kHz. V1 (A) is a plot of the rms error voltage versus frequency. Since it is essentially flat with frequency, it is testimonial to the wide open-loop bandwidth. Note that V1 increases to its clip level at 18 kHz, coincident with the slew rate limit point.

The B condition shows corresponding results with R4 removed, and the most obvious difference is the (apparent) increase in fp. Error voltage V1 (B) now increases 6 dB per octave with frequency, the inverse of the integrator's gain rolloff — what is necessary to maintain a flat output versus frequency for the overall circuit.

The *apparent* increase in SR for condition B is not an increase for this condition, but rather reflects a less than potential maximum SR *for the A condition*. This is so because the 10K resistor loading the integrator absorbs a portion of the charging current available to Cl for slewing.

These points are also brought out in the square-wave photos of Fig. 43. This shows response of the circuit of Fig. 42 to a 5-kHz, 20-V p-p square wave for conditions A and B.

For these test conditions, the transient performance is shown in Fig. 43. The slewing in Vo shown in 43A shows a quasi-linear ramp or a combination of ramp and exponential waveform caused by R4. Since R4 constrains the open-loop gain to a relatively low value, this is also reflected in the large error voltage shown in V1 (bottom).

The voltage V1 is clipped for the slew intervals (as expected) but also shows a very large potential (10 V) for the steady = state waveform positions. This excessive error voltage reflects a relatively large gain error for this circuit.

Figure 43B shows the Vo and V1 response for the same input drive but with R4 removed or condition B. Note that in 43B the slewing intervals are shorter and linear, as would be expected due to the constant and larger C1 charging current available. The error voltage shown in V1 is much lower in the steady-state periods, reflecting the increased gain available in the integrator. The low gain error is also reflected (more subtly) in the greater amplitude in Vo, compared to Fig. 43A.

This test indicates that, by both THD and transient response tests, there is no inherent advantage to a wide open-loop, small-signal bandwidth. By contrast, there are definite disadvantages to the constraint such operation can place on amplifier characteristics, such as limited LF loop gain and also some sacrifice in SR. And, while it is not apparent from this particular experiment, loading an integrator stage in a conventional amplifier will usually degrade the open-loop distortion characteristics.

Predicting A Non-Slew-Limited Response

We are now at a point where the information developed can be merged into a set of relationships useful in designing a *non-slew-limited* amplifier or an amplifier which is free of SID and TIM, by definition. This evolves in a fairly straightforward manner from the relations just discussed.

A non-slew-limited amplifier is simply one which *cannot* be made to slew for any signal input level below that which causes *amplitude* clipping. Input waveform shape is unrestricted and may include all waveshapes up to and including square waves. The square wave (as discussed in the sine-square box of Part II) is the most rigorous test to which an amplifier can be subjected because of its very high SS (infinite, for an ideal square wave). Therefore, if an amplifier can be proven to be free of slewing distortion for a square-wave test for all signal amplitudes in its linear range, it is by definition non-slew limited and will be largely free from SID or TIM problems.

All amplifiers will have by design a small-signal bandwidth, fc. This bandwidth will either be determined by the feedback configuration or an input pre-filter. The amplifier will then band limit a square-wave input signal to a bandwidth of fc. For simplicity at this point, we will assume this to be a single pole rolloff. For such a filter response it can be shown [33, 67, 70] that the signal slope of the resulting band—limited—output square wave is

$$SS_{(sq)} = \frac{2\pi Vppfc}{10^6} \qquad (53)$$

where Vpp is the peak-to-peak amplitude at the filter output, fc is the small-signal bandwidth, and SS is in V/µS.

That this signal slope is much higher than a sine wave at fc (passed through the same filter) can be shown by the relation of the two slopes. A sine wave at fc will be down by 3 dB

A

B

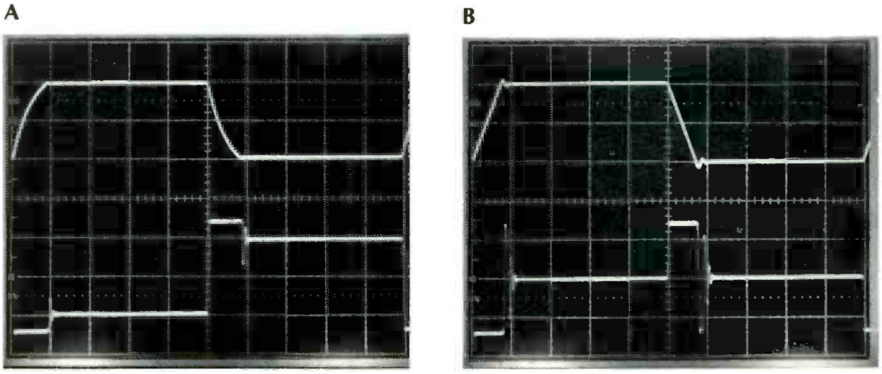


Fig. 43 — Transient performance of synthesized op- amp model with different open-loop gains to a 20-V p-p, 5-kHz square wave. Top traces are outputs, bottom traces error voltages. A, R4 = 10k; B, R4 = open. (Scales: 10 V/cm, 20 µS/cm.)

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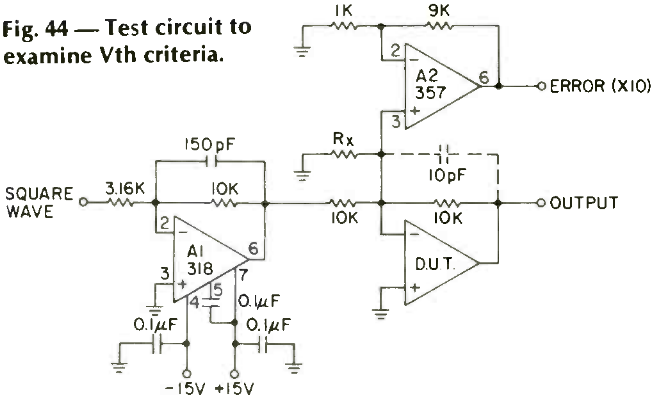
Fig. 44 — Test circuit to examine Vth criteria.



With simplification, we can express this in terms of Vth as

$$Vth \geq \frac{Vpp\,fc}{GBP} \qquad (58)$$

Equation (58) gives us an expression for a minimum Vth, but we can further simplify it by substituting (56), which yields

$$Vth \geq Vpp\beta. \qquad (59)$$

The rather simple appearance of this expression may hide its rather profound implications. Since Vppß is in fact equal to the peak-to-peak input voltage, this relationship states that Vth should be in excess of the maximum pp input amplitude. In other words, the input stage (alone) will not overload when driven with a full-scale input signal [47, 67].

That the criterion works can be illustrated with some data just presented. In test 1, condition C it was observed that the experimental amplifier did not slew limit when subjected to a full-amplitude square-wave input. For condition C, Vth was 3V and the SR was 18 V/ μS. If a minimum Vth is calculated from (59) for this amplifier, it is found to be 2V. Therefore condition C satisfies (59), since 3V>2V.

On the other hand, if condition B is examined, it will be noted that Vth is only 0.33 V, and slew limiting *did* occur (Fig. 41B). Here the criterion was violated; i.e., 0.33V< 2V.

Another example, more in the line of a real amplifier, was the variable-feedback amplifier from Part I, discussed in Figs. 3 and 4. If Figs. 4a, 4b and 4c are re-examined, it will be noted that slew limiting is evident in condition A and some in B. Condition C is a non-slew-limited case.

Since the gains in this case were 20, 40 and 60 dB, respectively, ß is correspondingly 0.1, 0.01, and 0.001. As the output level is 20 V p-p in all cases, it can be noted that conditions A and B violate the minimum Vth criterion, which says that Vpp should be less than the 301A's Vth of 0.104 V. In condition C, the criterion is satisfied, and no slew limiting is evident.

It may already have occurred to some readers that this criterion is a most restrictive one, as it dictates *very low feedback factors* to eliminate slew limiting *in the case of low Vth amplifier stages.* Inasmuch as all directly coupled, undegenerated bipolar-transistor differential-amplifier pairs have a Vth of 0.052, this can quite logically explain TIM and slew limiting possibilities in power amplifiers, where Vpp may be upwards of 70 V.

It is interesting to plug typical power amplifier numbers into the relationship of (59) to see what results. A 100 W-into-8-ohm amplifier with a gain of 20 (26 dB) has a Vpp of 80 V and a ß of 0.05, which results in a required Vth of 4 V . . . clearly many times in excess of the 0.052 V resulting when an undegenerated bipolar differential pair is used in the input stage.

As a historical comment, the vacuum tube, still favored by many, has a Vth on the order of 3 V, for a typically used type

in amplitude, which can be expressed by modifying equation (1) by multiplying it by $\sqrt{2}/2$, yielding

$$SS_{(sine)} = \frac{\sqrt{2}\pi Vpfc}{10^6}. \qquad (54)$$

Equations (53) and (54) can be combined to show their ratios as

$$SS_{(sq)} = 2\sqrt{2}\,SS_{(sine)}. \qquad (55)$$

Since this is nearly three times the signal slope of a sine wave at the frequency fc, it is clearly a more rigorous test. That it is the most rigorous test comes from the fact that the SS of the unfiltered square wave is infinite. It is clear then that an amplifier which passes a square-wave test without nonlinear distortion appearing in the output tends to be an optimum design. The question now arises, how can this be guaranteed?

We already know that to guarantee freedom from slew limiting we must, as a minimum, guarantee that the amplifier SR is in excess of the output SS for all possible signal conditions. For the non-slew-limited amplifier, this will encompass the signal slopes of square waves up to the rated output. We can set up a criterion to provide this with only a few parameters. Initially, let us consider a conventional feedback amplifier which follows the relationships discussed for Vth, SR, and GBP. By general feedback theory, we can express the bandwidth of this amplifier as

$$fc = GBP\ \beta \qquad (56)$$

where fc is the small signal bandwidth, GBP is its gain-bandwidth product, and ß the feedback factor. For this initial part of the discussion we will assume no other filtering, and the amplifier alone determines the bandwidth, as just outlined.

To guarantee no slew limiting, we desire that SR≥SS. To provide this, we can write an inequality, substituting the appropriate equivalents for SR and SS, as they pertain to this amplifier. SR is as described by (44), and SS by (53). The inequality is

$$\frac{2\pi\, Vth\, GBP}{10^6} \geq \frac{2\pi\, Vpp\, fc}{10^6}. \qquad (57)$$

A

B

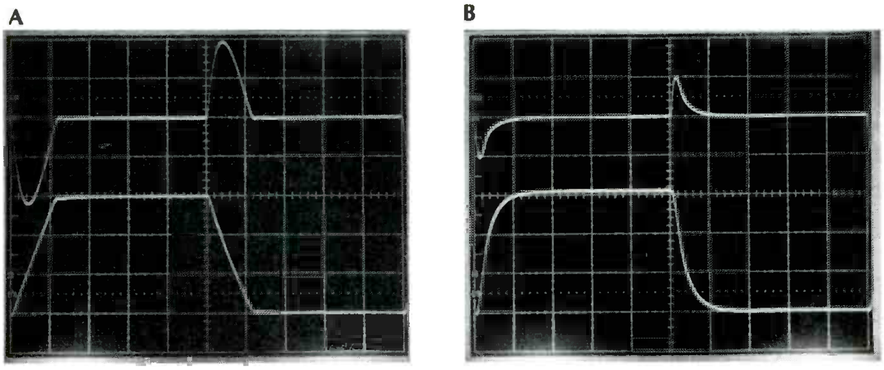


Fig. 45 — Transient response of a 301A, operated inverting with unity-gain compensation, Cc = 33pF, to 20-kHz square wave filtered at 100 kHz. Top traces are error voltages, bottom traces outputs. A, slew-limited response, and B, non-slew-limited response. (Scales: 5 μS/cm both; A, 0.5 V/cm top, 2 V/cm bottom; B, 0.1 V/cm top, 0.5 V/cm bottom.)

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The major problem with small, relatively less efficient loudspeakers is thermal overloading of the voice coils. KEF engineers have developed a unique self-powered electronic overload protection circuit, S-STOP (Steady State and Transient Overload Protector).

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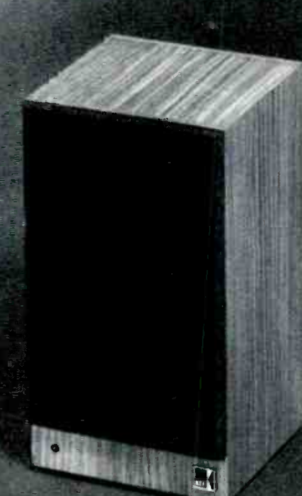

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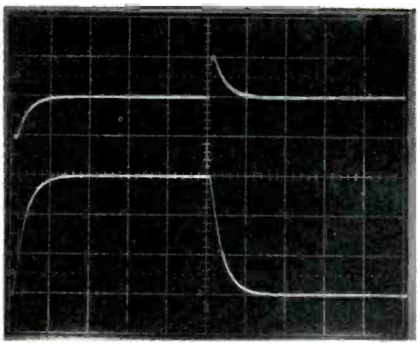


Fig. 46 — Transient response of a 301A, operated inverting and adjusted for slew suppression, Rx = 1.2 k, Cc = 5 pF. Top trace is error voltage, bottom trace is output. (Scales: 5 μ S/cm for both; 0.05 V/cm top, 2 V/cm bottom.)

such as the 12AU7. Viewed in this light, it is quite easy to see why a vacuum-tube design is much less susceptible to SID type problems; not only did they have less feedback in general, but they could also easily accommodate much larger inputs without first-stage clipping (47).

Viewed in just the above light, it is rather easy to conclude that the transistor audio power amplifier cannot be made to work. If, for example, we were to manipulate β to satisfy (59) for the 100 W amplifier, using a Vth of 0.05, β becomes 0.000625 (or less), which corresponds to a gain of more than 60 dB! While this probably is a completely impractical signal gain, it is possible to use special compensation "tricks" such as input compensation [25, 31, 63], which provide a low β, but at elevated frequencies (above the audio range).

Of much greater interest are practical techniques which can be used to design an amp for no SID, *without* having heavy restrictions placed on the feedback loop. This can be done by separating the filtering and amplification functions, so that each can be optimized separately.

If an amplifier is preceded by a low-pass input filter with a cutoff frequency of fc, the filter-plus-amplifier combination can control the output signal slope with relative independence of the feedback factor. There are still restraints upon the Vth (or Vpp) of the amplifier, however, they are lessened to a great degree.

For this discussion it is assumed that the amplifier operates linearly and its own natural cutoff frequency, as determined by (56), is sufficiently higher than that of the input filter so as to cause negligible interaction. For such a linearly operated system, the peak-to-peak output of the input filter can be scaled by the gain of the amplifier, and the SS resulting at the output is of the same form as (53), but the relevant Vpp is the rated output of *the amplifier*.

If we now write an inequality such that the amplifier SR is to be maintained greater than the output SS, it follows the initial development form to (58), which is repeated here

$$Vth \geq \frac{Vpp\ fc}{GBP} \qquad (58)$$

Written thus, it can be seen that as fc is lowered and GBP raised, the Vth required can be lowered. Within certain constraints, this allows considerably more design freedom. Like the previous relationship, this is one best understood by examining some performance which illustrates it functioning.

For an amplifier where Vth and GBP are fixed (as the 301A example of Part 1, Figs. 3 and 4), the only relief from the slewing problem is to decrease feedback in accordance with (59) until the criterion for Vth is satisfied. However, when we have control over GBP, we can manipulate things effectively to minimize slewing problems as we can by changing Vth.

A test circuit which can be used to demonstrate the relationship of (58) is shown in Fig. 44. Here A1 and the associated components form a 100-kHz single-pole filter, which drives the D.U.T., connected in an inverting circuit. This allows direct observation of the error voltage, thus this monitor shows directly when Vth is exceeded. The error voltage of the D.U.T. is buffered by A2, a high-speed FET amplifier, which furnishes a voltage gain of 10 to aid observation of low error voltages without loading the summing point. Rx is used to adjust the feedback of the D.U.T. test amplifier. A small (10 pF) feedback capacitor is used to minimize HF phase errors (which can obscure detection of slewing near threshold).

To check the validity of (58), a hypothetical amplifier stage was set up to pass a 6-V p-p output signal, after being filtered by the 100-kHz input filter. (Such a stage, for example, could represent the last stage of a preamplifier, and the numbers quoted are reasonable design figures.) A 301A compensated for unity gain with a resulting SR of 1 V/μS and GBP of 1.5 MHz was used, with Rx open. The results for this device are shown in Fig. 45.

The bottom trace of this photo, 45A, is the output, which as can be noted is severely slew limited for the 6-V p-p level. The error voltage (top) is 1 V peak in level, well in excess of Vth, a confirmation that slewing is present in the output.

If (58) is an accurate predictor of slew suppression, it should be possible to adjust this stage to a point where slewing is not present.

If (58) is rewritten in terms of Vpp, as

$$Vpp \leq \frac{Vth\ GBP}{fc} \qquad (60)$$

we should be able to calculate a Vpp below which this is true, for this circuit. Equation (60), with the substitution of the appropriate conditions, indicate that slewing should disappear below 1.5 V p-p, the level where Vth is 0.1 V.

A photo for these conditions (displayed similarly) is shown

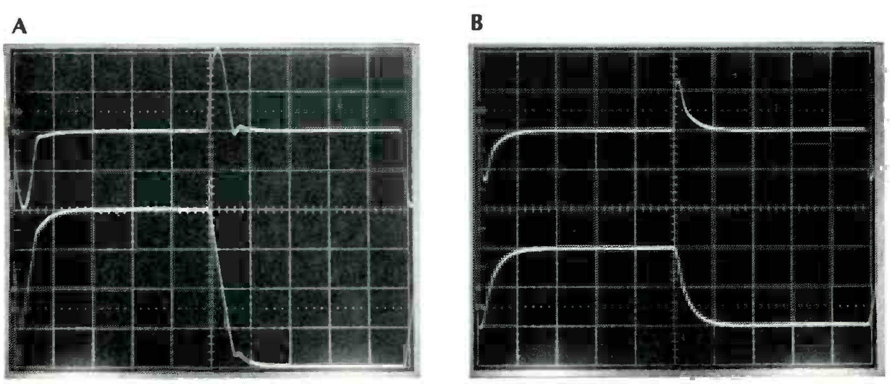


Fig. 47 — Transient response of TL070, operated inverting with unity-gain compensation, Cc = 33pF, GBP = 1.5 MHz, Vth = 0.67 V, to 20-kHz square wave filtered at 100 kHz. Top traces are error voltages, bottom traces outputs. A, slew-limited response; B, non- slew-limited response. (Scales: 5 μS/cm both; out puts both at 5 V/cm; error voltage, A, 1 V/cm, B, 0.5 V/cm.)

in 45B. As the output level and Vth indicate, slewing is just barely discernible in the output waveform (bottom). For levels below 1.5 V it will be absent; above 1.5 V it will appear with increasing degree, with increasing amplitude.

Equation 60 can also be used to adjust GBP to a point where higher output levels are possible without slewing. With the same 301A compensated with 5pF, its GBP became 10 MHz, which should allow the 6 V p-p output to be realized. For stability, Rx must become 1.2 K for this test.

The results, shown in Fig. 46, indicate that a 6-V output is realized without slewing. As can be noted, the error voltage is under 0.1 V (top) for this condition, indicating that operation is conservatively below the slew limit level. Equation 60 actually predicts a 10 V p-p output before slew limiting is reached.

Another demonstration of how the relationships of (58) and (60) operate is possible by using an amplifier with a radically different Vth to see if it predictably follows a similar pattern. This was done for a TL070 device, which for a similar compensation capacitance of 33 pF also has a 1.5 MHz GBP. However, due to its higher Vth of 0.67 V, the SR for this device and condition is 6.7 V/μS. As should be noted, these conditions produce a test amplifier with 6.7 times the Vth and SR over the 301A.

Figure 47A shows the output/error voltages for the TL070 compensated as noted for a 20-V p-p output. Slewing is evident in the output (bottom) and indicated by the 2-V peak error voltage (top) which is in excess of Vth. Equation (60) predicts that slew limiting should disappear below a 10-V p-p output, which is shown in 47B. Note that the error voltage is just over 0.6-V peak, and slewing is just barely noticeable in the output (bottom).

If this amplifier is adjusted for a higher GBP, as was done in the 301A case in Fig. 46, it shows a similar improvement. For this 10-MHz GBP condition, the output predicted by (60) would be 67 volts p-p or in excess of the supplies. The results at a 20-V level are shown in Fig. 48, and there is no slewing detectable at all.

It should be noted that these two examples do indeed demonstrate similar adherence to the relationship described. If the results are compared for conditions where the error voltage is at the Vth level, for example Figs. 45B and 47B, it can be noted that although the two output levels produced are different (due to different SR and Vth), *the error voltages are of a similar percentage of the output* or about 6.7 percent. This demonstrates that it is, indeed, possible to satisfy a common criteria (SR>SS) by different means, with similar errors by the different routes taken.

Another way of stating this is to rephrase an earlier statement, that Vth *in itself* is not a single totally important parameter—it is important to this subject to the extent it affects SR and input overload. The relationships set down in (58) and (60) are somewhat deceptive in this regard, as they do not contain an SR term. However, it should be remembered that these two relationships are *fundamentally based on an SR criterion* and, as such, contain terms which are useful towards manipulating or maximizing SR. In a very broad perspective, it should also be understood that it is incomplete to imply that input dynamic range, Vth, or other similar conceptual terms describe the entire situation in terms of a no-slew-limit guarantee, for they do not. As the experiments just described have demonstrated, even a low Vth amplifier can be effectively used. If its operating conditions are set up to provide an SR>SS, the obvious slewing distortion can be suppressed.

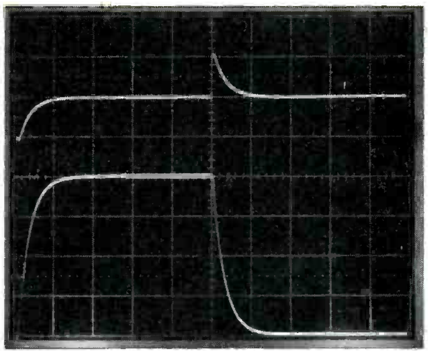


Fig. 48 — Transient response of a TL070, operated inverting and adjusted for slew suppression, Cc = 5 pF, Rx = 1.2 k. Top trace is error voltage at 0.1 V/cm, bottom trace is output voltage at 5 V/cm.

There is a great deal more which can be said about specific amplifier operating conditions and methods of suppressing SID by guaranteeing SR>SS. Unfortunately, however, the scope of all of these factors might be a complete article or series in itself. Therefore, we will limit comments on these points to the highlights at this time.

