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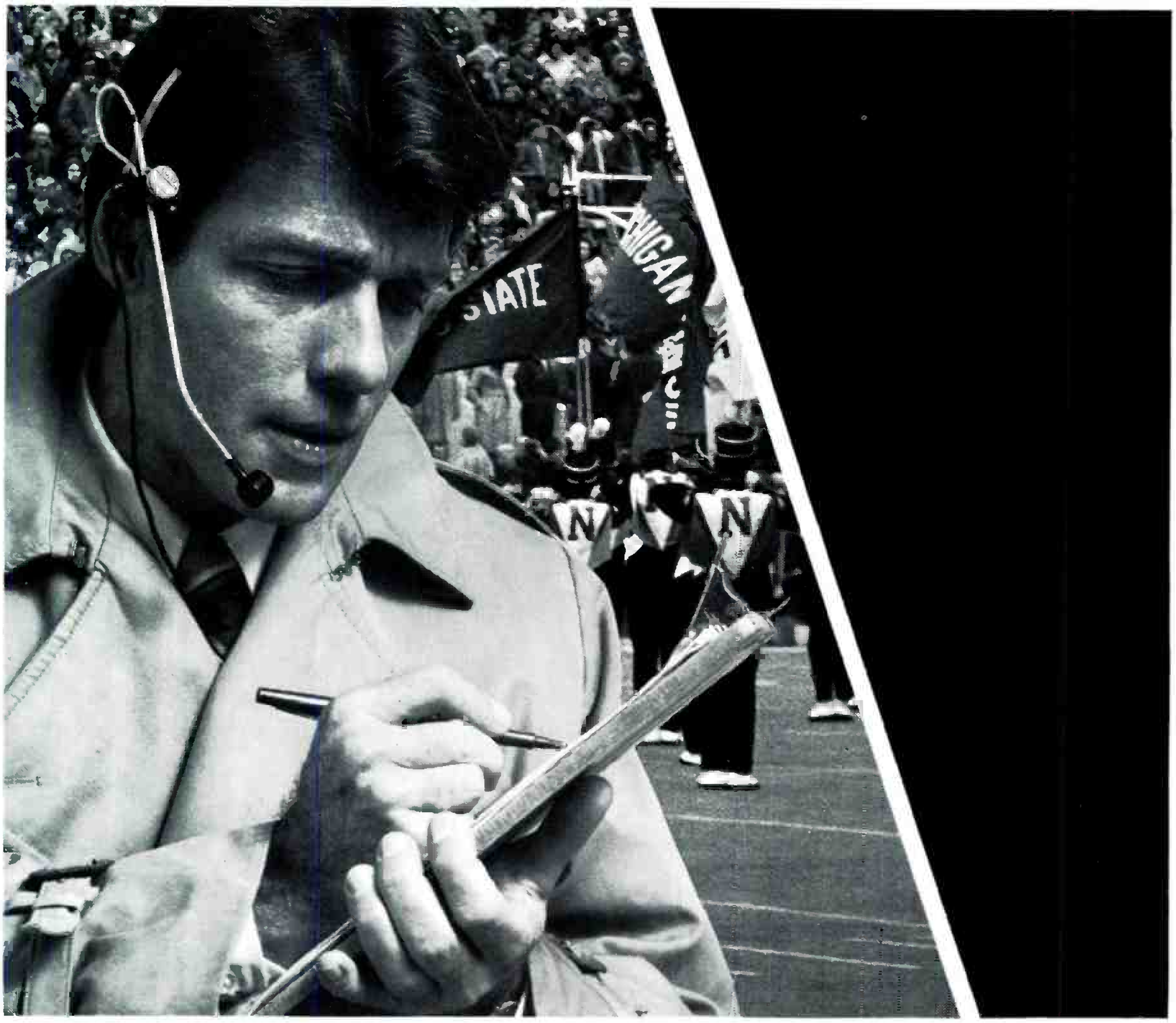
THE SOUND ENGINEERING MAGAZINE