What the relationships just discussed show is that when the output of an amplifier stage is, by design, purposely confined to signal slopes less than the SR of that amplifier, the amp will not slew limit. Further, if SR is maintained greater than SS for all output levels up to (or above) the clipping level, the amplifier will not slew limit for any input level below clipping.

While this was demonstrated with a model consisting of a separate input filter followed by the amplifier under test, it also holds true when the filter is integral to the amplifier, i.e. the amplifier is an active LP filter. An amplifier can, in fact, be designed in this manner for slew suppression, as described by Leach [10]. However, the conversion of an amplifier to an integrator at high frequencies will usually result in more compensation being necessary for stability, hence there can often be little net improvement for this approach.

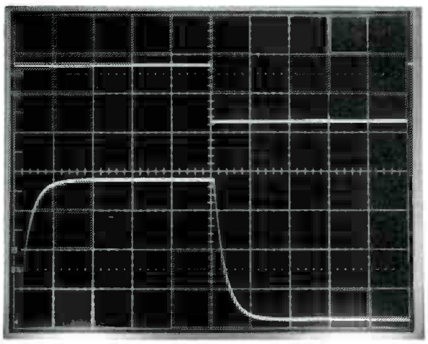


Fig. 49 — Transient response of a non-slew-limited amplifier design, loaded with 8 ohms, to a 10-kHz square wave. Top trace is input at 2 V/cm, bottom trace is output at 20 V/cm.

In practice, effective control and design freedom are also realized when the slope limiting filter is placed before the amplifier. This allows reduced compensation and a high SR in the amplifier, with complete control of maximum signal slope by means as simple as a single RC input section.

An example of a power amplifier design based on these principles is described in reference [71], and it is worth noting that a commercial design [72] following these principles has received some good marks from audiophiles and subjective reviewers. To illustrate the point that this amplifier is indeed a non-slew-limited design, a full-level output (80 W) square wave from it is shown in Fig. 49, along with the input square wave. It is clear that the response is small-signal-bandwidth limited only, and the 6 μS risetime does not, in fact, vary as a function of level.

The design techniques and experimental data described above for reduction of SS by prefiltering at the amplifier input have all been based upon single-pole, low-pass filters. While this type of filter has been shown to be quite effective for control of SS, and thus prevention of slew limiting, more sophisticated filter techniques are even more effective in reducing SS.

It has been shown [12, 66, 67, 70] that higher order filters are even more effective for reduction of SS, compared to a simple first-order type, for a given cutoff frequency. There are, of course, trade-offs to be made in comparing one to the other, considering the higher performance against the increased complexity. Also, the damping of the filter must be considered, as well as its frequency. However, the increased complexity of a second-order filter really depends on exactly how it is realized and may not in fact be prohibitive. For example, Leach has shown in [66] how the amplifier itself can be used as the active portion of the prefilter, without undue stability constraints, in what appears to be a practical and attractive topology. Further, in [70] it is shown that a second-order Bessel LP filter alignment will produce approximately 1/2 the SS of a single-pole filter for otherwise similar conditions. Unfortunately, time did not permit detailed experimentation with these techniques for this article, but they appear to have significant merit towards the reduction of SID effects.

Generally, the above discussion describes two alternate means which can be used to design a non-slew-limited amplifier and thus prevent SID and TIM. A logical question which may be raised is, do they yield equal results in auditioning? While we do not at this point have subjective response data to definitively answer this question, informal listening tests by one author (W.J.) tend to favor circuit topologies which are designed from a standpoint of equation (59), using linearized input stages, such as FET or degenerated bipolar devices. As time progresses, it is hoped that further listening tests will more clearly define the optimum choice between the two approaches.

Conclusions

In this article we have attempted to cover a quite broad topic from a multiplicity of viewpoints, in both discussion and analysis. These different techniques of analysis all indicate a common pattern of distortion in feedback audio amplifiers, which is a function of the ratio of signal slope to amplifier slew rate, a dimensionless parameter we define as SR ratio. When the SR ratio is less than unity, this distortion is suppressed; when greater than unity, strong nonlinear distortion products appear, which are subjectively objectionable.

Control of this distortion, which we call SID, can be achieved by maintaining linear amplifier behavior, with an SR greater than the highest SS, or stated in terms of SR ratio, an SR ratio less than unity. Since SS is both frequency and amplitude dependent, it follows that greater SR in an audio amplifier is required for higher voltage output stages, where the SS is highest.

Control of this distortion can be exercised by appropriate selection of amplifier type, by specifying an SR sufficient to the application. In design, it can be achieved by providing a sufficiently conservative SR (on the order of 0.5 V to 1V/ μS per peak output volt) or by designing for a non-slew-limited response. A non-slew-limited amplifier has an inherent SR greater than its maximum possible output SS and will therefore never slew for any input signal, including square waves, or its SR ratio is guaranteed <1. It is characterized by frequency response which is small-signal-bandwidth limited, for any output below its clipping level. As such it has no major nonlinear distortion products due to slewing effects. Such an amplifier is also said to be TIM free and may be described in this context as well.

It is recognized that there is considerable controversy on the relative importance of TIM and SID, their audibility, and some of the relevant design criteria. For this discussion, it is not our purpose to dwell excessively on the relative importance of SID, its audibility or other factors which are often subject to opinionated views. What we seek to do is describe means to quantify and control this distortion mechanism, and basically this is the only main point being addressed.

The existence of the distortion mechanism is, of course, *not* a subject of debate, and like other distortions in amplifiers, knowledge of its behavior patterns is valuable to either the circuit designer or the informed user of audio equipment. We would, however, like to express caution with respect to certain alarmist commentary, for example those to the effect that low TIM or minimal SID is the magic elixir of quality audio. While this distortion source is quite important, so are many others. Once sufficient linearity and slew rate have been provided in a design, there may actually be little gained by boosting SR further (to far beyond that necessary). The *optimu* audio amplifier is best designed with *all* contributions to audible defects given proper perspective.

We appear to currently be immersed in a specifications race on the part of some manufacturers in this regard, which is not only unfortunate for the confusion it spreads (as to what is most important), but doubly so from the standpoint that if nonlinear techniques are being used to achieve high SR numbers, the user can actually pay a penalty in *higher* distortion!

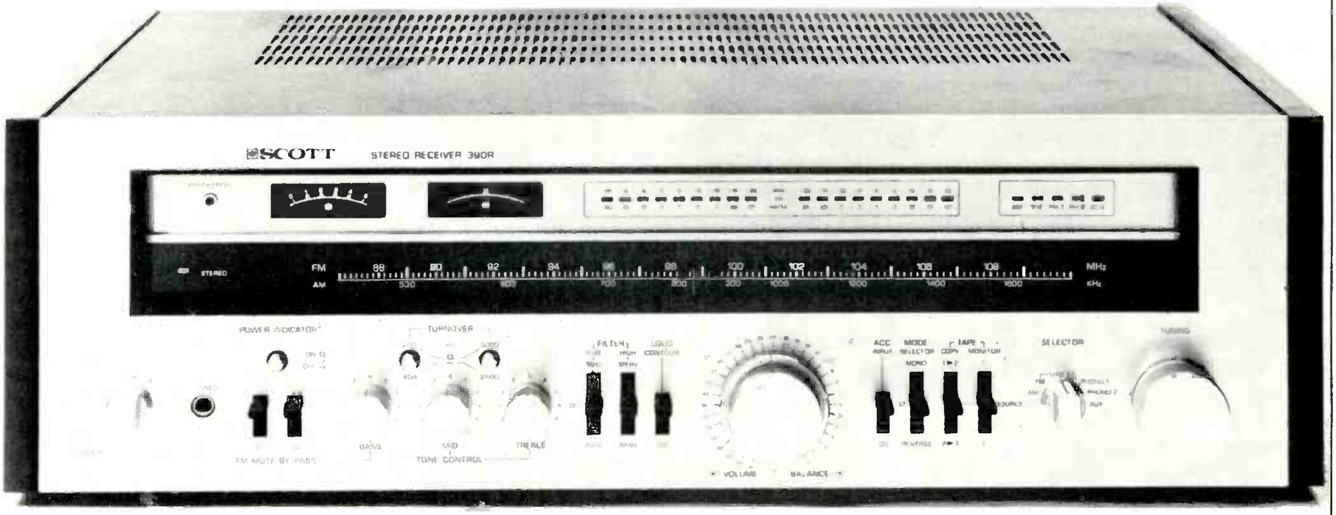
Another specifications race practice appears to be the quotation of amplifier maximum output SS *for small signal condition* as its specified SR. If an amplifier is operating linearly in non-slew-limited conditions, the output SS for a fixed signal will linearly follow the output level, and at no point will it reach the true amplifier SR, which is, in fact, a limit. It is therefore erroneous or misleading to quote a maximum SS as an SR in such a case, as the *true* SR limit is never reached. In our opinion, while such an amplifier has real merit, it might more clearly and suitably be described in such terms as "maximum linearly reproduced SS" or the qualifier added that it is a true non-slew-limited design, as described in the text. Using the terminology of SR implies that the amplifier *can* be made to slew; if, in fact, it *cannot* be made to slew this should be clearly stated, for it is a point which distinguishes the design.

(In Part II on page 44 in July under "Comparison of Test Methods," we made the statement that the squarewave's *fundamental* amplitude was 12 dB larger than the sine wave's. The square wave *itself* is 12 dB larger in amplitude, as described in the sidebar.)

We hope this discussion has served to bring together some of the various issues involved so as to create a new perspective for the reader. We recognize that some of the points made in this article have been made elsewhere and acknowledge the work of previous authors. We believe that the extensive bibliography will be helpful to the reader to appreciate this material, and to tie older data in with the new material presented within this article. A

Equipment profiles

Scott Model 390R Stereo Receiver



MANUFACTURER'S SPECIFICATIONS

FM Tuner Section

IHF Sensitivity: 9.8 dBf (1.7 μV).
50-dB Quieting Sensitivity: Mono, 15.6 dBf (3.3 μV); stereo, 35.6 dBf (33 μV).
S/N Ratio: Mono, 80 dB; stereo, 75 dB.
THD: Mono, 0.1 percent; stereo, 0.2 percent.
Frequency Response: 25 Hz to 15 kHz, ±2 dB.
Capture Ratio: 1.0 dB.
Selectivity: 80 dB.
I. f. Rejection: 100 dB.
Spurious Rejection: 100 dB.
Image Rejection: 90 dB.
Subcarrier Rejection: 74 dB.
Stereo Separation at 1 kHz: 50 dB.

AM Tuner Section

Usable Sensitivity: 150 μV/m with internal antenna.
S/N Ratio: 55 dB.
Selectivity: 50 dB at 1 MHz.
Image Rejection: 60 dB.

Amplifier Section

Power Output: 120 watts per channel continuous into 8-ohm loads, 20 Hz to 20 kHz.
Rated THD: 0.03 percent.
Rated IMD: 0.03 percent.
Damping Factor at 1 kHz: 100.
Input Sensitivity: Phono 1 & 2, 2.5/5.0 mV; high level, 150 mV.
S/N, "A" Weighted: Phono, 90 dB re: 10 mV input; high level, 95 dB.
Frequency Response: Phono, RIAA ±0.5 dB; high level, 20 Hz to 20 kHz, ±0.5 dB.
Phono Overload: 300 mV/600 mV.
Tone Control Range: Bass, ±10 dB at 100 Hz; midrange, ±6 dB at 1 kHz; treble ±10 dB at 10 kHz.
High-Filter Cutoff: 8 kHz/12 kHz, 12 dB/octave.
Low-Filter Cutoff: 18 Hz/40 Hz, 12 dB/octave.
Loudness Compensation at -30 dB: +3.5 dB at 10 kHz; +7 dB at 100 Hz.
Channel Separation: Phono at 1 kHz, 70 dB; high level, 75 dB at 1 kHz.
Crosstalk: 75 dB at 1 kHz.

General Specifications

Power Requirements: 117 V, 60 Hz, 320 watts.
Dimensions: 22⅞-in. (58.1 cm) W x 6½-in. (16.5 cm) H x 15¾-in. (40 cm) D.
Weight: 49 lbs. (22.2 kg).
Price: $774.95.

H. H. Scott's most powerful receiver is also its most versatile and feature-laden, all-in-one stereo component. Controls and switches, though plentiful, are logically arranged on the silver-colored front panel and nomenclature (with one exception) is clear and self-explanatory.

The upper section of the panel consists of a well-illuminated dial area with AM and linearly calibrated FM frequencies screened in a light color against a dark background. FM calibration is linear and precise, with marks at every channel width. The usual stereo indicator light is located at the left of the frequency scales. A contrasting light-colored area above the frequency scales contains the twin tuning meters (center-of-channel for FM and signal strength which is active in both the AM and FM tuning modes), a circuit-protection indicator light (which illuminates briefly after turn-on and in the event that protection circuits are activated), five program-source indicator LEDs, and two banks of nine LED indicators each of which serves as a power output metering system. These power output level indicators are calibrated in 5-dB steps from 0.01 watts (referenced to 8-ohm loads) to 100 watts.

All operating controls and switches are located along the lower section of the front panel. Rotary controls include a combination power/speaker selector switch (three sets of speakers may be connected, with one or two pairs operable at one time), bass, midrange, and treble controls; dual concentrically mounted, detented volume and balance controls; the program selector switch (which includes two phono input settings, AM, FM, FM-MPX-Filter, and AUX), and a flywheel-coupled tuning knob. The usual phone jack is located near the speaker selector switch. Nearby are a pair of toggle or lever switches, one of which activates the FM muting circuitry, the other labelled "bypass." It is this latter switch which sent us to the owner's manual where we discovered that what was meant was tone-control bypass and that the "On" position means that the tone controls are bypassed, rather than "On." A bit confusing until you figure it out. Above the two toggle switches is a pushbutton switch which deactivates the blinking power-output LEDs, should you tire of gazing at them.

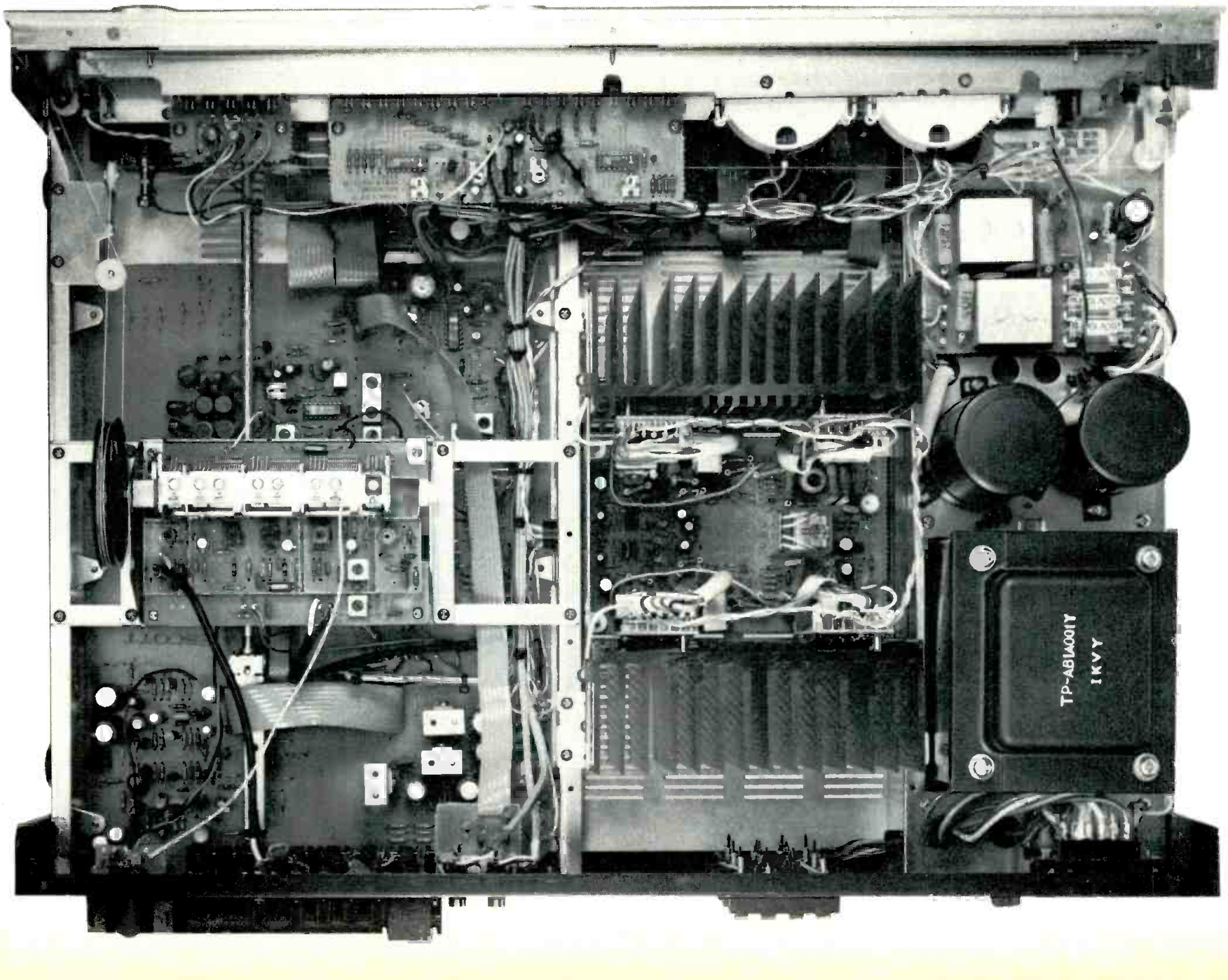
Above the three tone controls are two more pushbutton switches, each of which controls turnover positions for either the bass or treble tone controls. Turnover settings of 300 Hz and 100 Hz are provided for the bass control, with settings of 3 kHz or 8 kHz available for the treble control. Subsonic and high-cut filter switches (with cut-off points of 18 Hz or 40 Hz for the subsonic filter and 8 kHz or 12 kHz for the high-cut filter) come next, along with a loudness compensation *On/Off* switch. Four additional toggle switches to the right of the volume/balance controls introduce an "accessory " circuit interruption point (for connection of equalizers, expanders, etc.), select mono, stereo or stereo reverse listening modes, activate either of the two tape monitor circuits, and provide tape copying connections from either of two connected tape decks to the other.

The rear panel of the Scott 390R is equipped with the usual array of phono inputs (for two phono circuits), AUX and tape inputs, tape outputs (the Tape-2 circuits can be fed via a DIN multiple-pin connector as well as by phono-tip plugs), as well as with the aforementioned "accessory" in and out jacks. A slide switch near the phono inputs selects either 2.5-mV or 5-mV input sensitivities (for rated output). Antenna terminals are provided for external AM and 75- or 300-ohm FM antenna lines, and nearby is the usual pivotable ferrite-bar, AM internal antenna. A three-position slide switch selects either 75-microsecond, 50-microsecond (for use in Europe), or 25-microsecond de-emphasis, the latter required for Dolby FM reception when an outboard Dolby decoder is added.

Three identical sets of color-coded, spring-loaded speaker terminals; two convenience a.c. outlets (one switched, the other unswitched), a line fuse holder, and the a.c. power receptacle for the unit itself complete the rear panel layout. H. H. Scott has developed a powering format for all of their recently made products which includes a separable line cord that is supplied with each set. This enables the company to ship the same basic unit to various countries around the world, since the appropriate line cord, to fit receptacles in different parts of the world, can be packed with each of the firm's products.

Three dual gate MOS-FETs are used in conjunction with a 5-gang tuning capacitor and a low-noise bi-polar oscillator in the FM front end of the 390R. One transistor and two integrated circuits make up the basic circuit of the i.f. section. The transistor and first IC provide gain and differential limiting. The second IC provides three additional stages of amplification, wideband quadrature detection, and AGC-, meter- and mute-drive circuits. Three dual-element ceramic filters are used to provide selectivity, while the MPX decoder incorporates a phase-locked-loop IC decoder. Subcarrier filtering is accomplished with a three-pole LC filter which is designed to have no interaction below 15 kHz while effectively eliminating the 19- and 38-kHz subcarrier components.

The phono preamp-equalizer uses a three-stage configuration. The first two stages provide voltage gain, while the



FINE TUNING. BY CROWN.

At the outset, we have to confess that building the Crown FM1 stereo tuner was quite a challenge to us. Crown audio products have earned a reputation for reliability and sonic excellence under the most demanding conditions. A tuner would have to be very good indeed to be identified as a Crown product.

Crown's first tuner.

There was also the fact that this was our first tuner. We do know a great deal about how to create good sound reproduction in the audio band, but that didn't automatically translate into solving RF problems. We were realistic about that. And we were fortunate. For we got to know as friends and co-workers some very talented designers of RF equipment who served as consultants on Crown's "Project Tuner."

A few people even suggested we should buy a Japanese chassis and put a Crown front panel on it. These people told us it would sell, just because it had the Crown name on it. "Well," we said to ourselves, "maybe so, but would those buyers ever trust another Crown product?" So we scrapped that idea before it even got off the ground.

Made in America.

We did ask some other manufacturers if they could build a tuner to our specifications. (We had a good grasp of the features we wanted in our first tuner– and also a fair idea of the price at which it should sell.) They not only told us they couldn't do it– they told us it couldn't be done.

Well, we'd heard that story before. We were told in 1947 you couldn't build a rugged, reliable tape recorder that would work anywhere in the world. We were told in 1965 that high-power all-transistor amplifiers would be available when men walked on Mars. And having conquered both of those impossibilities– the first with Crown ¼" tape recorders, the second with the original Crown DC-300– we decided that a made-in-America tuner, worthy of the Crown name, was possible.

We are all very proud of the result, the FM1 stereo, programmable, digitally-controlled FM tuner.

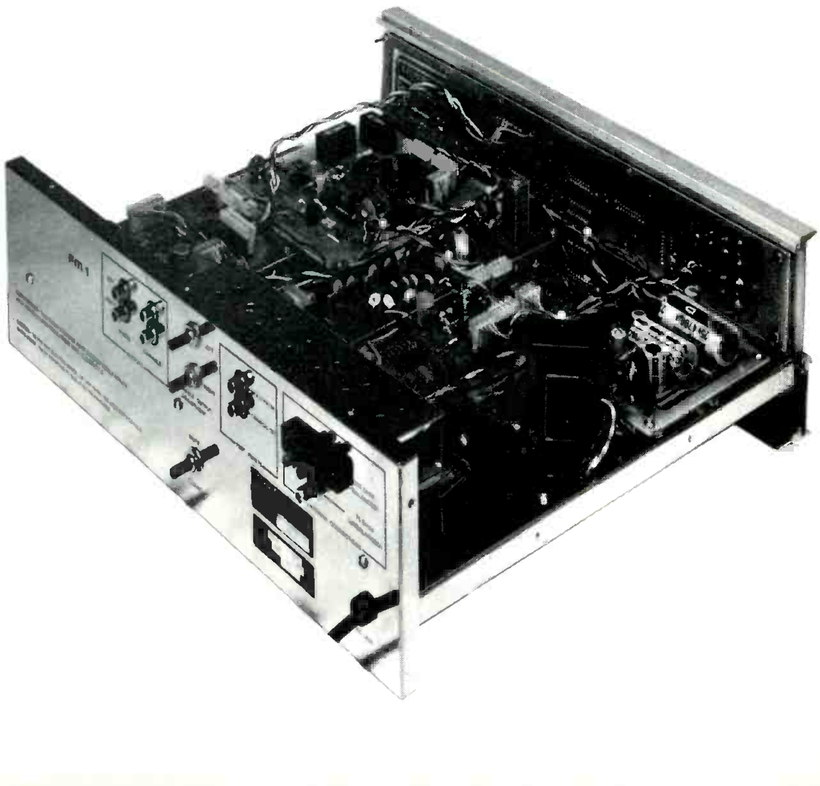
Touch tuning.

The most noticeable feature of the FM1 is the absence of a tuning wheel and dial. The FM1 is a true digitally synthesized tuner, and provides accurate, no-drift tuning.

A quartz crystal provides the basic reference frequency which controls the FM1 tuning section. This is the same system used by broadcasters to control their transmitter frequencies. When a particular frequency has been selected, (visible on a four-digit LED display), the FM1 locks itself to that frequency by comparing the desired frequency to the quartz crystal thousands of times per second. Drift simply cannot happen; tuning is automatic, precise and immediate. The only tuning variable you need to control is antenna position, and an LED multipath meter is included to assist you in determining the optimum position. Another LED meter provides useful information about the relative strength of station signals.

An unforgettable tuner.

Your FM1 tuner can memorize– infallibly– your five favorite stations for instant and fumble-free recall. A special EAROM integrated circuit is dedicated to remembering your instructions. Tune to the desired frequency with the touch/tap controls, tap *Program* and the channel (1 to 5) where the frequency is to be stored. Even if you now unplug the FM1 and move it to another location,



it will remember your station, (*without* batteries!) and get it for you instantly.

An analog LED dial displays the approximate dial location of your selected frequency. This simulated dial may help make the transition to the world of digital audio a little easier for you.

Automatic tuning.

The FM1 includes several tuning modes which have been automated, thanks to a special control chip with an unusual ability to manage a wide range of functions. Because of it you'll enjoy the use of the *Search, Stereo Search* and *Scan* functions. The two search controls will tune to the next station whose signal is above the mute threshold of a signal.

The *Scan* function is most unusual, and only possible with a digital tuner such as the FM1. When you tap *Scan,* the FM1 seeks the next higher station frequency of acceptable strength, pauses for seven seconds, moves to the next station, pauses again–and so on, forever–unless you tell it to stop. Great for finding a broadcaster whose mood at the moment exactly matches yours, or for finding out just what listening mood you're in.

Good sound.

It is, perhaps, not coincidental that almost all of our engineering staff are long-time audio enthusiasts. They know good sound–and they also know what it takes to build good audio components. FM1 prototypes were thus subjected to severe listening tests by these listening experts. (And if you don't believe that our company experts are allowed to express their opinions and that those opinions have an impact, you ought to discuss Crown with someone who's been there.)

These listeners insist the FM1 is better. They were very much impressed with the quality of broadcast sound coming out of the FM1. True, the FM1 will not allow you to evade any problems that the *broadcaster* might create for you, but a good broadcast signal at your antenna will be a good audio signal out of the FM1.

As you would expect, all of the details of importance for retaining the fidelity of the sound were carefully evaluated in the design of the FM1 circuitry. The latest in PLL (phase locked loop) stereo demodulators with pilot cancelling is used to decode the stereo signal. To increase the stereo separation to a maximum, additional crossblending amplifiers were added to allow the R into L channel crosstalk to be minimized without interaction with the L into R channel adjustments. This results in better stereo separation than can be provided by the PLL demodulator alone.

Is this the tuner for everyone?

Frankly, no. In the first place, we aren't planning to build that many FM1 tuners. Crown continues to be one of the deliberately small companies in the audio field. We're not sure we could produce Crown-quality components on a mass production basis. Your satisfaction with our product is much too important for us to radically expand a production line that's geared to careful craftsmanship and high technology.

Secondly, the FM1 tuner is a high-quality single-purpose audio component which may not match your current needs.

But for those whose lifestyle demands the very finest in sound reproduction, even if that means passing up some other of the fine things in life, we believe the FM1 tuner will be one of the more satisfying purchases in your life.

Listen carefully.

If you would like more information about the FM1 before making up your mind to purchase it, please send five dollars with the coupon below to obtain an advance copy of the Crown FM1 manual. Your five dollars will be refunded by Crown upon return of this manual, whether you purchase the FM1 or not. Find out all you can about the FM1. Listen. To friends. To dealers. And to your own ears. Then tune in. The FM1 can be a richly rewarding sonic experience for you.

To:
Crown International
1718 W. Mishawaka Road
Elkhart, IN 46514

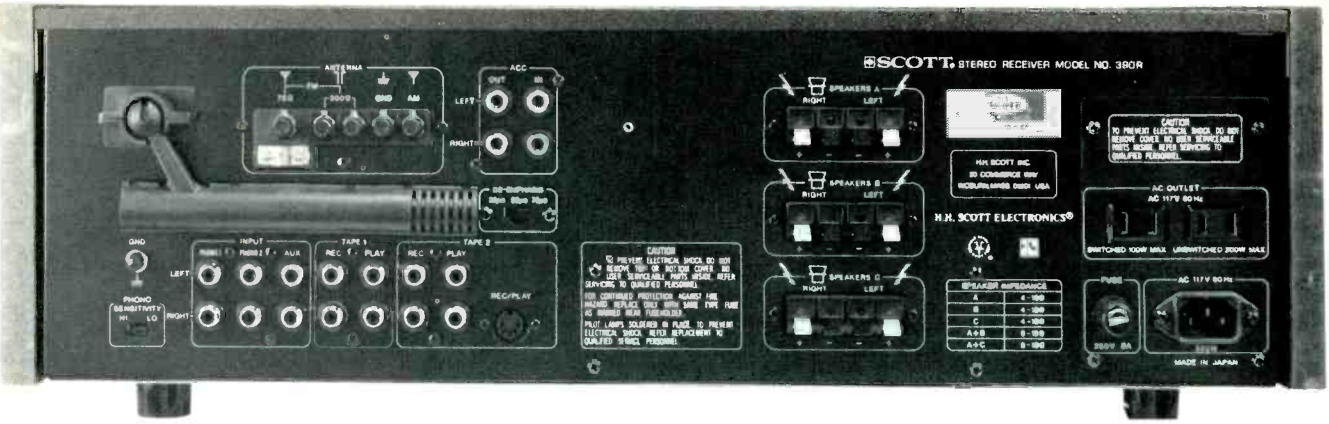
☐ Here's my five dollars. Please rush my FM1 Tuner manual.
☐ Please send a free color brochure instead.

Name ____________________
Home Address ____________________
City ____________________
State ____________________ Zip ________
Phone ____________________

crown

1718 W. Mishawaka Road, Elkhart, Indiana 46514

Innovation. High technology. American. That's Crown.



third, a Class-A push-pull stage, provides current gain for the EQ feedback network to prevent slew-induced distortion at high frequencies. The tone-control amplifier is a three-transistor design consisting of a single-package differential input followed by a voltage amplifier. When the tone controls are set to center, gain is unity. The tone bypass switch entirely eliminates this circuit from the signal path.

All low-level circuits work in Class A. Subsonic and high-cut filters have maximally flat, Butterworth alignment with 12-dB-per-octave slopes.

The power amps consist of a current-mirror, loaded differential pair connected to a Class-A voltage amp with a constant collector load. This drives a fully complementary, Darlington-connected driver and parallel output transistors which provide current gain. The differential transistors are housed in a single package to minimize d.c. offset drift and noise. The driver and output transistors were selected for high cut-off frequency to maximize slew rate and minimize high-frequency distortion.

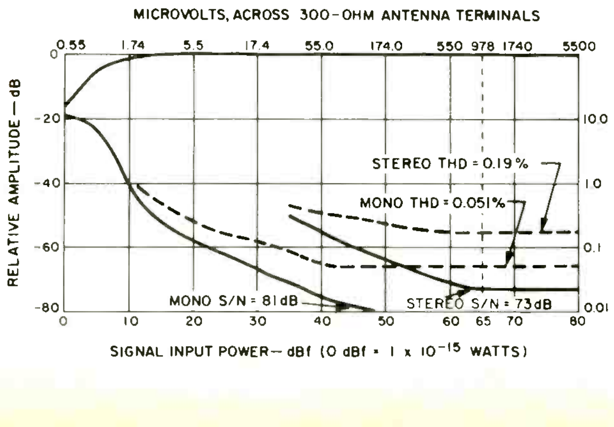
A split power supply configuration is used with a bridge rectifier and two 15,000- µF capacitors to supply dual polarity voltages to the power amps. Phono-preamp, tone-control, and voltage-amp stages are powered from voltage regulators which incorporate capacitance multiplers. The output stage is d.c. coupled to the speakers.

Tuner Section Laboratory Measurements

Figure 1 depicts the quieting and harmonic distortion characteristics (at 1-kHz modulation) of the mono and stereo FM sections of the 390R. Usable sensitivity in mono measured 10.3 dBf (1.8 µV), marginally short of the 9.8 dBf claimed, but the 50-dB quieting point in mono was better than claimed, with readings of 13.5 dBf (2.6 µV). Signal-to-noise ratio at 65 dBf in mono was an impressively high 81 dB, exceeding the claimed figure of 80 dB.

We were surprised to find that the mono/stereo switching threshold on this receiver was set at a fairly high 35.6 dBf (33 µV), which necessarily represents "usable sensitivity" in stereo as well. Since 50-dB quieting in stereo is obtained with

Fig. 1 — FM mono and stereo quieting and distortion characteristics.



just a bit more signal strength than this (36 µV or 36.3 dBf), we would like to have seen Scott set the stereo switching at a lower level, especially since they do provide a strong MPX-blend filter for reduction of noise in stereo FM. Scott informs us that the set-up specification on the mono/stereo switching is between 15 and 20 dBf.

Once in stereo, however, best signal-to-noise at 65 dBf, though 2dB short of claims, measured a satisfactory 73 dB. Distortion, at 1 kHz in mono, measured an incredibly low 0.051 percent, increasing to just under the specified 0.2 percent for stereo. At the other test frequencies of 100 Hz and 6 kHz, mono THD was 0.08 percent and 0.2 percent; while in stereo, the measurements were 0.24 percent and 0.4 percent.

Frequency response, displayed in the 'scope photo of Fig. 2, was well within the ±2 dB specified by Scott and in fact exhibited a slight rising characteristic at the high end of a fraction of a dB, unlike many tuner sections which exhibit a rolloff above 10 kHz because of pilot-carrier (19-kHz) filtering. Despite the excellent response out to 15 kHz and above, there was no problem with 19-kHz carrier leakage, which indicates an excellent and precise job of low-pass filtering.

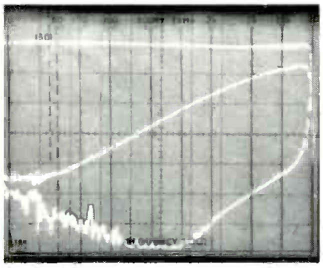


Fig. 2 — Stereo FM frequency response and separation. (Center trace is separation with blend circuit.)

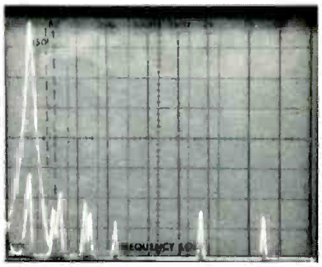
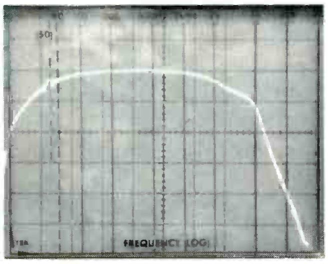


Fig. 3 — Composition of crosstalk in unmodulated channel.

The scale used in Fig. 2 (and all subsequent 'scope photos in this report) is 10 dB per vertical division. The lower trace represents the separation capability of the multiplex circuitry. Separation at the three required test points measured 51 dB (at 1 kHz), 50 dB (at 100 Hz), and an excellent 42 dB (at 10 kHz). The center trace illustrates the rather drastic reduction of separation when the "blend" or MPX-filter position is used. When this setting is employed, separation at 1 kHz drops to 24 dB, while separation at 10 kHz is approximately 8 dB. Users of this receiver are not likely to employ this filter since, as we noted earlier, stereo threshold is set at such a level that stereo reception is fairly noise free at switching and higher input signal strengths.

We have been noting for some time that our meter-measured separation figures are often at odds with the figures obtained by examining the spectrum-analyzer sweeps of separation which we also employ in these reports. The reasons

Fig. 4 — AM frequency response.



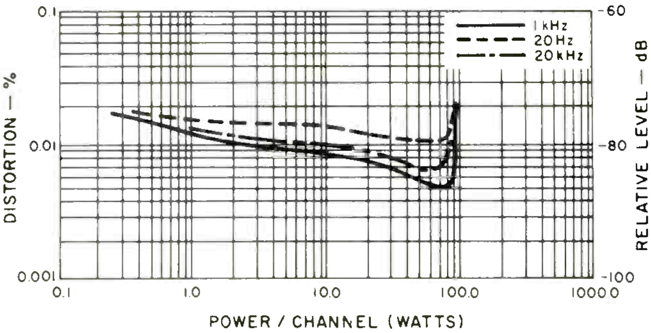


Fig. 5 — THD vs. power output.

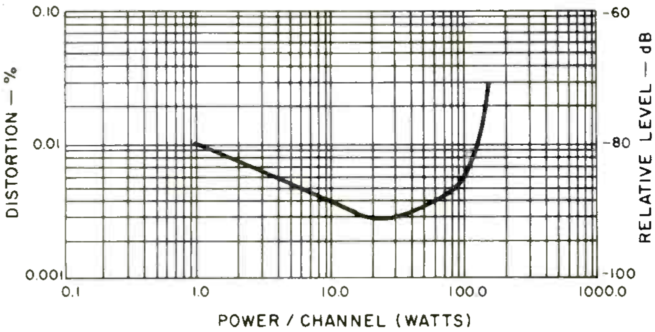


Fig. 6 — IM distortion vs. power output.

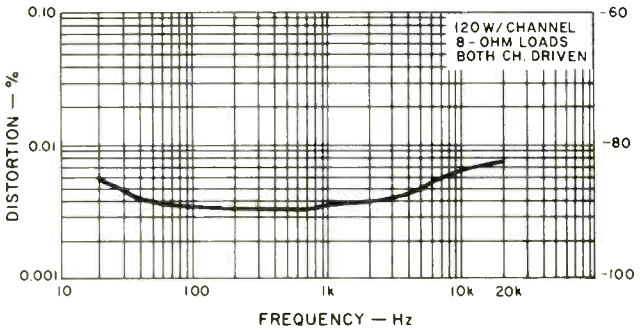
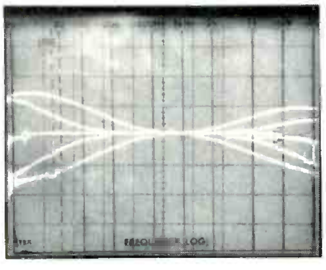


Fig. 7 — Distortion vs. frequency.

Fig. 8 — Bass and treble control range, both turnover settings.



for this discrepancy become clear when you examine Fig. 3 (a display which we will be incorporating in all future tuner and receiver test reports). Two superimposed sweeps are represented here. The first, taken at the left-output with a left-only signal modulating the FM carrier shows the "desired" signal (the tall spike at the left of the display), in this case a 5-kHz modulating tone. The second sweep is obtained by reading the right output while the 5-kHz tone still modulates the left input of the stereo generator.

The amplitude of the 5-kHz signal in this undesired channel (shorter spike contained within the earlier, tall spike) is some 50 dB below the "desired" signal. This represents the actual *separation*. In addition, however, we also see second, third, and fourth order harmonics to the right (having amplitudes which are around 57, 62, and 66 dB below "desired" signal level in the opposite channel) as well as the two subcarrier sidebands located at 33 kHz and 43 kHz. (Note: In this display, sweep is *linear*, with each linear horizontal division on the 'scope face representing 5 kHz. The log frequency notations do not apply and should be ignored.) Thus, we see that the single-meter reading of "cross talk" really includes more than just the undesired 5-kHz signal.

Capture ratio measured a bit higher than the 1.0 dB claimed, while alternate channel selectivity measured a very satisfactory 83 dB. The i.f. and spurious rejection both equalled or exceeded the 100 dB claimed (the maximum we can measure), while image rejection measured exactly 90 dB as claimed. AM suppression, not specified by Scott, measured a satisfactory 57 dB.

AM frequency response for the AM section of the Scott 390R extended from 50 Hz to 3.5 kHz for the 6-dB roll-off points, and a full sweep display of the frequency response characteristic in AM is shown in the 'scope photo of Fig. 4.

Amplifier Performance Measurements

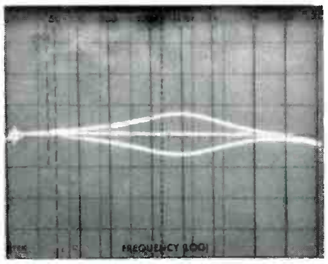
The power amplifier section of the Scott 390R delivered 149 watts of continuous power, at 1 kHz, into 8 ohm loads before the rated THD level of 0.03 percent was reached. At the frequency extremes of 20 Hz and 20 kHz, it was able to produce 136 watts of continuous sine-wave power per channel for the same rated THD. Power band for rated output (120 watts per channel) extended from below 10 Hz to 40 kHz. At mid-frequencies, THD measured 0.003 percent for rated output of 120 watts per channel. Figure 5 plots distortion (THD) vs. power output for 1 kHz, 20 Hz, and 20 kHz, while Fig. 6 plots IM distortion vs. power output. Rated IM distortion was reached at a power output equivalent level of 154 watts per channel, while at rated output, the IM distortion measured 0.0074 percent.

Dynamic headroom for this amplifier section measured 1.9 dB, and slew factor, measured per the new IHF measurement standards, exceeded 5.0. Damping factor, measured for a signal frequency of 50 Hz, measured 75. THD vs. frequency, at rated output, is plotted in Fig. 7.

Frequency response of the amplifier, measured via the AUX inputs, extended from 7.5 Hz to 35 kHz, ±1 dB, while the 3-dB rolloff points were 4 Hz and 65 kHz. Referenced to 1-watt output, high-level input sensitivity measured 13 mV, and signal-to-noise level, referred to 1-watt output with 0.5 volts input, measured 83 dB, "A" weighted. At minimum volume settings, hum and noise was 91 dB below 1-watt output.

Phono input sensitivities were 0.22 mV and 0.44 mV (depending upon the setting of the rear-panel phono sensitivity switch) for 1-watt output. The "A" weighted signal-to-noise in phono, referred to 1-watt output and with 5.0 millivolts of input at 1 kHz, measured 74 dB in the low-sensitivity position and 77 dB in the alternate sensitivity setting. Phono overload measured 300 mV and 600 mV for the two sensitivity settings. RIAA playback response was absolutely dead accurate from 30 Hz to above 10 kHz, with deviation from the prescribed curve of -0.2 dB at 15 kHz.

Fig. 9 — Midrange tone control range.



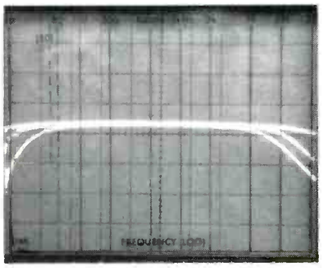


Fig. 10 — Action of low- and high-cut filters.

Figure 8 represents a 'scope sweep plot of the maximum boost and cut range for the bass and treble controls for each of their two turnover settings. Figure 9 is a display of the maximum boost and cut range of the midrange tone control. Figure 10 is a graphic 'scope plot of the action of the subsonic and high-cut filters showing the rolloff obtained in each of the two settings available for each of these filter circuits.

Listening and Use Tests

The Scott 390R performed particularly well in FM listening tests, when connected to a properly designed 5-element directional outdoor antenna, pulling in every mono and stereo FM station signal which we normally expect to hear in our listening area, some 20 airline miles from New York City, where most of our local transmitters are located. Using the supplied "indoor" T-wire antenna, weaker stereo signals were unable to exceed the required stereo threshold signal-strength and were received monophonically (albeit with noise-free results). Frequency calibration was extremely accurate over all but the very high end of the dial, where a deviation of 140 kHz was noted. Center-of-channel meter indications corresponded well with minimum-distortion tuning.

The power indicating LEDs were extremely accurate in their indication, and though the highest power indicator corresponds to 120 watts per channel, this visually interesting metering system cannot show when clipping or severe overload has occurred in the amplifier section, which, as we have noted, can deliver well over its rated 120 watts per channel.

Phono reproduction was excellent, with no evidence of overload even when listening to heavily modulated direct-to-disc records. Transient response rivalled that heard using some of the better separate, d.c.-configured integrated and separate power amps that have recently passed through our lab and listening room. The tone control arrangement, for those who seek a high degree of control, worked smoothly and did not seem to introduce any audible distortion when it was switched in and out of the signal path. Use of the 18-Hz low-cut filter position significantly reduced the IM distortion effects caused by turntable rumble and tended to unveil musical reproduction somewhat without audibly chopping into musical content on any of our musical test records.

The Scott 390R is a full-featured receiver that operates reliably, without generating high heat levels, even when driven to levels approaching maximum output for hours on end. Its suggested retail price seems more than appropriate for a receiver in this category. *Leonard Feldman*

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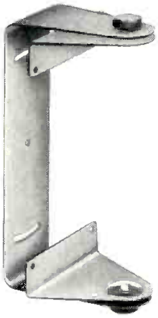
Minimus-7

This amazing little hi-fi speaker costs only about a third as much as some mini speakers, but we think they compare very favorably. How could they? Well, we gave ours a heavy-magnet large-excursion 4″ woofer, a soft-dome wide-dispersion 1″ tweeter, a precise L-C crossover network, and a diecast aluminum enclosure. The result is astonishing bass and crisp highs from a 7-1/6″ tall system that fits on any bookshelf. Audio response is 50-20,000 Hz and power capacity is 40 watts RMS. All for only 49.95* each.



Now listen to this! Just 14.95* buys you a pair of the fully adjustable mounting brackets pictured here, so you can install two Minimus®-7s in your car. Or van or pickup or RV. Discover Minimus -7, the mini-size, maxi-value speaker for home or mobile use. Sold only at Radio Shack.