SEPTEMBER 1977
$1.00

db



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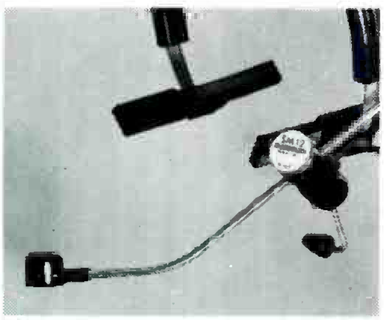

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Coming Next Month

- Signal control systems are our topic.
- David Robinson of Dolby Laboratories has contributed DOLBY B PROCESSING FOR F.M. AND T.V. SOUND TRANSMISSION. In it, this broadcasting method for improving sound quality is fully explored.
- Martin Dickstein takes a broad look at a fascinating new studio tool—VARIABLE SPEECH CONTROL.
- Sid Smith will detail the advantages that a specially designed vectorscope can offer to recording and broadcast engineers.
- A db Test will examine a new dbx product, the Model 162 stereo compressor/limiter.
- Coming in October in **db, The Sound Engineering Magazine.**

About The Cover

- This cover shows a 1906 Edison Home Phonograph Model-C. As a cylindrical type with a sophisticated (for its time) spring motor, speed constancy was achieved. And since there was straight line tracking of the stylus, sound was equal in quality from the start to the finish. If you think that modern stylus shapes are a recent development, note that this system had an elliptically polished stylus. As with all Edison units, even later discs, groove modulation was vertical (hill and dale). We thank the Audio Technica Company both in the U.S. and Japan for the photograph by Susumo Endo.

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THE SOUND ENGINEERING MAGAZINE

SEPTEMBER 1977 VOLUME 11, NUMBER 9

db is listed in Current Contents: Engineering and Technology

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db Letters

THE EDITOR:

Some comments on Patrick Finnegan's article on f.m. broadcast monitors (*Broadcast Sound*, June, 1977). The most effective, and I believe most simple, way of matching the monitor load to the coaxial cable feeding it is to place a fixed attenuator at the input to the monitor (rf input). A fixed 10 dB attenuator (50 ohm impedance) with power handling capability adequate to handle the power level at the monitor input will effectively dampen any reflections that might otherwise arise due to the mismatch of the coaxial feeder cable and the monitor. The available rf level will of course have to be 10 dB higher than otherwise required, due to the 10 dB insertion loss of the pad. High quality pads are available from numerous sources at reasonable cost. The use of a 10 dB pad improves the "match" by 20 dB, i.e. any reflection is reduced by 20 dB. If you're really fussy about this match you could use a 20 dB pad and reduce the reflection by 40 dB! We do this all the time in matching cable t.v. head-end equipment to long feeders. Most of the tests that Mr. Finnegan describes using a communications receiver can be done much more easily and accurately with a good laboratory-type spectrum analyzer. e.g. Tektronix 7L13 system. If you don't have one, go out and rent one. It will save you time and money!

I. SWITZER
Switzer Engineering Services
Mississauga, Ontario

Mr. Finnegan replies:

Mr. Switzer is correct on both counts. The use of a good rf pad will properly terminate the line, and there is no question about the spectrum analyzer checking the accuracy of the carrier deviation. The use of the directional wattmeter, however, will also permit measurement of the input to the monitor at the same time you are adjusting for a good match to the coaxial cable: it is important that the monitor input not be overloaded as well as matching the line. Many of the smaller f.m. stations cannot afford expensive test equipment, so other methods must often be used. The communications receiver is often more available than a spectrum analyzer.

(continued)

index of advertisers

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THE EDITOR:

I've been fascinated by Norman Crowhurst's columns about education. After getting straight As at MIT in every math and engineering course I took, I now find I understand very little of the material I'm supposedly familiar with.

My request is a specific one: I would like to purchase Mr. Crowhurst's *Basic Mathematics* series. No bookstore I can find in Seattle has them and I could not keep the library's copies long enough for them to be useful. I'm also told that they are no longer in print. Do you know of some place where I could get a set?