*Retail prices may vary at individual stores and dealers.

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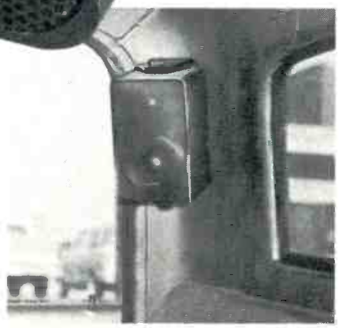
Use 'em on a shelf



Use 'em in your vehicle

Bravo!

That's the Jensen R430 Car Stereo Receiver. That's the thrill of being there.

Bravo indeed for the superlative performance of the 60 watt Jensen R430 Car Stereo Receiver. The top-of-the-line of six receivers that boast a compliment of features found only on better home receivers.

Features like a separate trunk-mounted Power Amplifier unit as well as a twin amplifier section in the main unit.

The advanced Bi-Amp capability of the R430 makes it possible to selectively send high frequency power information to a car's front speakers, and low frequency info through the Power Amp to the rear speakers. This bi-amplification allows for greater volume and less distortion.

Jensen has refined the R430 with other unique features like feather-touch electronic switches. And an automatic tape alarm.

Dolby® Noise Reduction processes out tape hiss and improves the dynamic range of Dolby-encoded tapes and FM broadcasts.

A Fader control adjusts levels front to back; separate Balance control adjusts left to right. There's even a Loudness Compensation function and for the extra-sensitive FM tuner, Interstation Muting.

But all the features in the world don't mean a thing if they don't combine to do one thing a receiver is built to do...recapture and deliver to you all the power and intensity that went into the original performance.

That's the thrill of being there.

That's the Jensen R430 Car Stereo Receiver.

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Decca London International Tonearm & Mk VI Gold Elliptical Phono Cartridge

MANUFACTURER'S SPECIFICATIONS

Tonearm
Effective Mass: 9 grams.
Effective Arm Friction: Better than 0.02 grams.
Offset Angle: 27°.
Tracking Angle Error: 1 degree, 40 minutes maximum deviation.
Stylus Overhang: 0.625 in. (16 mm).
Stylus Force Variation: From ¼ gm to 3 grams.
Overall Height: 3 in. (76 mm) max.
Height Adjustment: 1¼ to 2¼ inches.
Weight: 7.75 oz. (220 gm).
Price: $149.50.

Phono Cartridge
Frequency Response: 20 Hz to 20 kHz.
Output: 5 mV/5 cm/sec.
Stylus Radius: 0.0006 x 0.0003 inches.
Nominal Vertical Tracking Angle: 15°.
Compliance: Lateral, 15×10^{-6} cm/dyne; Vertical, 7×10^{-6} cm/dyne.
Inductance: 560 mH per channel.
D.c. Resistance: 2200 ohms per channel.
Tip Mass: Less than 1 mg.
Price: $174.50.

Decca has been making stereo cartridges since the beginning of the stereo era, about 20 years. The Decca MkVIe GOLD stereo cartridge is the latest version of a basic design which has undergone a continuous evolution since the late 1950s when I first made its acquaintance. At that time, shortly after the introduction of the modern stereo disc, the London/Scott ffss matched stereophonic arm and cartridge was advertised in *Audio,* on page 61 of the January, 1959, issue as being ". . . in a class apart from all the others . . . ." This quote was taken by Scott from a review that appeared on p. 48 of the Sept. 27, 1958, issue of *Saturday Review* magazine. The tip mass was stated as being 1 mg, which was very low for those days, and the ad mentioned the ill effects of tonearm mass/cartridge compliance resonance effects at some low frequency. At that time, the Decca cartridge-arm attachment method required that the Decca cartridge be used only with the Decca arm. Since then, an adapter, which allows the Decca cartridge to be slipped on and off the arm very easily, has been developed, so the Decca cartridge may be used with other arms. More on this later.

I remember my first impression of the early London/Scott arm-cartridge combination was more than favorable. It had an uncanny ability to bring out inner detail in the early stereodiscs and was very revealing. The idea of spending $58.00 for an integrated arm and cartridge (which precluded using cartridges other than the Decca) must have then seemed a disadvantage to some, but it allowed Decca to design for maximum compatibility of the arm-cartridge combination. (In the same issue of *Audio,* for price reference, a GE GC-5 stereo cartridge and a GE universal tonearm were advertised for $26.95 and $29.95 respectively.) It would seem that to this day, the advantages of an integrated arm-cartridge design are traded for flexibility by most buyers. This flexibility probably allows more average or even poor arm-cartridge combinations than it does truly excellent ones. The manufacturers know this but they must respond to demand for flexibility and caution the buyer as to the pitfalls as best they can.

In the case of the present review, both arm and cartridge are made by Decca, but some few tradeoffs in absolute compatibility had to be made to enable other cartridges to be used with the Decca arm. One tradeoff was the increase in effective mass due to the extra mass of the interchangeable headshell arrangement. This is true of all so-called "universal" tonearms which utilize plug-in headshell arrangements. The extra mass of the coupling hardware is usually out at the pickup end of the arm, which is the worst place to add mass.

The quote mentioned previously was true in one sense. The Decca cartridge is in an engineering design class by itself. I am not aware of any other available cartridge which uses the same arrangement of coils or stylus assembly. The arrangement is essentially a vertical-lateral scheme which is electrically matrixed to extract the 45°-45° groove-wall modulations of the modern stereo disc. It derives from the early days of disc cutting. Some disc cutter heads allowed either lateral or vertical discs to be cut. Commercial monophonic phonograph records were lateral-cut discs in which the groove modulations were from side to side. Some radio transcriptions were cut with vertical modulations of the groove, as were the original Edison cylinders.

Some of the first modern stereo discs were cut using a lateral-vertical cutter head; one channel was lateral and the other was vertical. Since effects such as warp, rumble noise, etc. were dissimilar in each channel, it was decided to matrix the signal so that the same effects would be balanced between the channels. This also made the 45°-45° stereo record compatible with mono records since lateral modulation (mono signal) appears equally in both channels, making the source appear to come from the center between two speakers when the listener is positioned between the speakers. (Movement toward the left or right by the listener will cause the apparent source of the sound to come from the nearest speakers due to the Haas or "precedence" effect, since there is no time difference in a mono signal.)

Since phono cartridge designs such as the Western Electric and Decca were available, which had coil configurations allowing either laterally or vertically cut discs to be played, it was natural that a matrix scheme for 45°-45° stereo disc playback would be designed. Such a design is still with us in the Decca MkVIe.

The stylus cantilever system of the Decca cartridge is also different than that used in most other cartridge designs. Rather than being supported by a damping block near the center, the Decca armature is clamped at one end. Figure 1 shows the arrangement. Because the signal from the groove modulations are picked up near the stylus tip, and not at the other end of a cantilever, Decca has called their system "Positive Scanning."

The mass of the Decca London cartridge has been reduced from its predecessors by a factor of over four, a considerable achievement. The susceptability to hum and stray magnetic fields has also been reduced. The output has, at the same time, been increased by about 50 percent. A process called "super cooling" is used to temper the stylus cantilever to eliminate the stress relaxation problems associated with forming it to its final shape.

We feel that the relative ease or difficulty in achieving a satisfactory mounting of arm to turntable and cartridge to carrier is worthy of exposition. In order to be certain that some of the things encountered with the Decca arm were not just due to our single sample, we obtained a second unit for test and there were some differences between the first and second arms. While the mounting flange supplied with the first arm was metal, the flange supplied with the second arm was plastic. We tried to use the metal flange of the first arm with the second arm. There was additional play since the column of the second arm seems to be smaller. Also we discovered that the template supplied with the second arm called for 8⅜ inches from the turntable center to the center of the arm-mounting hole. The mounting distance had been 8½ inches on the template supplied with the first arm, yet the dimensions of both arms themselves are identical. The final pivot-to-stylus distance is set by sliding the cartridge in the headshell, and Decca supplies a template which is to be used to make this adjustment. After mounting the new plastic flange, we realized that the fit of the second flange and arm was too tight to allow easy adjustment of the arm height, so we shaved a small amount from the inside of the plastic flange. After doing this, the arm was mounted and could be adjusted, and there was no play between the arm column and flange after the two locking screws were set.

The template supplied to locate the arm-mounting hole is similar to those supplied by most tonearm manufacturers, requiring that the center of the mounting hole be projected down to the mounting surface. With high turntable platters, this distance can be a source of error, so a good amount of care should be taken to see that center of the projected mounting hole is directly below the hole in the template. An interesting trick is suggested by Decca for platter leveling prior to mounting the cartridge into the headshell. Since there is spirit or bubble level built into the headshell, Decca recommends that the headshell be placed on the edge of the turntable platter and the turntable then made level. After the cartridge is fitted, the headshell can no longer be used this way.

Mounting the Decca cartridge carrier to the Decca headshell, as shown in Fig. 2, is a bit more delicate than the more usual methods. The little spacers can be easily lost, and fumble-fingers are cautioned to take steps to avoid problems of this sort by spreading out a work cloth before beginning. The Decca cartridge slides into the carrier after the carrier has been fitted into the headshell; the Decca cartridge itself has no integral mounting holes. The headshell with cartridge is slipped into a socket on the end of the arm, and while there is no locking mechanism, the fit is tight. In fact, "slipped" is probably not quite a strong enough word to describe the effort required. The Decca cartridge has only three terminals since it uses a common ground terminal; we chose to solder both ground returns to the single ground pin of the cartridge carrier. The clearance between the cartridge and the record is very small so adjustment of the arm height should be checked carefully. Make certain that all the screws are secure and, after adjusting the tracking force with the counterweight, adjust the tilt with the lateral weight adjustment provided.

THE LONDON CARTRIDGE

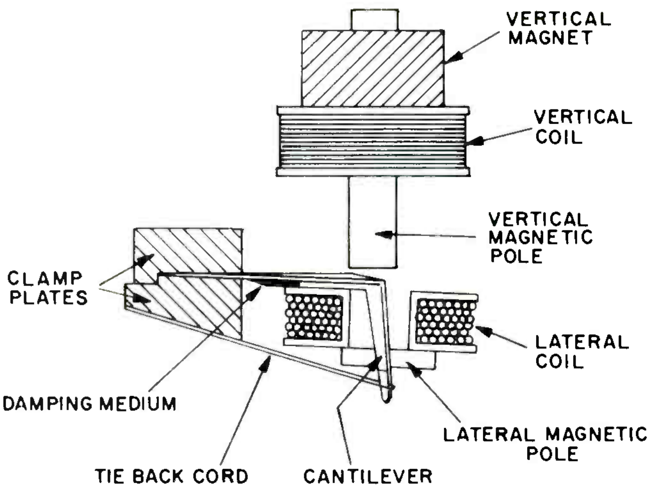


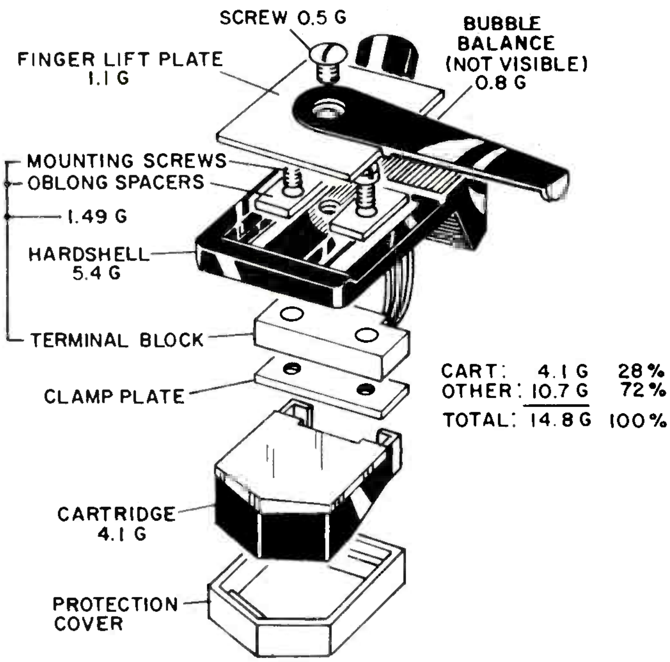
Fig. 1 — Layout of the coils and magnets for the Decca London phono cartridge.

Check to see that there are no rattles or excess play in the arm cartridge system. At this point, we recommend that the viscous fluid be applied to the arm pivot. It will take about 24 hours for the fluid to properly fill the cup around the pivot.

The Decca London arm was mounted to a Pioneer PLC-590 turntable using a 4¾-in. square mounting block of ¾-in. thick particle board which fits neatly and securely into the PLC-590 platform. The arm rest can be mounted by drilling a single hole on most turntables, but in the case of the PLC-590 the area in which the arm rest would be mounted contains the electronic controls.

The Decca London cartridge and headshell plus fittings weigh a total of 14.8 grams, with over 70 percent of this mass

Fig. 2 — Exploded view of the cartridge/headshell mounting and weights.



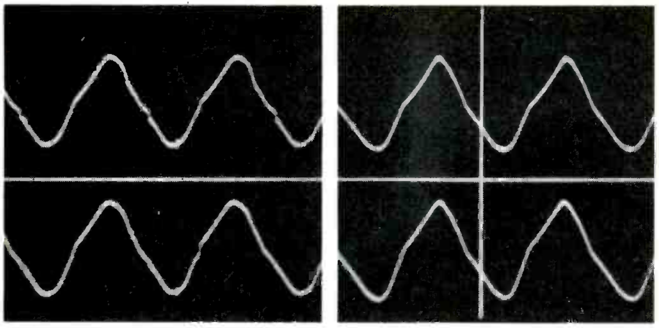


Fig. 3 — Tracking on the CBS STR-112 test record, Band 9,+18 dB re: 11.2 μM at 300 Hz. A) Tracking force at 0.7 gm, and B) at 1.5 gm.

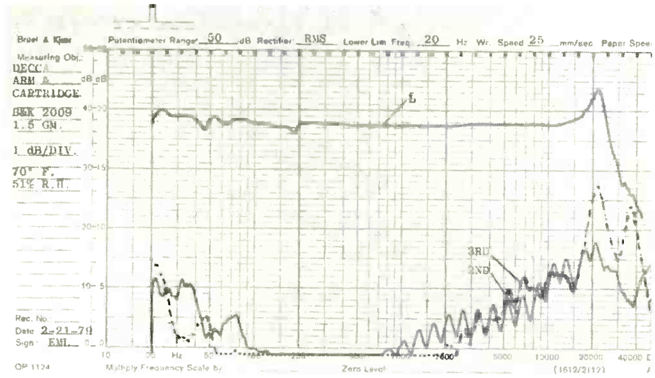


Fig. 4 — Second and third harmonic distortion vs. output in the left channel. Note: Some of the high frequency distortion is due to the B&K 2009 test record.

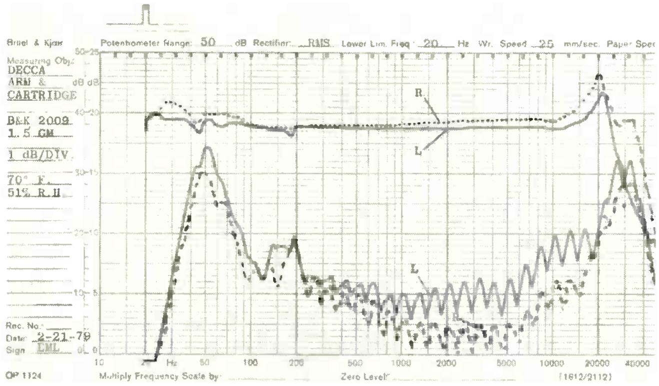


Fig. 5 — Interchannel output vs. frequency with the B&K 2009 test record. Notches in crosstalk are due to filter switching. Note increases in crosstalk at 160 and 200 Hz.

Fig. 6A — Amplitude vs. time on both channels of the B&K 2009 test record, Band 3. Sweep of 20 Hz to 20 kHz, with stop action at 3 kHz.

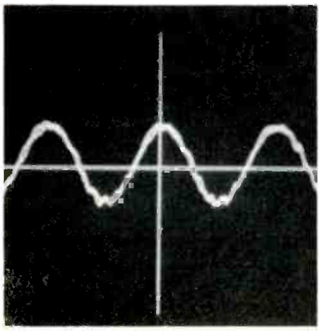
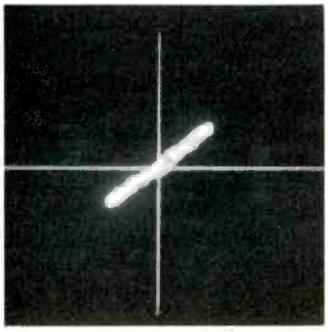


Fig. 6B — X-Y display of right vs. left channel for the same signals as shown in Fig. 6A. Identical channels would make a straight 45° line.

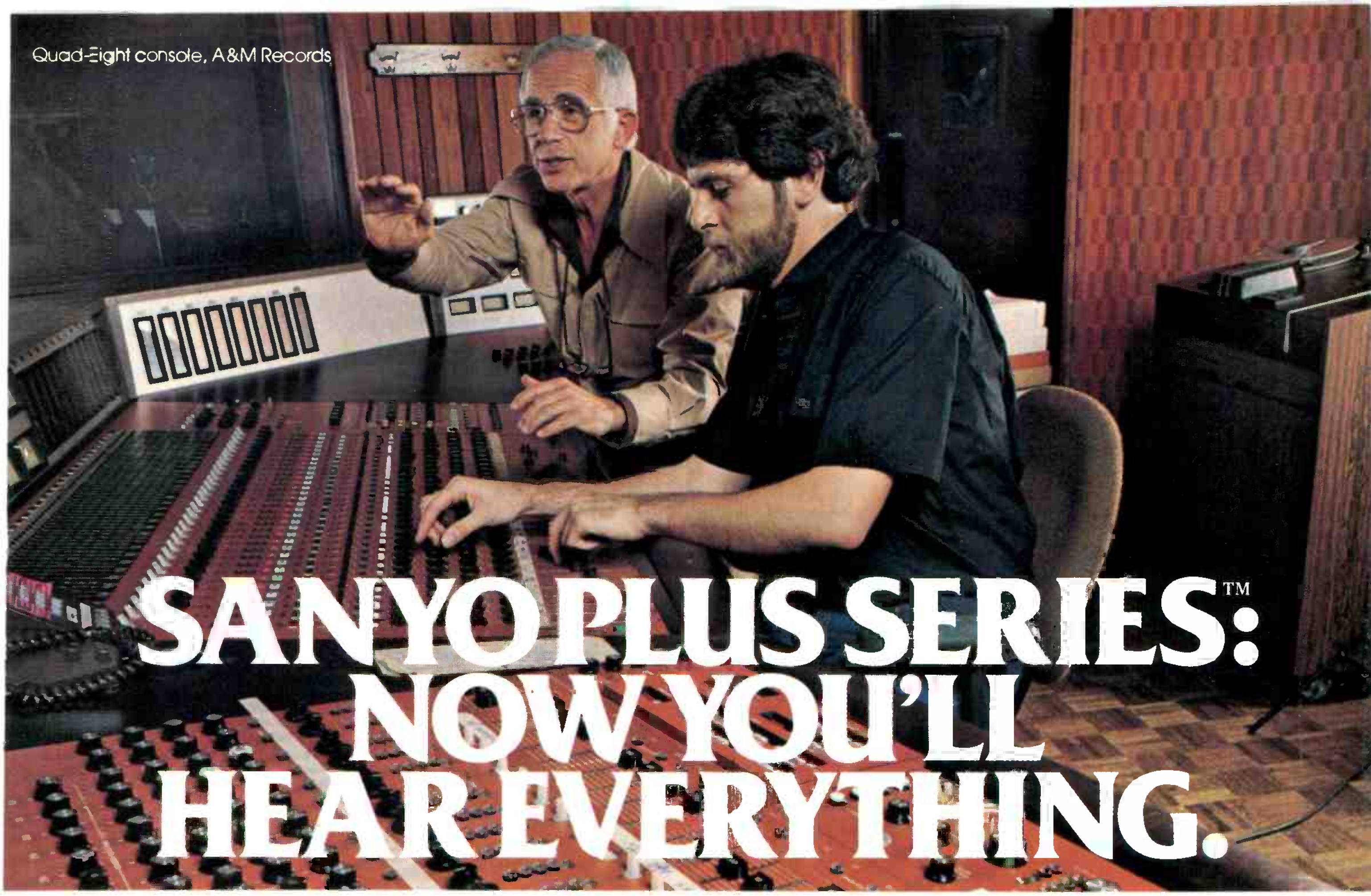


at the end of the tonearm going into the shell and fittings. The cartridge itself weighs 4.1 grams; the headshell 5.4 grams; the plastic holder, threaded bar, screws, and washers 2.9 grams, and the bubble balance and finger lift 2.4 grams. However, Decca has done what they had to do, in a careful way without adding unnecessary mass, in realizing a design where part of what is normally the cartridge body is here part of the headshell.

Figures 3A and 3B show the left (upper) and right (lower) channel outputs while playing band 9 of CBS STR-112. This represents a level of +18 dB referenced to an amplitude of 11.2 μm. The notch in the waveform shown in Fig. 1a indicates slight mistracking at a tracking force of only 0.7 grams. Increasing the tracking force to 1.5 grams eliminates the mistracking but the distortion of the waveform shown in Fig. 3B remains. The listening panel made comments which could be partly attributed to the harmonic distortion exhibited in Figs. 3A and 3B, which occurs at a *very* high level of modulation. At lower modulation levels, the distortion does appear to be lower.

Figure 4 shows the 2nd and 3rd harmonic distortion vs. frequency. It is below 1 percent (-40 dB) until about 700 Hz. It reaches about 6 percent (-24 dB) at 10 kHz. The panel agreed that guitar sounded less precise than when listening to the reference system but had remarkable clarity and detail in the middle register. The lower guitar notes sounded less well controlled and a bit bloated. Flute, while exhibiting a natural spectrum, did sound a bit bright and, perhaps, a little raw . . . saxophone also had this characteristic, but both instruments were reproduced with excellent definition. The rise in amplitude vs. frequency response at about 20 kHz, along with the rise in distortion components, particularly the odd-order components, may account for some of this perceived brightness. The low bass response seemed to be a particular strong point of the Decca arm/cartridge combination. On classical recordings it tended to give the impression of being even a bit better than the reference system. The upper bass was judged a bit poorer than the reference system, being a little heavier or bloated. Perhaps the clue lies in the crosstalk shown in Fig. 5, the crosstalk from about 140 Hz to 200 Hz showing a tendency to increase. The spread of energy between both channels would be affected by this increase in crosstalk, tending to cause the image to be larger than intended. There is also a small discontinuity in the main channel outputs at about 180 Hz, indicating a resonance which means that the sound will not decay immediately in this part of the spectrum, as if notes, in this range, were played with more sustain.

The stereo image appeared relatively stable for simple program material played by small groups. This is corroborated by the data shown in Figs. 6, 7, 8, and 9. Each figure is divided into A) which shows the amplitude vs. time response of each channel of the cartridge to an essentially steady state sinusoidal signal, and B) which presents the left vs. the right channel to the same signal. The photos represent, in another form, the same information shown in Fig. 5, since the same B & K 2009 sweep-frequency test record is used. The waveforms are captured by a digital storage system under computer control. As the swept recording reaches the desired frequency, it is captured. The data stored may be displayed in the different formats seen in the figures without making different measurements. This makes comparisons between the data much more reliable. The cursors (the straight lines in the photos) may be used to relate between the two channels shown in the A) part of each figure or to relate between the A) part and the left vs. right channel format used in the B) part of the figures.



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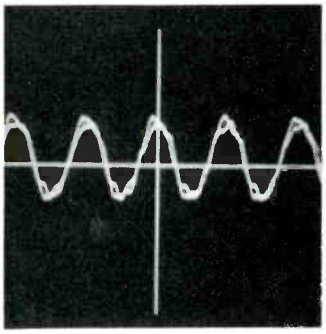


Fig. 7A — Same as Fig. 6A, except stop action at 5 kHz.

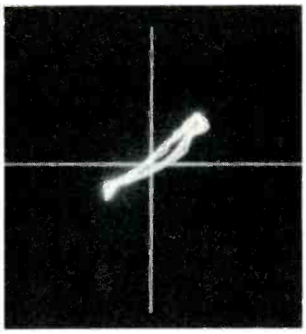


Fig. 7B — Same as Fig. 6 B, except at 5 kHz.

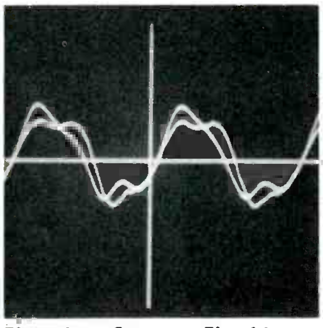


Fig. 8A — Same as Fig. 6A, except stop action at 10 kHz.

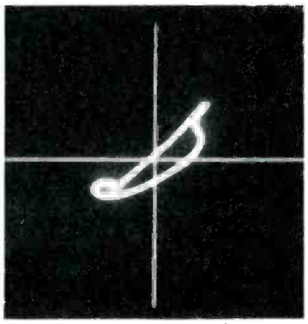


Fig. 8B — Same as Fig. 6B, except at 10 kHz.

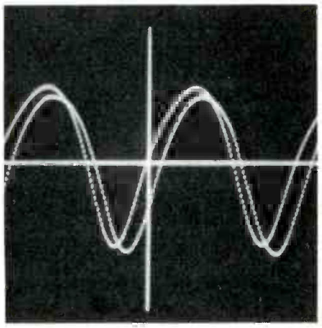


Fig. 9A — Same as Fig. 6A, except stop action at 20 kHz.

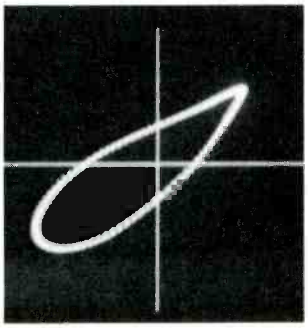


Fig. 9B — Same as Fig. 6B, except at 20 kHz.

The jitter in Figs. 6, 7, 8, and 9 is related to a certain smearing in transients indicated by the listening panel. The jitter can not be seen directly for obvious reasons, but it is indicated by the extent that it is exciting the natural high-frequency resonance of the effective mass at the stylus tip and the compliance of the record material. This resonance is at 23.8 kHz and is fairly prominent. Although waveforms shown in Figs. 6, 7, 8, and 9 appear rather unclean, the condition causing the visual effect is not as aurally disastrous as one might be led to think. To be sure there is an effect, as noted previously, upon the image stability but it is subtle for simple muscial passages.

Figures 10A, B, and C show the response to the 1-kHz square wave of Band 1 of CBS STR-112 test record. This signal represents a fundamental at 1 kHz and the odd harmonics of 1 kHz with known amplitude and phase relationships. The "squareness" of the right and left channel waveforms indicate that the amplitude and phase relationships of the reproduced square wave are very good. The "ringing" indicates that at about the high frequency resonance at 23.8 kHz, there is phase shift and a rise in amplitude. Figure 10B shows that there is also interchannel phase shift at this frequency. The amplitude is also greater in the right channel. The panel noted that there appeared to be a smearing of the high frequencies in both their overtone-to-fundamental relationships but also as related to the positional accuracy of the stereo image. Although this smearing was present it was not thought to be so bad as the photos may lead one to believe. Figure 10C shows the right vs. left channel relationships. Until one has seen many such representations of left vs. right channel responses to the square wave test, it is best to reserve judgment about its effect upon the reproducing accuracy of arm/cartridge combinations. If the reproduction accuracy were perfect, there would be two bright dots in the upper right and lower left quadrants and a few dots on a straight line between them due to the finite rise time of the recorded square-wave test signal and the cartridge.

Figure 11 indicates the scanning loss between the outer and inner grooves due to the interaction of the stylus shape and the modulated groove. The difference shown by the London cartridge is only 3 dB at 20 kHz which is reasonable. Were it not fpr the use of diameter equalization during disc cutting, recorded passages with high frequencies would tend to sound duller in the inner grooves, and the demands made upon the stylus to accurately trace high frequencies in the inner grooves are, of course, increased by the diameter equalization technique.

The "glitches" at 45 Hz and 170 Hz appear about 2 dB worse in Fig. 11 than they do in Figs. 4 and 5. During the testing of the Decca arm and cartridge, the compliant rubber coupler, which isolates the rear of the arm and counterweight from the main part of the arm, became looser. Changes in the exact vertical position of the arm due to changes in the relationship between the two opposing mag-

Fig. 10A — Left and right channels with a 1 kHz square wave from the CBS STR-112 test record at 3.54 cm/sec.

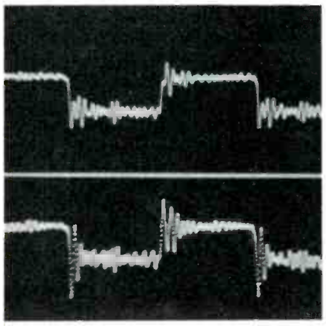
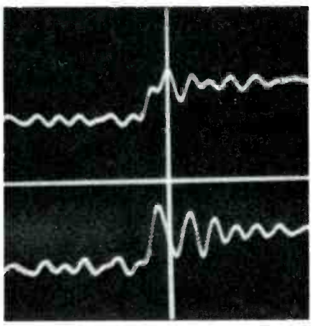


Fig. 10B — Same as Fig. 10A, except expanded to show the leading edge. Note relationship of high frequency phase indicated by vertical cursor.



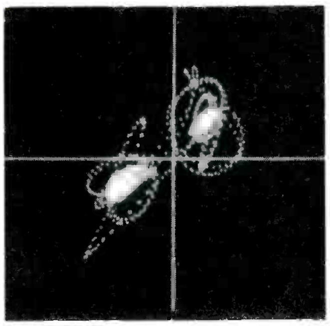


Fig. 10C — Same as Fig. 10A, except left vs. right presentation. For perfect channel relationships the two bright dots should appear in the lower left and upper right quadrants.

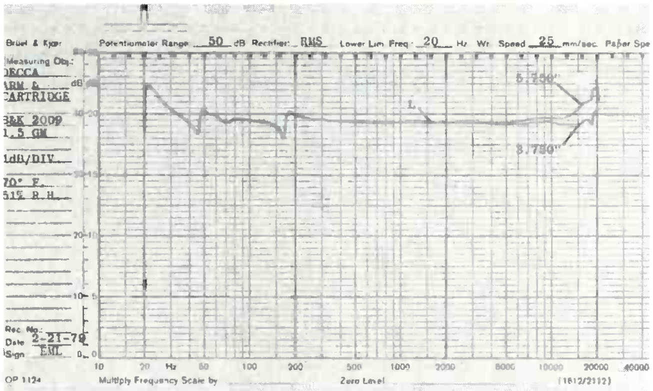


Fig. 11 — Scanning loss vs. disc radius. This loss is due to the geometric relationship between the stylus and the modulated groove. All practical styli will exhibit this effect to varying degrees. Note increase in size of "glitches" at 45 and 170 Hz.

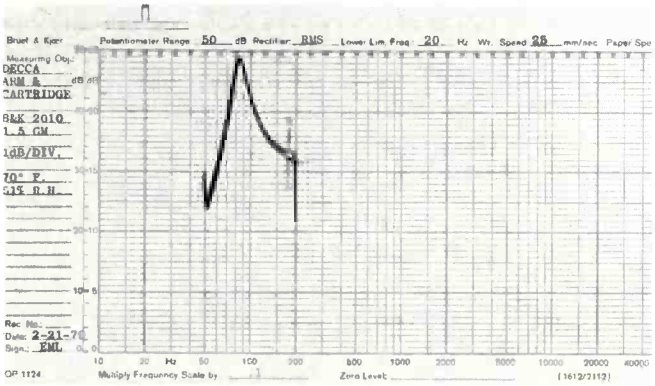


Fig. 12 — Low frequency resonance due to effective tonearm mass and cartridge compliance. Resonance occurs at 8.2 Hz, and Q is 6.3.

Fig. 13 — Rise time of the Decca London phono cartridge, 18 µS.

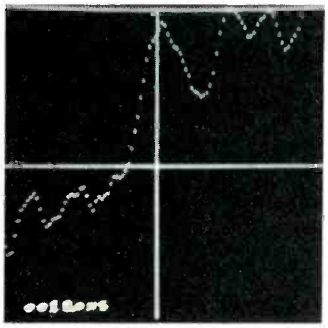
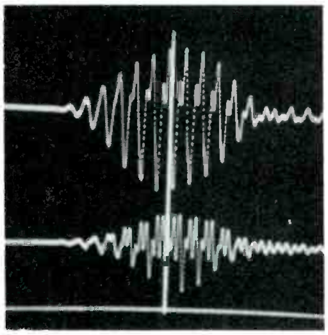


Fig. 14 — Filtered tone burst at 10.7 kHz with the Shure TTR-103 test record, Band 4, at 30 cm/sec. Top trace is the left channel and bottom is the right channel.



nets which float the unipivot from the main pillar also occured. These changes caused the glitch at 180 Hz in Figs. 4 and 5 to shift down to 170 Hz in Fig. 11. During the test for scanning loss, the effects of these changes can be seen as an increase in the Q of these resonances due to these design elements of the arm. The use of opposing magnets to float the arm pillar allows movement between the arm and turntable, and ideally there should be no movement between the arm and turntable. The idea was to reduce the effects of vertical rumble and the transmission of external shocks to the arm/cartridge combination. The coloration in the upper bass range noted by the listening panel can very likely be traced to these resonances. The play in the counterweight and horizontal adjustment weight systems, although partially isolated from the pivot, probably also contributes to the perceived colorations. During the listening tests, great care was taken to minimize these effects, but they could not be totally eliminated.

The low frequency resonance caused by the interaction of the effective mass of the arm and the compliance of the cartridge is shown in Fig. 12. The frequency is a bit lower than desirable and the Q is quite high. The low bass output is affected by this condition and an increase in this range is a direct result of this high Q condition. A large subsonic output can also cause problems in the rest of the reproducing chain.

The rise time of the London cartridge is 18 µS. Figure 13 shows the maximum rise time under the test conditions. An interesting comparison can be made between the Decca London cartridge and the ADC ZLM of a previous report. Although the high frequency resonance of the Decca London is lower at 23.8 kHz than the ADC ZLM at 28.6 kHz, the rise time of the Decca is faster at 18 µS compared to 24 µS for the ADC. The high frequency resonance is due to the interaction of the effective stylus tip mass and the compliance of the record material. The rise time is a function of the mechanical and electrical attributes of the cartridge alone, without reference to the record material. The effective tip mass of the Decca London cartridge appears to be greater than that of the ADC ZLM and yet it is still capable of faster rise time. An interesting quandary, and yet the listening panel made no negative comments about the lack of extreme highs with the Decca London as they did with the ADC ZLM.

The response of the Decca arm and cartridge combination to the 10.7-kHz tone burst on the Shure TTR-103 test record gives another indication of the problems at high frequencies noted by panel members during the listening tests. Spectral information around 10 kHz seems to cause problems for the Decca arm and cartridge. Above 10 kHz, the condition seems to improve. This is verified by the information in Fig. 9 which shows the signal at 20 kHz. It appears less distorted than the 10 kHz signal shown in Fig. 8. The folding in the interchannel phase relationship at 10 kHz shown in Fig. 8B also indicates a more complex problem than the relatively simple phase relationship shown for the 20 kHz signal in Fig. 9B. This interchannel complex relationship can also be seen in Fig. 14 which shows the left (upper) and right (lower) channel responses to the 10.7 kHz tone burst. This test signal allows a further correlation between the quality of reproduction as perceived by the listening panel and technical measurements.

The effect upon the Decca cartridge of various capacitive loading values is not shown, as the capacities would have to be far outside the range normally encountered to be of any consequence. The reason for this immunity to ill effects due to capacitive loading is due mainly to the coils of the Decca London cartridge, the resistance of which is higher than that of most other cartridges (about 2.5 times greater than the

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The RS2010, below, has great performance specs like superb 1.7 μV (9.8 dBf) FM sensitivity, and plenty of power (100 watts min. RMS per channel, into 8 ohms, 20-20,000 Hz, with no more than 0.09% total harmonic distortion). Other models are available from 30 to 150 watts per channel.

Listen to the Fisher RS2000 series receivers. Once you do, you'll never be satisfied with the sound of a receiver without an equalizer.

The RS2010 is about $700* at selected audio dealers or the audio department of your favorite department store.

For a copy of the new Fisher guide to high fidelity, send your name and address and $2 to: Fisher Corporation, Dept. H, 21314 Lassen St., Chatsworth, CA 91311.

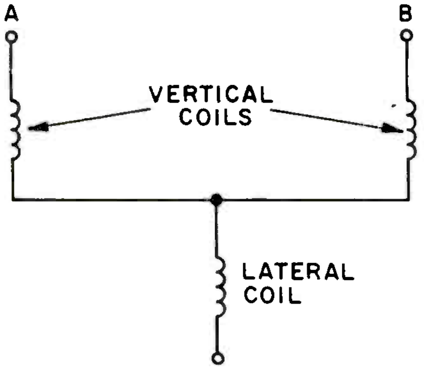
*Manufacturer's suggested retail value. Actual selling price is determined solely by the individual Fisher dealer.

FISHER

The first name in high fidelity.

RS2010

Fig. 15 — Coil schematic for the Decca London phono cartridge. A matrix arrangement of vertical and lateral coils is used to derive the 45°-45° stereo groove modulation information on the record.



ADC ZLM, for example). This means that the Q of these coils is very low, to the point where they act almost as a resistance alone. It also makes measuring the inductance of the Decca London coils a real problem. The coil matrixing scheme, which is used to extract the 45°-45° stereo groove information from what, as described earlier, is a vertical-lateral coil configuration, also contributes to the measurement problem. Figure 15 shows the electrical schematic of the coils. Each channel consists of a vertical coil which is connected in series with the common lateral coil.

The stylus of the Decca London cartridge is centered in a hole of the lateral pole piece by the tension of a tiny string. This string is subject to stretching which can result in a change in the vertical tracking angle as well as a misalignment with respect to the pole piece. Cleaning the stylus and pole area is a very delicate operation, yet it should be done frequently if optimum results are to be obtained, and this can lead to problems after a period of time. The Decca London cartridge must be returned to the selling dealer for exchange, and it will ultimately be returned to Rocelco, the North American distributor.

To conclude this report, I would like to emphasize my personal feelings about the Decca London cartridge. While I feel strongly that the basic design ideas of the Decca cartridge are quite well worth pursuing, the present embodiment of these ideas, the Decca London cartridge, is very delicate and at times frustrating. Also, the combination of the London cartridge with the International arm does not seem to be the ideal combination it could be. The same fussiness in setup and handling vs. the great clarity and detail of sound that have engendered a long-standing "love-hate" relationship among some of us is still present. The end result is a *caveat* to all but truly dedicated and patient audiophiles. A paraphrase of a line from Dickens seems apropos: "It was the best *at* times; it was the worst *at* times."

The many long hours spent preparing this report should indicate that I feel there is great potential in the Decca design. I hope that I have piqued your curiosity enough that you will try to audition a properly setup Decca arm and cartridge combination. If you do, you may well just become a Decca-phile!

Edward M. Long.

Measured Data

Decca London Phono Cartridge

Serial No. E-2870

	Left	Right
Inductance, mH	53.5	53.5
Resistance, ohms	2060	2070
Output mV/cm/sec at 45 degrees (B&K 2009, Band 3)	1.12	1.30

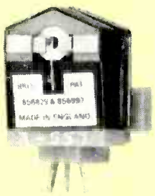
Dynamic Tracking Force, grams required to track B&K 2010 (Gms x 980=dynes)

Band 3, 0 dB (=7.07 cm/sec at 45°)	0.5
Band 4, +2 dB	0.7
Band 5, +4 dB	1.0
Band 6, +6 dB	1.2*
Band 7, +8 dB	1.5*

*Visual Distortion on 'scope

Tracking vs. Radius, grams, (HFS-75,300 Hz, +15 dB, ref. 1.12 x 10^{-3} cm)

Outer Grooves, 0.6
Middle Grooves, 0.7
Inner Grooves, 0.8

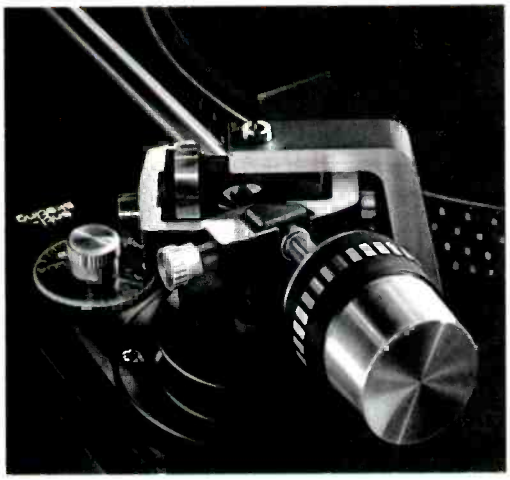


Cartridge Mass: 4.1 gms.
Microphony: Resonant clunk when tapped.
Hum Rejection: Good.
High Frequency Resonance: 23.8 Hz.
Rise Time: 18 μS
Low Frequency Resonance: 8.2 Hz.
Low Frequency Resonance Q: 6.3.
Recommended Load Resistance: 47 kilohms.
Recommended Tracking Force: 1.5 gms.

Decca International Tonearm

Pivot-to-Spindle Distance: 8.5 in. (21.6 cm).
Pivot-to-Stylus Distance: 9.125 in. (23.2 cm).
Pivot-to-Rear of Arm Distance: 2.5 in (6.4 cm).
Spindle-to-Rear of Arm Distance: 11.0 in (27.9 cm).
Overall Height Adjustment: 1.375-2.25 in. (3.5-5.7 cm).
Tracking Force Adjustment, Maximum 1.5 gms (with Decca London cartridge, 4.1 gm).
Cartridge Weight Range: 3 to 10 gms.
Counterweights: Nonremovable.
Counterweight Mounting: Rubber decoupler for rear of arm and counterweight.
Sidethrust Correction: Opposing magnets with moderate uniformity.
Pivot Damping: Viscous fluid.
Lifting Device: Finger lift with accessory Deccalift available.
Headshell Weight: 6.2 gms.
Headshell Offset: 27 degrees.
Overhang Adjustment: Sliding screw mounts in headshell, with template.
Bearing Alignment: Horizontal adjustable weight.
Bearing Friction: Less than 50 mG in both planes, too low to measure accurately.
Bearing Type: Jeweled unipivot.
Lead Torque: Minimal.
Lead Length: 36 in. (91.5 cm).
Structural Resonances: 45 and 170 Hz.
Base Mounting: 1.125-in. diameter hole through board. Flange mounted with two screws.
General Comments: This is a very delicate and fussy arm to set up and use.

We'll match the tonearm on our lowest-priced turntable against the tonearm on their highest-priced turntable.



We'd like to be very clear about what we have in mind. By "their" we mean everyone else's. And, our lowest-priced turntable is the new CS1237.

The CS1237's tonearm is mounted in a four-point gyroscopic gimbal—widely acknowledged as the finest suspension system available. The tonearm is centered, balanced and pivoted exactly where the vertical and horizontal axes intersect.

From pivot to tonearm head, the shape is a straight line, the shortest distance between those two important points. (Curved tonearms may look sexier, but at the cost of extra mass, less rigidity and lateral imbalance—none of which is consistent with good engineering practice.)

Tracking force is applied by a flat-wound spring coiled around the vertical pivot, and this force is maintained equally on each groove wall whether or not the turntable is level. The tonearm's perfect balance is maintained throughout play.

By contrast, tonearms which apply tracking force by shifting the counterweight forward are actually unbalanced during play and prone to mistracking. For example, on warped records the stylus tends to dig in on the uphill side of the warp and to lose contact on the way down.

Vertical-bearing friction in the CS1237 tonearm is astonishingly low—less than 8 milligrams. It can track as low as 0.25 gram—which means it will allow *any* cartridge to operate at its own optimum tracking force.

There's still more. The counterweight is carefully damped to attenuate tonearm resonances. Anti-skating is separately calibrated for all stylus types. Cueing is damped in both directions to prevent bounce. And because the CS1237 can play up to six records in sequence, the stylus angle can be set for optimum vertical tracking in either single-play or multiple-play.

To find any other tonearm that seriously matches the CS1237's, you have two choices.

You can consider one of the more exotic separates. But you'll find they cost as much as the entire CS1237. (Price: less than $180, complete with base and cover.)

Or you might compare it with one of the higher-priced Dual turntables. You'll find a few additional refinements, but no difference in design integrity or manufacturing quality. Which is why no other turntable quite matches a Dual. Any Dual.

For the life of your records **Dual**®

United Audio, 120 So. Columbus Ave., Mt. Vernon, NY 10553

Nakamichi 582 Stereo Cassette Deck

MANUFACTURER'S SPECIFICATIONS

Frequency Response: 20 Hz to 20 kHz.
Harmonic Distortion: 1.0 percent for EXII and SX tapes, 0.8 percent for ZX metal-alloy tape.
Signal/Noise Ratio: 66 dBA with Dolby NR.
Separation: 37 dB.
Crosstalk: 60 dB.
Erasure: 60 dB.
Input Sensitivity: 50 mV.
Output Level: Line, 1.0 V; headphone, 45 mW.
Flutter: 0.05 percent wrms, 0.1 percent W. peak.
Dimensions: 19-11/16 in. (500 mm) W x 5⅛ in. (130 mm) H x 13-¾ in. (350 mm) D.
Weight: 18.3 lbs. (8.3 kg).
Price: $890.00

The Nakamichi 582 deck is of immediate interest because of its ability to use the newly introduced metal-particle tapes. This excellent performing unit also shows its sophistication in its three-head configuration, the transport drive scheme, and other features detailed below. The front-loading tape compartment moves out and tilts with use of *Eject*. After cassette insertion, the top of the door is pushed for smooth closing and latching. Snapping out the clear window obtains excellent accessibility for maintenance tasks. Five small holes in the bottom of the door provide access for height and azimuth adjustments of the record and play heads and for tape-guide alignment. These are all best left to qualified service personnel, with the exception of record azimuth, as discussed later. The heads were of particular interest because of Nakamichi's different approach. The record and play heads both fit within the center opening of the cassette, but the head structures are actually separate. The head surfaces are also cut away beyond the areas of tape contact, which the manufacturer claims will extend head life. Another innovation is the pressure-pad lifter on top of the play head to eliminate the influences of pressure-pad variations.

Tape transport is logic controlled with actuation by six narrow horizontal bars, each with its own status light. The functions are standard with the exception that the use of *Pause* while in fast wind shifts the moving tape close to the play head for a *Cue* mode, with winding at one-third normal speed. Pressing either wind bar at that time will reduce the speed further, which facilitates shuttling back and forth to find the exact spot. This is a well-thought-out scheme for cueing, with the desirable slow wind speeds. It was mildly disappointing, however, that there was no provision for flying-start recording; perhaps not essential, but it's a helpful feature for copying. The 582 does have the nicety of loose-loop take-up which takes the slack out of any cassette when it is inserted, something not mentioned in the Nakamichi literature.

Six rotary switches with small bar knobs provide selection for (1) memory, timer play or record, or *Off;* (2) EX (ferric), SX (chrome-type) or ZX (metal-particle) tapes; (3) 70- or 120-µS EQ; (4) 400-Hz or 15-kHz test tones or *Off;* (5) Dolby NR: out, in and with multiplex filter, and (6) tape or source monitor. There are front-panel adjustments for bias and record

Fig. 1 — Frequency responses with Nakamichi SX tape.

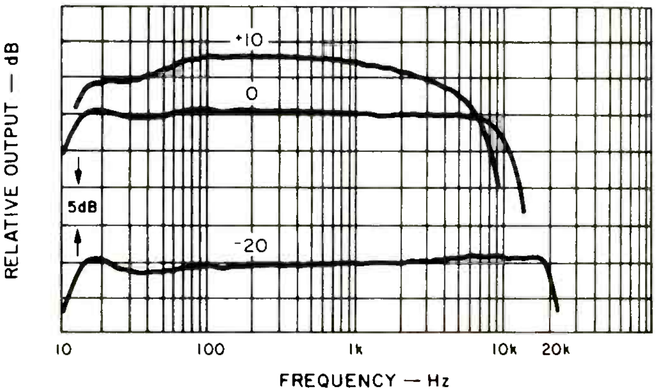
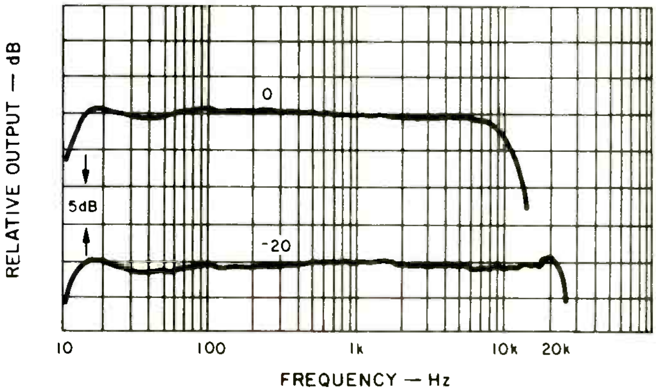


Fig. 2 — Frequency responses with Nakamichi EX-II tape.



level (sensitivity) for each channel and for each tape type. The small access holes aid in aligning the screwdriver provided for the purpose. Record levels are controlled with a dual-section pot in conjunction with a balance pot with center-position detent. The balance pot is different from many in that rotation to gain a relative increase in left, for example, actually reduces the level in right. The output pot has the same style knob, convex-shaped with a knurled band around the edge, easily turned, albeit different.

The wide-range (-40 to +7 dB) meter scales are printed in white and red on the same black background as the rest of the front panel, very legible with the top lighting used. The white lettering used for panel labels and designations was easily read with fairly low levels of illumination. The counter and its reset, the power switch, and the jack for headphones complete the front panel.

There are line in/out phono jacks and a DIN socket on the rear panel. There are sockets for d.c. power to one or more Nakamichi Black Box series components and for an optional remote control, wireless or with cable. The d.c. will power such accessories as a mike mixer, a subsonic filter or a line amplifier. With the top-and-side cover removed, attention could be directed at the internal construction. There were two large PCBs, with the main one about twice the size of the one with all the logic. All of the soldering was excellent, and interconnections were made with multi-pin plugs and wirewrap. Parts were all identified, although the cards were components-down. Some adjustments were marked on the top (solder) side. Mechanical construction was rigid with side and center girders between front and rear panels. The three-motor system appeared to be of quality construction, although there was some slight out-of-roundness noted in the spindle-drive hubs. The use of different diameters was noted, part of Nakamichi's "diffused-resonance" scheme. More on that later. It was interesting to watch the action of the control-cam head-positioning mechanism, driven by the third motor.

Performance

The playback responses of the 582 deck were within ± 1 dB for both equalizations and all frequencies, with the exception of a bit more boost at the highest frequencies on one channel with 70-μS EQ. Level indications from the Dolby standard tape were just 0.6 dB high. As received, the unit was all set up for the Nakamichi EX-II, SX and ZX tapes supplied by the manufacturer. The alignment between the record and playback heads was checked with the record/playback of a 10-kHz tone. The phase error was about 40 degrees which is about half the discrepancy that has been measured on one-housing, sandwich-type record-and-playback heads. Using the built-in 15-kHz (15,278 Hz actual) test tone, alignment was trimmed using the meter indications to -45 degrees, equivalent to -30 degrees at 10 kHz, which is quite good. The tone itself is actually recorded at -20 dB, but a 20-dB amplifier inserted in this test mode obtains the 0-dB indication, which makes alignment much easier. As a means of gaining some information on the effects of tape skew and the stability of the alignment between the separate-but-close record and play heads, no adjustments were made to the record head azimuth for any of the tapes used for the entire duration of the tests. All responses taken showed no signs of high-frequency roll-off, and a 10-kHz phase check at the very end gave results of -35 degrees, substantially the same as at the start — excellent stability. The phase jitter was 40 degrees, better than average for a cassette deck.

The record/playback responses for the three Nakamichi tapes were all outstanding, as shown in Table I and the plots. Take note of the fact that all three are within ± 1 dB from less

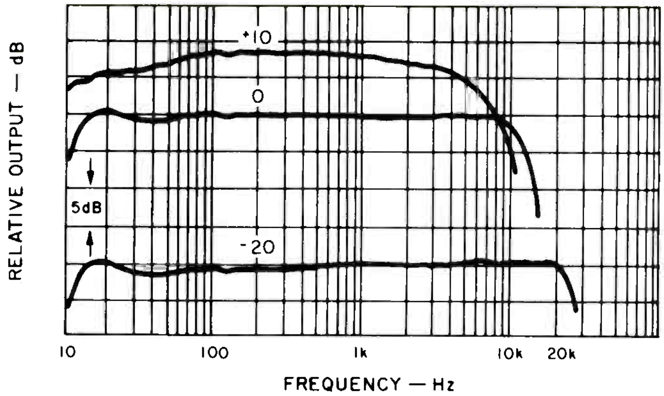


Fig. 3 — Frequency responses with Nakamichi ZX tape.

than 20 Hz to 20 kHz or more at -20 dB. Further note the excellence of the 0-dB responses, particularly for the metal-particle ZX tape. Plots were made of both SX (chrome equivalent) and ZX with +10-dB record level. There is obvious compression with both tapes, but metal-particle is more linear. On the other hand, the results with SX are excellent indeed, superior to many other decks. The Dolby tracking and channel matching was superb in all cases, with any differences less than a dB except at the high-frequency roll-off point. Using the built-in 400-Hz tone (411 Hz actual) to adjust record sensitivity and the 15-kHz tone to set bias, a number of tapes were matched to deliver similar results. Among the best were Fuji FX-I and FX-II, Maxell UD XL I and UD XL II, TDK AD, SA and MA (metal particle), and Scotch Metafine (metal particle). For the tapes mentioned, the responses were within 0.5 dB, as per Crown RTA-2 analyzer, even in Dolby mode, *without* realigning the record head. The record sensitivity controls had close to a 10 dB-range, and with one tape, there was 12-dB peaking at 16 kHz with minimum bias and a reduction of 10 dB across the band with maximum bias, plenty of range. In the multiplex-filter position, the response was down 32.5 dB at 19.05 kHz. Bias in the output during recording was satisfactorily low. The record/playback response of a 1-kHz square wave had a good shape, with some ringing on the leading edge.

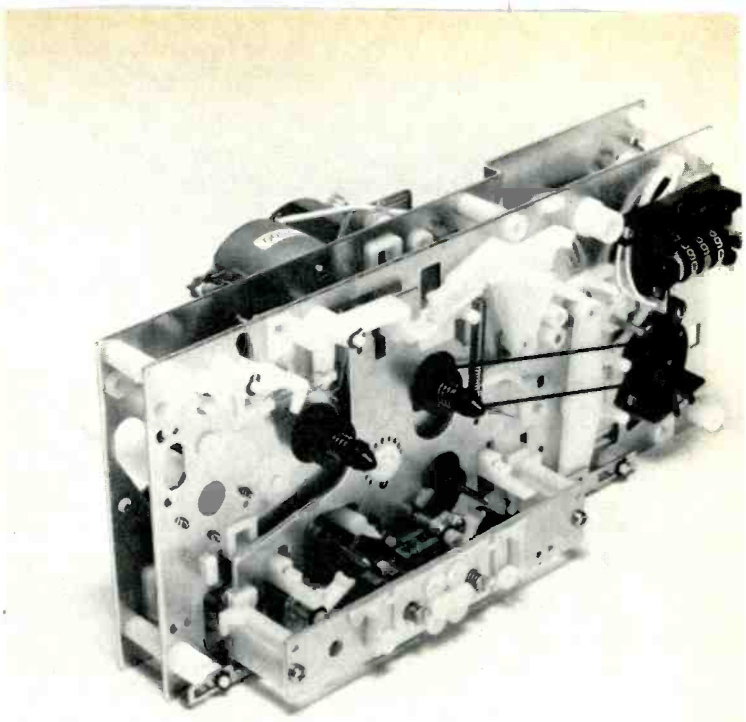
Data on HDL_3 vs. record level was taken on the three tapes at 1 kHz in Dolby mode. The curves were very linear for all tapes with the exception of some curvature at maximum levels. The distortion values were low and quite close for the three tape types, and all had high-level 3-percent points. HDL_3 was measured at -10 dB with ZX tape in Dolby mode from 20 Hz to 7 kHz, with excellent results. HDL_2 and HDL_5 were low at all frequencies and levels, additional evidence of

Table I — Record/playback responses (-3 dB limits).

Tape Type	With Dolby NR				Without Dolby NR			
	Dolby Lvl		-20 dB		Dolby Lvl		-20 dB	
	Hz	kHz	Hz	kHz	Hz	kHz	Hz	kHz
Nakamichi EX-II	11	9.9	11	22.8	11	10.0	11	25.2
Nakamichi SX	12	9.7	11	20.6	12	9.9	11	22.0
Nakamichi ZX	11	12.0	11	22.5	11	12.0	11	23.7

Table II — Signal/noise ratios with IEC A and CCIR/ARM weightings.

Tape Type	IEC A WTD (dBA)				CCIR/ARM (dB)			
	W/Dolby NR		Without NR		W/Dolby NR		Without NR	
	@ DL	HD=3%	@ DL	HD=3%	@ DL	HD=3%	@ DL	HD=3%
Nakamichi EX-II	59.8	66.3	50.3	56.6	58.8	65.3	48.2	54.5
Nakamichi SX	61.6	67.9	52.3	58.3	60.5	66.8	50.4	56.4
Nakamichi ZX	61.5	69.6	52.4	60.2	60.9	69.0	50.6	58.4



excellence in magnetic design. HDL₃ figures were about 40 percent higher without Dolby NR. Signal-to-noise ratios were measured with and without Dolby NR with both IEC A and CCIR/ARM weightings (see Table II). The results are all excellent, and the metal-alloy ZX tape is about 2 dB better than the chrome-type SX tape. At a frequency of 1000 Hz and a record level of 0 dB, erase and crosstalk were about 80 dB down, both *much* better than the specified 60 dB. Separation between tracks was 47 dB, also better than spec. Erasure of the more-challenging 100 Hz with the high-coercivity ZX tape was still a good 67 dB.

Line input sensitivity was 45 mV, and input overload was at a very high 22 V. Output clipping was at a level equivalent to 16.6 dB above meter zero. The sections of the record-level pot were within a dB over a 60-dB range down from maximum. The input impedance was above 50 kilohms out to 10 kHz, with some drop above that frequency. The impedance was reduced when the balance control was rotated for more than a few dB correction, probably an unlikely setting. The line output was 1.0 V to a high impedance in record or in play, both channels—excellent matching and right to spec. The output impedance averaged 2.7 kilohms across the band, which is fine for most situations, but the output did drop 1.5 dB with the standard IHF 10-kilohm load. The sections of the output pot tracked within a dB over a 50-dB range from maximum. The headphone jack was driven at 580 mV (or 43 mW) with the 8-ohm load, plenty high for all types of phones.

The meters had responses 3 dB down at 4 Hz and 25.8 kHz. Their dynamic response was faster than VU-type meters, but they required more than 100 mS for full indication. As they do not meet the British or IEC standards for peak-reading meters, they might be considered "fast-response" meters. Scale calibrations were generally within a fraction of a dB. Tape play speed was about 0.4 percent fast. There was no variation in average tape speed with the changing of line voltage, but there were some small changes with time. Typical values for flutter were 0.095 percent weighted peak and 0.065 percent wrms. In testing for "diffused resonance," spectrum analysis of the flutter test tones in playback of the 582 and another deck with lower readings did show that the 582

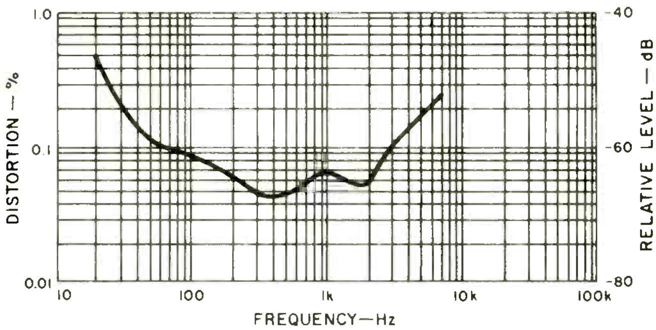


Fig. 4 — Third harmonic distortion vs. frequency in Dolby mode at 10 dB below Dolby level with Nakamichi ZX tape.

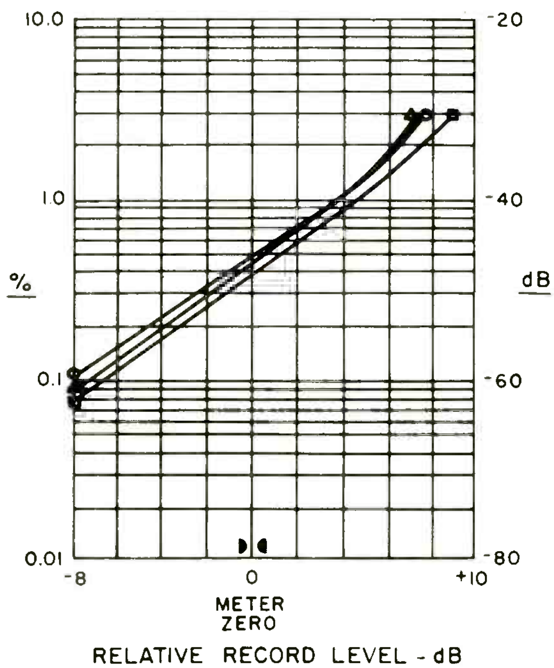


Fig. 5 — Third harmonic distortion vs. level in Dolby mode at 1 kHz with Nakamichi EX-II, SX, and ZX tapes.

did not evidence discrete sidebands as the second deck did. Still, it would seem desirable to keep resonance effects low at the same time they are diffused. Wind times averaged just over 50 seconds, smooth and fast. All response times in tape transport control were 1 second or less. The loose-loop take-up upon cassette insertion automatically put in a 2-second delay to complete that process before accepting a *Play* command.

In-Use Tests

Tape loading and removal was always smooth and simple. Maintenance was easily performed with the removal of the snap-on door cover. The tape-motion controls always worked reliably without any form of malfunction, including the use of *Pause/Cue* for monitoring the tape during fast winds. It was nice to have the status lights in each of the control bars. As suggested earlier, I personally like to make flying-start recordings, but others may find this lack a small thing. The meters were very easy to use with all types of music, and the impression was of faster response than what the tests showed. All switches and pots worked smoothly throughout the testing. Any head adjustments or use of the 400-Hz or 15-kHz tones were most easily accomplished, aided by the meter indications.

The owner's manual has excellent text and very good illustrations. There is coverage on tape selection, and detailed information on record-head alignment and on record-level and bias adjustments for proper tape matching. In the record/listen tests, particular attention was given to piano sources, including a live concert of a Liszt *Hungarian Rhapsody*. Absolutely no indication of flutter appeared during critical listening. The fineness of the reproduction pointed up the limitations in some of the source material, although a Samuel Barber work provided more challenge, which was easily met. The ZX tape was used to copy an open-reel tape of a live performance of Handel's *Dixit Dominus*. At times, the level was purposely set very high, but the results remained impressive even then. Record, pause, and stop noises were substantially non-detectable, with the exception of stop clicks, barely out of the noise. The Nakamichi 582 has a high price for which it delivers superb performance in most every area and the capability to match and use many formulations, including the new metal-particle supertapes. *Howard A. Roberson*

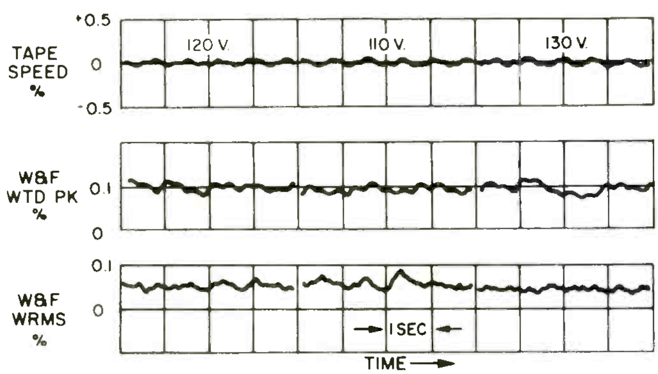


Fig. 6 — Wow and flutter (three trials) and tape play speed vs. time and line voltage.

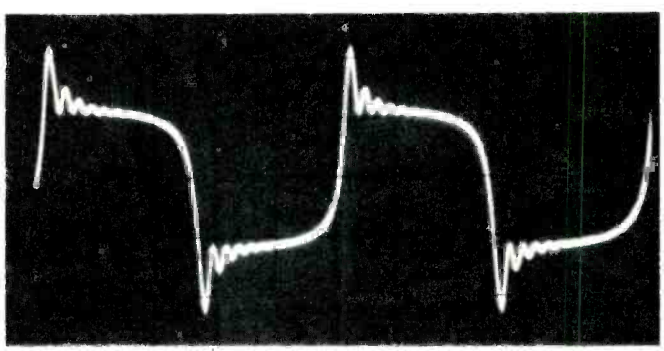


Fig. 7 — Record/playback of a 1-kHz square wave.

Top of the pile

Postscript: The Low-End on Crystal Clear's Virgil Fox Organ Records

When I reviewed the two Fox discs in the April issue, I stated that the low-frequency response went lower than the ⅓-octave analyzer I had access to at that time could register. Since that time, I have been privileged to use the B&K Model 2131 analyzer, which goes down to 1.6 Hz! Response on the disc does, in fact, go down fairly flat to 20 Hz (low E on a 32-foot stop).

The accompanying ⅓-octave spectrum shows response from 4 Hz up to 1600 Hz (*one-tenth* the normal range for examining audio spectra). The spectrum is for the closing measures of the soft, middle section of the *Finale* from the Vierne *Sixth Symphony* on the second of the two discs. This is the portion where the grooves are closely spaced (dark looking) at a radius of about 3.5 to 3.75 inches. Those measures end with a low G in the pedals (about 24 Hz); note that the peak for this is in the 25 Hz band of the spectrum analyzer.

I mentioned in the earlier review that a simple equation could be used to determine low frequencies directly by inspection of the disc. Where a clear moire pattern can be seen, we can use this equation:

$$\text{frequency} = \frac{(.555)2\pi a}{l}$$

where a is the radius (in inches) where the pattern can be seen, and l is the distance (in inches) between successive repetitions of the pattern.

Examining the passage in question, note that the radius is about 3.5 inches. Just before the high-level program returns, note that the spacing in the pattern is about 0.5 inch. Hold the disc so that it picks up the reflection of a large, brightly lit surface, and you will have no difficulty seeing the pattern. Putting these numbers into the equation yields a frequency of 24.4 Hz, in close agreement with what we know to be on the disc at that point. Those readers who really want to be convinced that the recordings contain information even lower than this are invited to examine side II of the Bach recording (end of band 2). Moire patterns are quite in evidence here, some of them about 11/16 inch at a diameter of 4 inches. This corresponds to low E at about 20 Hz.

Now, if loudspeakers only went down that low . . . . *John M. Eargle*

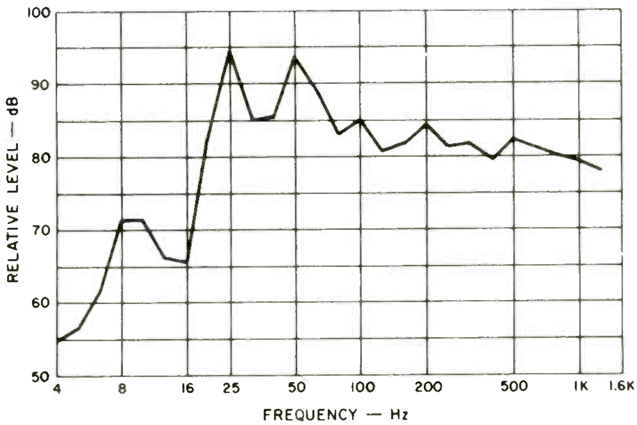


Fig. 1 — Peak-hold spectrum of Crystal Clear's Virgil Fox Vierne *Sixth Symphony*.

Comparison of Two Technologies

Chopin Program: Malcolm Frager, piano. Telarc DG-10040, digital recording/half-speed transfer, $17.98.

Chopin Program: Edward Auer, piano. RVC RDCE-7, direct-to-disc, $15.95.

When these two discs arrived some weeks ago, I saw an excellent opportunity to compare two techniques of recording: "direct to disc" and "digital half speed to disc." With two such companies as Telarc and RVC, I knew that both discs would be excellent. I also felt before playing these discs that most of the aspects of technology, *per se*, would be pretty much subordinated to the musical variables. My surmises were correct; the choice of recording venue, instrument, performer, microphones, and microphone placement easily mask the respective advantages and disadvantages of direct-to-disc and digital-to-disc technologies. Of course, this is the way it should be.

Let us begin with the Telarc disc. The instrument on which Malcolm Frager plays is a Bosendorfer Imperial grand, a nine-foot, six-inch Austrian instrument which has nine more notes at the bottom of the range than are found on a standard grand piano. Although these notes are not used in Frager's Chopin program, the extra size of the instrument results in more breadth in the lower range than is typical for a standard nine-foot concert grand. Of course, miking has a great deal to do with the expansive low end of this record. Spaced-apart B & K omnis were used; these are instrumentation microphones and, as such, have not been optimized in terms of residual noise spectra for recording use. This is clear from an examination of Fig. 1. The higher noise floor of the Telarc disc is noticeable at slightly elevated listening levels. One assumes, based on hearings of quieter discs transferred from digital sources, that the noise is due to the microphones and not the Soundstream recorder.

The most notable aspect of the Bosendorfer's character is not the basic spectrum, which has far more bottom end than the Steinway used in the RVC disc, but rather the glorious way the instrument behaves during crescendos. We are all used to pianos which "clang" during louder passages. Not so with the Bosendorfer; it maintains its superb balance at all levels.

The Steinway played by Edward Auer in the RVC disc is typical of the brightly voiced Steinways which are to be found all over Japan. The spectral differences between the two instruments are apparent from Fig. 2. Note the wide difference in the spectra between 50 and 160 Hz. Actually, a "normal" piano recording, if we can refer to such a thing, would have a spectral balance somewhere between these two recordings. Overall, the Telarc disc comes across as the better sounding instrument if the listener thins out the LF response somewhat. The RVC disc sounds a bit brash on peaks and does not quite hold its own at inner grooves.

As far as high-frequency energy is concerned, both discs are cut at about the same level. One good friend in the audiophile community has told me of repeated difficulties in tracking the Telarc disc, but I can attest to no problems at all, using either the Pioneer PC1000-II (a superlative Japanese moving-magnet cartridge) or the Ortofon MC-20 cartridges.

Both discs are practically flawless in terms of ticks and pops. The Telarc disc, interestingly, begins modulation at a somewhat *smaller* diameter than is standard. The effect of this is to reduce to nothing the usual "roar" that one often hears during lead-in grooves just prior to the start of modulation (due to crimping of the metal stamper for forming the grooveguard contour of the disc).

Both players are excellent. Frazer's brand of musical intelligence seems to me to be best suited for Chopin. He delineates the musical structure in a more logical way than Auer, whose playing tends more toward episodical treatment of the music.

In terms of packaging, the honors must go to Telarc. One gets the impression, and accurately so, that the Frager disc is the product of professionalism on all counts, including excellent notes on the music by the organist, Michael Murray. The RVC disc is thoroughly a Japanese production, giving due attention to the disc as essentially an audiophile production with lots of photos of the session, microphone layouts, and the like.

John Eargle

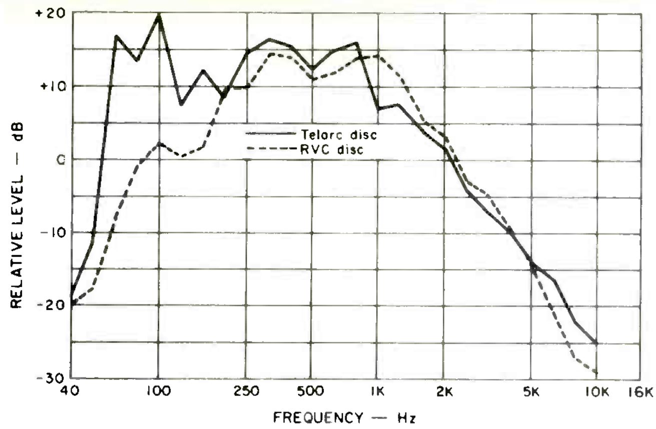


Fig. 1 — Noise spectra. Unmodulated grooves between bands, A-weighted. Solid line, Frager disc; dashed line, Auer disc.

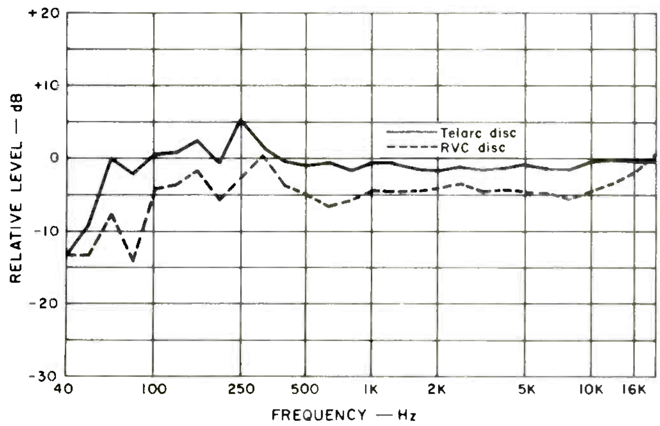


Fig. 2 — Peak-hold ⅓-octave spectra. Solid line, Frager disc, last measures of *Polonaise* in A-flat. Dashed line, Auer disc, closing measures of *Scherzo* in B-flat minor.

Gershwin: Concerto in F for Piano and Orchestra, An American in Paris, Rhapsody in Blue. Jerome Lowenthal, piano; Utah Sym. Orch., M. Abravanel, cond. **Vanguard/Barclay-Crocker Van E 10017,** stereo, $8.95.

This has always been one of my favorite versions of these works . . . but only because I had become familiar with the original Dolby A master tapes during my engineering days at Vanguard. To be perfectly honest, the disc version of this recording is abominable, mostly due to the fact that each side is over 31 minutes long. This much music, with such a wide dynamic range, simply cannot be compressed on to a single disc without suffering the consequences of muddied and distorted sound.

But now, thanks to Barclay-Crocker, the sound of the Utah Symphony and the Mormon Tabernacle has been returned to their original sonic splendor. Particularly impressive are the percussive opening bars of the concerto.

As I recall, this recording was produced in the late 1960s, with a half dozen or so mikes mixed directly onto two tracks and utilized the then relatively new Dolby A process. Since all the balances were set at the original recording session, there was little or no processing of the tapes later on. The usual careful Barclay-Crocker duplication process gives us a tape that is a perfect replica of that two track original. Thank you, Barclay-Crocker!

Charles P. Repka

Chopin: Scherzo No. 2 in B Flat Minor; Piano Sonata No. 3 in B Minor. Edward Auer. **RCA RDCE-7,** direct-to-disc, stereo, $15.95.

You can't generalize about a system such as direct-to-disc. I find the added sound quality and the much shortened content seldom worth the cost, for my musical ears — but who knows? This one I'd go for any day.

It is not merely good in sound . . . that we ought take for granted, if the disc goes into production under RCA's name and at such a price. More than the sound, the piano itself is very well picked up by the mikes from a musical point of view, an excellent sound, hard, clean, and sharp. And the performances of the two big Chopin works are exemplary. Indeed, it is a fine thing to have top-quality audio and fine music combined!

Edward Auer is an American and looks it, but in this operation he is surrounded (see album) by swarms of Japanese colleagues, the technicians who produced this disc in a Japanese concert hall. For your money you get the usual gatefold album full of photos and statistics, Neumann M-49C, U-67, Schoeps CMC-55, Studer 089 console, also Neumann 169, and so on right down to the cutting stylus and the monitor speakers, JBL and KEF. Wow — they even list the lacquer, the inimitable Pyral. There are mike diagrams, three of them close to the piano on stage and four more, M-49C, far out among the empty seats. (We aren't yet quite back to the one-mike technique, it seems). All of this, typical of many direct-to-the disc offerings, is instructive and interesting for the eye and the mind. But what matters is the disc itself and this one is good from every viewpoint. Also, I might note, it is a good solid length. (One earlier RCA ran about six minutes per full LP side, at double price!)

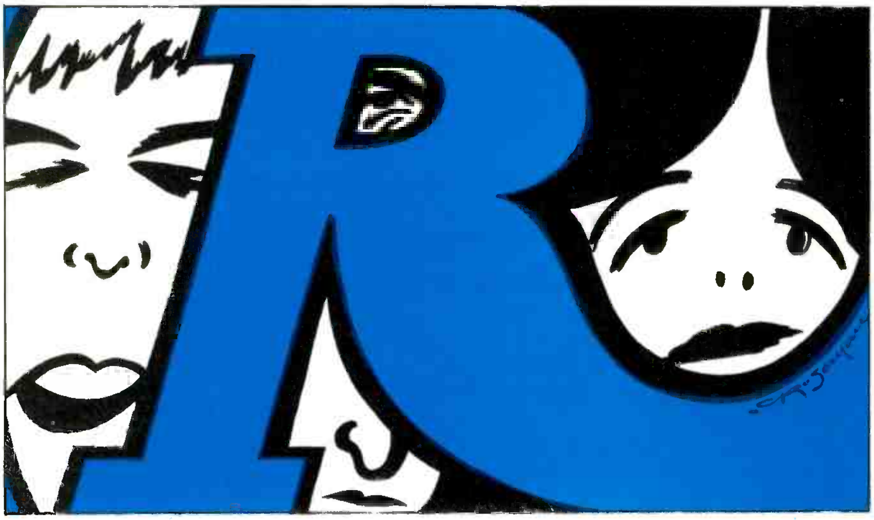
Edward Tatnall Canby

Sound: A Recording: A- Surface: A-

The column

Michael Tearson

Jon Tiven



The Roches
Warner Bros. BSK 3298, stereo, $7.98.

The Roches — sisters Maggie, Terre and Suzzy — are something most special in the context of what has been happening to popular music. Their album innocently, artfully, entrancingly flaunts the face of "What Sells" to present an album whose acoustic starkness rivets your attention to the marvelous instruments that the three voices are. The producer is Robert Fripp who has been slowly coming out of his post-King Crimson quiet.

The Roches sing of a dog's life — how nice and fun-filled affairs with married men are and the fretting caused by the inconveniences of an imminent tour of Ireland (that never actually took place) — such as the danger of no health food. Then there's going to Mr. Sellack at the restaurant to beg for a job back. And commuter trains. And more. There's *We* which serves as their all-purpose introduction and question answerer — "Sometime our voices give out/But not our ages and our phone numbers." *Hammond Song,* which follows, has perhaps the lushest production of anything on the album. While relating poignantly the inevitable parent/child split, the voices blend into organ-like sustained chords. *Mr. Sellack* is mock vaudeville at its best, when Maggie's voice swoops low to sing "Give me a broom and I'll sweep my way to heaven." Terre's *Runs in the Family,* with a haunting melody and arrangement, is the old family-way thing. Song after song are crystalline gems.

There is a magic in their live performances that inevitably is missing on record. What Fripp calls "Produced in Audio Verite" is more or less an enhanced live performance. The "enhanced" is the almost subliminal little swirls or lines of synthesizer or guitar. Fripp calls much of this effect Fripperies, and his newly released and forthcoming solo projects bear serious listening.

But I digress.

That The Roches' album (their second, the first being a duo album on another label and long out of print, of course) is something special is obvious. It is at once mature and innocent, with wit and charm in ever-shifting complementary amounts. Most of all, they have real identity. Cherish them. Hear their record. *M.T.*

Sound: B+ Performance: A

Flag: James Taylor
Columbia FC 36058, stereo, $8.98.

Flag is a different record than I expected from James Taylor at this time. The last one, **JT,** was all gloss and no core to my ears. But it was a gigantic success. **Flag** says a bit more and with more gumption than James has shown in a long while. Producer Peter Asher, professional as ever, has coaxed a more aggressive biting sound out of James and the session guys.

The best stuff is the most charged emotionally. *I Will Not Lie* is sung to the lady of a brother after she's been coming on. *Johnnie Comes Back* is about various additions. *Sleep Come Free Me* is for the convict, *Millworker* is for the factory girl. A song from James' album for Apple long ago, *Rainy Day Man*, resurfaces in a beautiful updating. On the lighter side fall the doo-wop of *Is That the Way You Look?* and the near dance beat of *Day Tripper*. Another oldie, *Up on the Roof*, drags and falls flat.

The formula hasn't really been changed on **Flag.** The sound is safe, if fun and slightly bracing. Somehow **Flag** makes me think of the spirit of Woody Guthrie, and I suspect that would please James. *M.T.*

Sound: A- Performance: B+

Van Halen II: Van Halen
Warner Bros. HS 3312, stereo, $8.98.

One of Tearson's laws of Rock Marketplace Dynamics states that "there is always an ugly hard rock band that is fabulously successful." This year's Grand Funk Railroad is Van Halen. 'Nuff said. *M.T.*

Sound: C Performance: C-

You're Never Alone With A Schizophrenic: Ian Hunter
Chrysalis CHR 1214, stereo, $7.98.

Poor Ian Hunter. Back on the comeback trail after over three years of inactivity, old shade-eyes has hooked up with his former companion Mick Ronson (who was first in his group, then his producer *and* in his group, then split to join Bob Dylan's band) now that both are thoroughly American-

Breakfast in America: Supertramp
A&M SP-3708, stereo, $8.98.

Supertramp is a state-of-the-art recording band. Their production and sound coalesced several albums ago on **Crime of the Century** and has become ever more refined through **Crisis . . . What Crisis?** and **Even in the Quietest Moments,** which was their first self-produced album. They have become an audio experience that is almost unsurpassed on conventional albums. They were also one of the first groups represented on the recent super-fidelity remasterings with **Crime.**

Breakfast in America, the new chapter, is the most lavishly wrought yet. Musically it is perhaps not the most arresting they've done, but with time and familiarity the songs have the remarkability of becoming friends. The central conceptual core is the old theme of the rigors of the road, but the group has some fun with it and their spirit is always good-natured. *The Logical Song,* which has become their biggest hit very rapidly, is a goodie. *Goodbye Stranger* and *Just Another Nervous Wreck* are two more. The only one that lets me down is the finale, *Child of Vision,* which could easily have been cut a couple minutes earlier than it was.

Special kudos to the guys at Village Recorders in L.A. who obviously put a lot of love into the project.

Supertramp has gradually evolved into a top-rate functioning pop group. Their records sound terrific. And live, if you've not seen them, they are an absolute delight. **Breakfast in America** has all the earmarks of a breakthrough album. *M.T.*

Sound: A Performance: Aized and hungry for fame. Originally the album was to be recorded in England with a former Sex Pistol and an ex-Jethro Tuller, but when that situation flopped Mick and Ian recruited Bruce Springsteen's rhythm section and keyboardist to get Ian back on track. The result is a surprisingly hard-hitting record, not quite as incredible as the Roy Thomas Baker-produced **Overweight Angels,** but certainly more consistent.

Actually, the songs on the record resemble the simplistic rock tunes of Ian's first solo album (produced by Ronno) and late period Mott The Hoople more than the lame Americanisms of the more recent **All American Alien Boy** or the ultra gimmicky **Angels.** I expected that Hunter's new album would be a companion piece to Springsteen's **Born To Run,** but if I hadn't been told beforehand that the E-Streeters were accompanying him, there's no way I would have guessed. The sound is overall much harder and Ronson's guitar sears through, without upstaging front-and-center Hunter.

Not that these are his best tunes ever, as it seems with songs like *Cleveland Rocks, When the Daylight Comes,* and *Bastard* that he's gearing

himself a little too strongly towards what is "commercial for American audiences," but at least his hunger drives home some fine performances (the opening cuts on each side and *Wild East* in particular). There's nothing to touch the perfection of *All the Way From Memphis, Once Bitten Twice Shy,* or even *Marionette* here — but who cares? Ian Hunter at his most average is still miles beyond most of the crud around, and this is well above average. *J. T.*

Sound: B Performance: B

Handsworth Revolution: Steel Pulse
Mango Mlps 9502, stereo, $7.98.

Steel Pulse's reggae is fine, deep, heady stuff. They feel a lot like Bob Marley and The Wailers' **Burnin'** album, both in material and sound thrusts. The sound is actually very good reggae sound with a big, big bass, crisp percussion, voice mixed nicely up and backing voices convincing as counter-currents. The album is sorely deficient in credits, which, of course, doesn't affect the music at all. But it bothers me, because I look for things like that. Steel Pulse is prototype reggae. *M.T.*

Sound: A- Performance: B

Wave: Patti Smith Group
Arista AB 4221, stereo, $7.98.

If not for the collaboration with Bruce Springsteen on *Because the Night,* Patti Smith would have gotten kicked off her record company and probably never made a record again, but we are not so fortunate. Ms. Smith got her hit, and her latest album's first song, *Frederick,* is a lame attempt at another by taking Bruce's vocal improv from the fade of *Prove It All Night* and turning it into a song about her latest squeeze, Fred Sonic Smith (ex-MC5). Whether it becomes a hit or not — tis not for me to say — the semi-disco beat and noticeable lack of guitars seem to pave the way for Patti Smith's career as an MOR torch singer/civil libertarian.

Wave is a confusing and barely musical statement lacking both quality and direction. Of course, Smith's background is hardly a musical one, so when you see her fall back on her traditional roots it means she reverts to Sixties covers *(So You Want to be a Rock 'n' Roll Star* — which adds nothing to the version by The Byrds in terms of interpretation or vigor) and production by ex-boyfriends (this time Todd Rundgren). It's difficult to take

the band seriously, as no one in the group can really play, with the possible exception of guitarist Ivan Kral (who is a fair rhythm player). They never fall into any kind of a groove or sound like they're playing together — they all sound like they're playing "parts" from a lead sheet. No matter, as Smith will no doubt fire them when she records her disco album, or her Edith Piaf tribute album. Once I was worried that Patti Smith's records would give rock music a bad name, but since what she does is hardly what I'd call rock, it's more like she's giving poetry albums a bad name.

Rolphe Young

Sound: B Performance: D

Twilley: Dwight Twilley
Arista AB 4214, stereo, $7.98.

The innate talent of Dwight Twilley is undeniable, but perhaps the most surprising aspect of his career is that his first single, *I'm On Fire,* was a solid hit. He's found it difficult to grapple with the reality of not having a hit since '75, and unfortunately he's made some poor decisions along the way which have further hampered his career. He's refused to find an ally either in a musical partner or producer to help guide him, most recently chucking his co-frontman Phil Seymour (who actually had a sterling voice as well as an uncanny drum sound), and instead has become a member of a dangerous clique that has endangered the careers of even the most secure rock stars, The Society of Self-Produced Solo Artists. His third album, *Twilley,* although loaded with rough gems, has about as much chance at the charts as Ornette Coleman.

First off, the song order of the album is all wrong — it starts off with an Electric Light Orchestra/John Lennon type ballad that's untypical of the album as a whole and which isn't exactly a quality piece of work. The best songs on the album, *Standing in the Shadow of Love, Darlin',* and *I Wanna Make Love To You,* are buried at the end of side one and the middle of side two where radio programmers can easily miss them. What's more, the sequencing is sloppy — songs in the same key and similar sounding are placed together, an instant tune-out to any listener. It's as if they didn't even care how the album held together as long as the songs they chose for singles got priority placement.

Secondly, Dwight Twilley has always distinguished himself from the rest of the power-pop set by his strong rhythms, and without Phil the drums simply aren't there. His vocals could be stronger, not to mention better recorded, and the album's mix is messy and not hard enough. Rumors have it that the entire production crew and Dwight were on acid during the recording (which could explain the cops from **Sgt. Pepper's** *She's Leaving Home* in *Darlin'*) but that's a sure way to sabotage a recording career if there ever was one. Dwight Twilley is badly in need of help to make the album he wants to; the three best tunes on this record are very good, but by the third album he should be making hits and not songs that sound like they could have been hits sometime in the last 20 years. *Sally Young*

Sound: D+ Performance: B-

Wavelength: Van Morrison
Warner BSK 3213, stereo, $7.98.

Compared to last year's very tentative sounding **A Period of Transition** which was the first Van Morrison album in over three years, **Wavelength** is very impressive. Some songs might not be as strong as Samson, but Van has finally made an album that *feels* right. Where **Transition** was forced and stiff, **Wavelength** is relaxed and swinging. At its best — *Kingdom Hall, Natalia* and the terrific title song — it is stirring even if there is nothing really new going on.

The band is just right. Peter Bardens on keyboards used to play with Van in Them nearly 15 years ago. Former Jeff Beck vocalist Bobby Tench adds guitars here and, with the rhythm section of Peter Van Hooke and Mickey Feat, couldn't be a better fit for Van. Garth Hudson of the Band cameos with accordion, synthesizer, and organ on several cuts. And no Van Morrison album is complete without the angel voices he's been partial to for so long.

Judging from the cover photo, Van has lost weight since the Band's *Last Waltz* film in which he appeared fat. His health looks radiant, and it shows in the music. **Wavelength** may or may not bring Van Morrison back to the foreground where he belongs, but it feels good. *M.T.*

Sound: B Performance: B

Jazz & blues

Einstein on the Beach: Philip Glass
Tomato TOM-4-2901, four records, stereo, $29.98.

Einstein on the Beach is a collaborative opera between Philip Glass, who wrote the music and lyrics, and dramatist Robert Wilson, who designed the staging and directed the performance. The work stands as a high plateau in Glass's career. He is associated with the Holy Trinity of minimalist music which includes Steve Reich and Terry Riley along with their Godhead, LaMonte Young. The unifying factor is their use of cycles and layers along with a pervasive Eastern aura. While the music of the other three tends to be too ascetic or cerebral for many people, Glass has maintained a relatively large following with his electric instrumentation and heavy-metal baroque structures.

Einstein is of a piece, musically, with earlier Glass works. In fact, themes from *North Star* and *Music in Similar Motion* crop up at different points with new arrangements. Glass writes music in synchronized layers of short, shifting rhythmic and harmonic patterns. While using an additive process of composition, he tends to break down the various elements into a seemingly infinite array of surfaces and perspectives. The mix of soprano reeds, voices, and electronic keyboards is often demonic in its stroboscopic intensity, yet he also creates a Gothic religious fervor with extensive organ and choral counterpoints.

Glass's music is perfectly suited to a surrealistic representation of Einstein. Its insistent repetition and permutation suggest the infinity of Einstein's theory of relativity. The one flaw in **Einstein** is Glass's literal descriptions of the music while it is in progress. The singers are often found chanting numbers (one, two, three, . . . six) or singing in solfeggio (do, re, mi . . .). According to Glass's notes, the numbers represent rhythmic structure and the solfeggio represents the harmonic patterns. In terms of the scope and force of Glass's work, these effects seem to trivialize it and tie it down to something less than transcendent.

Under repeated listenings, any faults become obscured by the overall thrust of this work. The nearly three hours of **Einstein** is almost effortless listening when taken as a whole. With a limited number of shadings to choose from, Glass has created rainbows. The album is full of contrasts such as the solo violin of Paul Zukofsky (Einstein played violin for relaxation) which is joined by the full-blown Glass ensemble. Glass shifts emphasis from juggernaut rhythms to the plaintive organ and voice section of *Bed*. There is also the new addition of humor. The "Trial/Prison" scene features an incoherently babbling judge and concludes with a disjointed dissertation on WABC radio station in New York.

Einstein on the Beach was recorded and mixed under the supervision of Kurt Munkacsi. Since Munkacsi has been Glass's personal soundman for years, it accounts for the fully realized, all-encompassing presence that is essential to Glass's work. Glass has been a primary influence on the music of Tangerine Dream, Mike Oldfield, and Brian Eno. With **Einstein on the Beach** he sends up a flare from the source.

John Diliberto

Sound: B+ Performance: A-

Double Date: Sam Donahue & Les Brown
HEP 14, stereo, $7.98.

What a lesson in precision big band jazz can be found on this little gem imported from Great Britain. These are two stereo broadcasts recorded on the West Coast in 1957 and 1958 by two of the most skillful big bands of the time. The way the sections attack and release, the matching tones of the saxophonists in both bands blending in the ensemble are something to marvel at. Stick your stylus onto the Donahue *More Than You Know* track and revel in the fantastic rapport of the saxes; the Shorty Rogers-styled trumpet section that plays with guts, power, and finesse. Musicians like flugelhornist Burt Collins and trombonist Dick Kenney play punching, melodic leads and jazz solos with rich, brassy tones, and a finely balanced sense of phrasing.

This Hep item is a must for big-band lovers, and the stereo sound is exceptionally clean. *John Lissner*

Sound: C+ Performance: A+

Newport Rebels
Barnaby/Candid Jazz BR 5022, stereo, $7.98.

During the 1960 Newport Jazz Festival, bassist Charles Mingus and drummer Max Roach, incensed by what they felt to be poor treatment by the Festival producer, George Wein, and scornful of Newport's accelerating commercialism, staged their own counter-festival at the Cliffwalk Manor, a small hotel located a few blocks from the main event.

Though not as consistently brilliant as the concert Mingus organized in 1953 at Toronto's Massey Hall (with Parker, Gillespie, and Bud Powell, preserved on a Prestige double-set), the Cliffwalk Manor "rebellion" sessions offer some stimulating moments. Actually, the original Candid recordings were made after the counter-festival was over, when some of the rebels returned to New York City and cut these sides under Nat Hentoff's supervision. Producer-critic Hentoff managed to successfully bridge the stylistic chasm between mainstream/swing and what was then called modern jazz. The ease with which two generations of musicians, such as Roy Eldridge, Jo Jones, Eric Dolphy, and Tommy Flanagan, blend their talents attests to the timelessness of the art of jazz. On one particularly bristling track, *Mysterious Blues*, Mingus, Dolphy, Jones, and Eldridge meet on common blues ground with Little Jazz uncorking a flaming trumpet solo that matches his best efforts in the Swing Era.

Mingus contributes a number of engaging solos and some robust bass walks throughout. Perhaps the most interesting cut on the album is *Tain't Nobody's Business*, the Bessie Smith/Billie Holiday favorite, which gets an acidulous reading from ex-supper club singer Abby Lincoln, Max Roach's wife. Ms. Lincoln is accompanied and, indeed, sometimes upstaged by trumpeter Benny Bailey and alto saxist Eric Dolphy and their exhilarating obligatos and solos.

The original Candid LP was recorded in both mono and stereo; the Barnaby/Candid re-release is, naturally, in stereo and the sound is lively and well-balanced. *John Lissner*

Sound: B Performance: A

Bush Baby: Arthur Blythe
Adelphi AD 5008, stereo, $7.98.

It would take some excellent musicians to pull off a performance using one conga drum, a tuba, and an alto sax; Arthur Blythe almost does it though. Blythe's alto has been a dominant force in the *avant-garde* for a few years now. He plays with incredible tone control, extracting new subtleties from every note. His improvisations are full of melodic invention that never slip into easy cliches.

It's Blythe's strong playing that allows **Bush Baby** to work at all since he gets little support from his sidemen. Bob Stewart is an agile tuba player but he never takes off in flights with Blythe to challenge him. He's content to stay in the background as a minor foil and counterpoint to Blythe's alto. Ahkmed Abdullah and his one conga would be hard pressed to create any real drive for this session. Lacking the formidable chops of Mtume, Abdullah becomes almost an annoyance. It's up to Blythe to generate themes and drive on his own. With no support or feedback, his solos become episodic, rather than the long, sustained explorations he's capable of.

Bush Baby is a simple recording with no frills, and many unused spaces.

John Diliberto

Sound: B- Performance: B-

European Letter *Continued from page 8*

ronmental controls are mid-frequency with controlled attenuation between 1 kHz and 3 kHz, plus a controlled attenuation above 3 kHz.

A most impressive "live versus recorded" sound demonstration by B & W's British Product Manager, George Hooley, included speech comparisons and a fine musician playing the clarinet, wood blocks, etc., both in A/B switch-over comparisons. From even a short period of auditioning, these latest 801s from B & W are loudspeakers one could happily live with, if you can afford £845 (without top cover) or £895 (with cover), to acquire a pair. These prices include our 12.5 percent Value Added Tax.

Raymond Cooke's KEF Electronics company, following its success with the Model 105 system, has added another LS to their Reference Series, Model 101. Although based on the same design concepts as its predecessor, the 101 is suitable as a bookshelf loudspeaker with its dimensions of 340 x 180 x 190 mm. It is a closed-box enclosure type, with internal volume of 6.7 liters. This system has a minimum amplifier power rating of 20 watts into 8 ohms, and a power handling rating of 100 watts. The 101 (with two drivers) has an S-STOP (Steady State and Transient Overload Protection) self-powered electronic circuit to protect the speaker against accidental overload. If the safe operating limit is exceeded, the S-STOP instantly cuts down the voltage and the output volume is reduced accordingly. A red light on the front of the 101 indicates when this has happened. As soon as the voltages are within safe limits, either because the music has become quieter or the amplifier has been turned down, the volume returns to the proper level. As with the B & W 801, a first-class demonstration of the Model 101's characteristics was presented by Laurie Fincham and Raymond Cooke, of KEF, at the Cunard.

As seen and heard at all audio shows around the world, loudspeakers proliferate embracing all types, shapes, and sizes. The 1979 gathering in London was no exception, and space will allow mention of only a few systems that attracted my attention, for instance, the latest Jim Rogers design, the JR 150 Twin Bass enclosure with its cylindrical shape. Two bass drive units have long-throw Bextrene cones working in parallel, with a 1-in. soft-domed tweeter linked with a 24-dB-per-octave, 16-element crossover unit.

One of the smaller manufacturers, PWB, offered a different approach to LS design in demonstrating their Dyna-X 100 speaker system. The company has developed a material made of 0.0003-in. aluminum foil thermo-bonded to 0.00025-in. polyester film. A coil is etched on the aluminum foil, which is then placed between powerful magnets. The interaction of coil and magnets produces a low-mass diaphragm movement substantially the same as an electrostatic unit. This method permits direct connection to amplifiers without the severe HF degradation that the usual ELS matching transformers introduce. PWB's designer Peter Belt has for three years used a similar diaphragm material in his excellent Dyna-X headphones. The Dyna-X 100 system consists of a 20 x 5-in., low-mass speaker panel mounted on top of a 13 x 9-in., expanded polystyrene, wedge-shaped bass driver, loaded in a transmission line enclosure. A novel and promising design.

Wharfedale launched an up-market product in their fourth and largest loudspeaker in the E series. The E90 is a reflex-ported, five-unit design, with a DIN power rating of 140 watts. As well as two 10-in. bass units and two 4-in. mid-range drivers, it has a horn-loaded tweeter, all mounted in a cabinet of 100-liter capacity. The E90 cabinets are made in mirror-image pairs and have five position upper and lower contour controls. Rear-mounted castors and handles are fitted to ease movement of these heavy systems.

The Chartwell range of speakers is fitted with polypropylene cone drivers, which are claimed to have very consistent performance due to dimensional accuracy and resistance to high temperature and humidity often found in cars and the tropics. The designers claim superior performance to paper diaphragms or doped bextrene cone materials.

My survey by no means covers all the loudspeaker systems displayed at this London hi-fi exhibition, but I must mention the five new speakers from Sansui, the Program Monitor 400 from RAM Audio, and a new three-way IB system from Richard Allan — again christened a Domestic Monitor — as is Monitor Audio Company's Audio Monitor MA4 Series II. Celef has a new Studio Quality model, the RT1, and Rola-Celestion offers three new models, the Ditton 442, 551 and 662 systems. Apart from what I call "disco noises" on some loudspeakers, the quality standard, as heard at the Cunard, reflects many design improvements in this area.

In closing this column from England, I am happy to mention that the 65th Audio Engineering Society Convention will be held at the London Hilton Hotel from 25th to 27th, February, 1980.

Classical reviews

Edward Tatnall Canby

Joseph Haydn, All the Sacred Works, Vol. 1: Stabat Mater, Salve Regina, Missa Brevis, Great Organ Mass. Soloists, Stuttgart Ch. Choir, Wurttemberg Ch. Orch., Bernius. **Vox Box SVBX 5215,** three discs, stereo, $11.95.

Vox begins yet another of its remarkable all-out complete sets here with the usual excellent performances by names unknown (to us provincials, anyhow) and, with only mild reservations, the usual competent recording, up to anybody's at a higher price. This is the antithesis of the big-company celebrity album, and it is a healthy thing, if only to keep us in some normal perspective concerning the art of music! Not all the world's good musicians are international traveling stars.

The well-known big choral works of Haydn fall into two familiar groups, all of them late works in a very long career of composing, two big oratorios, *The Creation* and *The Seasons*, plus a group of Masses, each with its nickname, like the *Mass in Time of War*, the *Harmony Mass*. How many of us who enjoy Haydn have heard any other of them?

Here comes Volume I of this edition and not a single work on six sides has ever been recorded before! All of these are from the early and middle years of that long composing life, the time of the dozens of lower-numbered Symphonies, up into the fifties, which are now widely heard and recorded. The *Missa Brevis*, a delightful short and very worldly piece with two solo sopranos, and the short *Salve Regina*, actually come from Haydn's unknown youthful period, even before he signed up with the Esterhazy princes as permanent court musician.

And how astonishing to find two major works, the *Stabat Mater* on three LP sides and the *Great Organ Mass* on two, unfolding from the loudspeakers, complete with full complement of solo voices, big chorus, orchestra and organ, as though they were world-famous masterpieces known to every musician and listener! They were, in their time, and will be again.

These are impressive performances, with a brace of big-voiced soloists, a strong, professional choir and an excellent orchestra, even if maybe you have never heard any of their names. In fact, the soloists are a bit too strong, letting forth high notes that will rattle your chandeliers, helped by the recording engineers, who have put them too close and too loud for their big voices. Not overloaded on the VU! Just loud and hefty. That's the way a lot of listeners like it, I'll admit. The overall sound is OK, though not superb.

Sound: B Recording: B- Surfaces: B+

Saint-Saens: The Two Violin Sonatas, Op. 75, 102. Robert Murray, Jane Abbott. **Musical Heritage MHS 3785,** stereo. (Mail order: 14 Park Rd., Tinton Falls, N.J. 07724.)

It is hard to understand why for so long so little of Saint-Saens' enormous musical output has been heard—and still isn't. Partly because he composed so fluently and easily, which to many (outside of France!) means facile. You're supposed to tear your hair as you compose. Facile, yes, in the sense that the music is always relaxed and effortless. And very seldom tortured. But not facile in any degrading sense.

These two Sonatas, for equal violin and piano, are witness to the real values of this man, especially in the relaxed form of a recording for home use. Heavyweight music, so fashionable in the concert hall, is much less effective in the confines of the living room, where this graciously Romantic music easily comes into its own. I enjoyed it.

This is a good team, working extremely well together. The recording, particularly good of the piano, brings the two instruments into exactly the right balance for the music, listenable without a bit of sonic strain. (How often the big-name violinists are overly close and very loud, with the piano off behind.) I liked the Second Sonata best, a sort of easy-going Brahms with all the Germanic weight removed. The First is more of a show-off piece, bravura, but a good contrast. These were composed in the Nineties of the last century; old Saint-Saens kept right at it until his last year, 1921.

Sound: B+ Recording: A Surfaces: B

Kurt Weill: Concerto for Violin & Winds. Detmond Wind Ens., Michaels. **Hartmann: Concerto Funébre for Violin & Strings.** Wurttemberg Chamber Orch., Heilbronn, Faerber. Susanne Lautenbacher, violin. **Vox Candide QCE 31105,** stereo/quad (QS), $4.98.
William Schuman: Concerto for Piano & Orch. M.I.T. Symph., Epstein.
Walter Piston: Concertino for Piano & Chamber Orch. Philharmonia Virtuosi of N.Y., Kapp. Gary Steigerwalt, piano. **Vox Turnabout TV 34733,** stereo, $3.98.

Here, at two low-low prices, are excellent four-sided surveys of a period, the early pre-war "neo-classic" — so long ago already. The Kurt Weill-Hartmann disc is Continental, German; the Schuman-Piston recording is American, a bit later. All have a very nostalgic and characteristic sound, of the 1920s and 1930s.

We all know the late, great Kurt Weill — how many realize that he began as a highly "classical" modernist? This violin concerto with winds is strictly in that category, but you can hear the familiar Weill melodiousness and strong rhythms, the acid edge, the stark and lugubriously humorous orchestral sound! I loved it, and the violinist, Susanne Lautenbacher, is one of the great fiddlers of our day, so clear and strong, so accurate in tune and in understanding. Hartmann, pure German and less known here, composed his Funeral piece for the downfall of the Czechs in 1938 — in of all places, Hitler's Munich. A courageous act.

I studied with Walter Piston over several years, before the *Concertino* was composed. He was the ultimate neo-classicist, dry, sardonic, talking in undertones out of the corner of his mouth, yet obviously a highly taut and emotional person; but in those days you didn't let it all out. You acted sardonic. The *Concertino* indeed brings him back to me — it is an honest piece, fumbling in its emotions, half dry humor and half passionate Romanticism, and full of dissonant fugues and very old-fashioned endings. It is he! William Schuman, a much tougher and more successful person, writes similar music of the time but much longer, more proficient, yet cold. I always thought he was cold, still do. Big administrator, great business success, etc. I like Piston better.

The pianist in both works is Gary Steigerwalt, formidable prize winner with critical acclaim. In the Schuman he is in his element — just the same personality. But in Piston he bangs, plays hard, which is NOT Piston, except as a big transparent bluff. I should know! For all his noise, Piston was a gentle and lovable soul, and I am sure his colleagues will agree.

Sound: B,B Recording: B,B+
Surfaces: B+

Mozart: Davidde Penitente, Cantata, K. 469. Caspo, Koban, Baldin, Wurttemberg Chamber Choir & Orch., Kurz. **Candide CE 31107,** stereo, $4.98.

So you know your Mozart? Bet you never heard of this one. It is a curious piece, made out of another that is very well known but exists only as a half-finished torso, always a problem in performance. The Great C Minor Mass. Mozart's refashioning of the music into an Italian-language Cantata on the Penitence of David, adding two brand-new movements, was a stroke of his usual genius, and this version is complete in its own right. It should be heard more often, that's obvious.

Vox didn't give me a text sheet, nor is there even a synopsis of the plot, nor so much as an Italian title for the various movements; so I am in the dark as to what the singers are singing about. (Even the Italian itself is blurred in good German fashion into unintelligibility!) So this might just as well be the *Great C Minor Mass,* for all anybody can tell. Except for a rearranged order, and for two lovely extra movements, giving more scope—a lot more—to the tenor and the soprano solo voices. Most impressive music, some of it clearly surpassing even the later and better known *Requiem,* Mozart's last work of all, and many listeners will already know the sound of it very well. The soprano solo piece *Laudamus te* (in the original Mass) is even better known, a standard show piece in every coloratura's repertoire—it sparkles beautifully here, though I don't even know what it is called in Italian.

The excellent Wurttemberg Orchestra (see also the Sacred Works of Haydn, Vol. 1) is conducted at a fast and lively speed but the chorus and solo voices are easily up to it and there is no forcing. The three solos are good, though they all sing with those shatteringly loud high notes that are *de rigueur* today, and were surely not the style in Mozart's time. The Wurttemberg Choir is one of those beautifully blended ensembles (boys' voices?) that occur in our country only among amateurs, but these are pros in every respect. They do a marvelous job on Mozart with a precision and understanding I've not heard surpassed.

Sound: B Recording: B
Surfaces: B+

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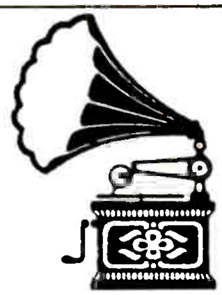

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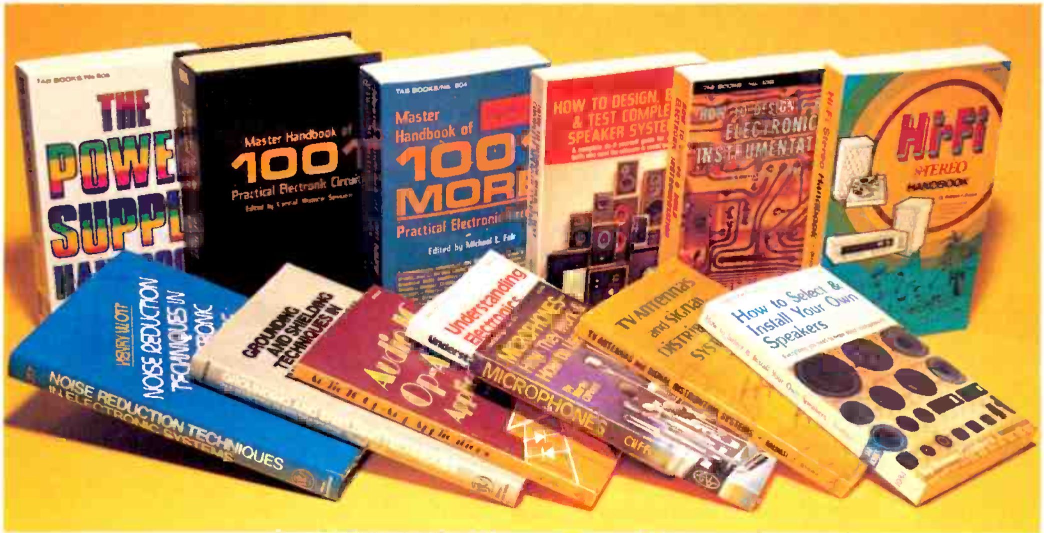

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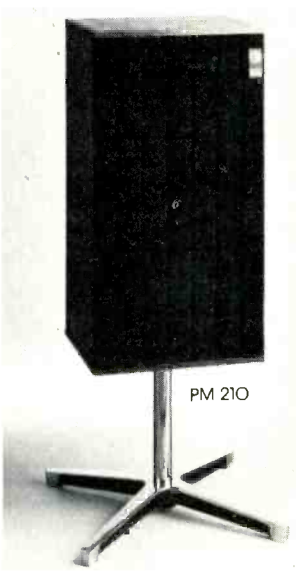

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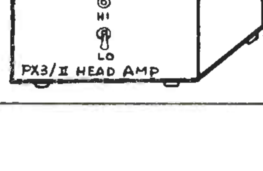

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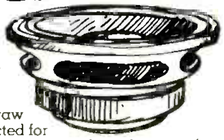

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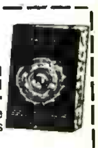

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Like the first cassette deck with integral Dolby* noise reduction in 1971. And the first cassette transport to break the 0.1% wow & flutter barrier in 1973. Designs that helped make the cassette deck a respectable high fidelity component.

Today, we're producing cassette components with instrumentation drive systems. Mechanisms taken right out of our own data recorders. These transports are built to withstand continuous read/write use in computer installations. Where megadollars are at stake. And reliability is everything.

Soon you'll see the first popularly priced cassette decks with integral dbx** noise elimination. Originally designed for open reel recorders in professional recording studios, the dbx system gives you sound so quiet, so noise-free, it's scary.

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So next time you're distracted by an Astro-this, Fluoro-that or Spectro-something else, remember: a tape recorder is a machine.

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Look into a TEAC, and you'll find that we've got the guts. To show you what's inside. To let you evaluate our performance. To make you the final judge.

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Another big surprise is the SU-C01 preamp. It's one preamp but it works like two. Because it has a built-in preamp for moving coil cartridges. It also has gold-plated connections to maximize signal transfer.

To add the finishing touch, there's the ST-C01 tuner. It gives you great FM specs and great FM sound. And that's a big achievement considering its small size.

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Experience the Micro Series. Once you do, you'll agree: The big thing about them is definitely not their small size.

Technics
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SE-C01

Continuous power per channel into 8 ohms, 20 Hz – 20 kHz	Total Harmonic Distortion	Signal to Noise Ratio
40 watts	0.03%	110 dB

SU-C01

Total Harmonic Distortion	Phono Signal to Noise Ratio	Frequency Response
0.005% (phono) 0.003% (aux)	90 dB (MM, 2.5 mV) 78 dB (MC, 250 μV)	3 Hz – 100 kHz, –1 dB

ST-C01

FM Sensitivity 50 dB (stereo)	FM Selectivity	Stereo Separation (1 kHz/10 kHz)	Total Harmonic Distortion (stereo)
38.3 dBf	75 dB	45/35 dB	0.15%

With performance this big, the last thing you expect is components this small. The Micro Series by Technics.