HARRISON J. KLEIN. Chief Engineer
King Radio Eleven
Seattle, Washington

Mr. Crowhurst replies:

Mr. Klein's letter just about makes my day. I have received letters similar to Mr. Klein's from professors and graduates of Yale, Harvard, Princeton, Georgia Tech, and a great many other prestigious institutions. Although the Basic Mathematics *series is out of print, I have a small stock of my alternative book,* Taking the Mysticism from Mathematics. *Rather than being a textbook, this tells why people have hangups in mathematics and similar subjects, the condition to which Mr. Klein refers, and how to overcome these hangups to effective learning. Anyone interested in obtaining this book can get a copy for $5.50 by writing to me at 1183 S.E. Godsey Rd.. Dallas, Oregon 97338.*

THE EDITOR:

In my article, *Low-Frequency Sound Reproduction*, which appeared in the May 1977 issue of **db**, several editorial lapses occurred.

1. In the text, reference is made to "points" on the four figures which identify the results in the examples. When my figures were redrawn, the points were omitted but the text stayed the same.

2. On Figure 4, at the top, the quantity which should be *DF equal to 200* is erroneously labelled 2,000.

MICHAEL RETTINGER
Encino, California

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db Calendar

SEPTEMBER

16-18 **Consumer Hi-Fi Show.** Sheraton Motor Inn, New York, N.Y. Contact: Charles Ray, Communications Show Corp. 30 E. 42nd St., Suite 1620, New York, N.Y. 10017. (212) 986-7592.

26,27 **Electronic Representatives Assoc. Show.** Statler Hilton Hotel, New York City. Contact: Gil Miller c/o Gilbert E. Miller Assoc. 375 N. Broadway, Jericho, N.Y. 11753.

19-21 **Altec Sound Contractors' Seminar/Clinic.** Lancaster, Pa. Contact: Altec Corp., 1515 Manchester, Anaheim, Ca. 92803. (714) 774-2900.

29-Oct. 1 **Altec Clinic.** Litchfield Park, Arizona

30 **Society of Broadcast Engineers,** regional convention, equipment show. Syracuse Hilton Inn, Syracuse, N.Y. Contact: Charles Mulvey, WNYS-TV Syracuse. N.Y. 13214.

OCTOBER

5-7 **Synergetic Seminar,** Boston, Mass. Contact: Don Davis, Synergetic Audio Concepts. P.O. Box 1134, Tustin, Ca. 92680. (914) 838-2288.

18-20 **Synergetic Audio Seminar.** Philadelphia, Pa.

5-9 **Hobby Electronic Fair,** O'Hare Exposition Center, Chicago, Ill. Contact: Industrial & Scientific Conference Management, Inc., 222 W. Adams St., Chicago. Ill. 60606.

9-14 **Audio-Visual Institute,** Indiana University, Audio Visual Center, Bloomington, Ind. 47401.

15 **Start Your Own Business Seminar,** sponsored by the Wharton School, U. of Pennsylvania. Hartford, Conn. Contact: Heidi E. Kaplan, New York Management Center, 360 Lexington Ave., New York, N.Y. 10017. (212) 953-7262.

16 **Start Your Own Business Seminar,** New York, N.Y. (See above)

15-19 **Instrumentation - Automation Conference.** Philadelphia Civic Center, Philadelphia, Pa. Contact: Instrument Society of America, 400 Stanwix St., Pittsburgh, Pa. 15222. (412) 281-3171.

11-12 **Sound Business Show** (ERA Consumer Products Div.) Rodger Young Ctr., Los Angeles, Ca. Contact: Alan Gediman, Marshank Sales (213) 559-2591.

16-21 **SMPTE Technical Conference & Equipment Exhibit.** Century Plaza Hotel, Los Angeles, Ca. Contact: SMPTE, 862 Scarsdale Ave., Scarsdale, N.Y. 10583.

18-20 **Western Educational Society for Telecommunications Conference.** Harrah's Hotel, Reno. Nevada. Contact: Wendell H. Dodds, Radio-Television Ctr., University of Nevada 89557.

25-26 **New York University R&D Management Seminar.** Chicago, Ill. Contact: Heidi Kaplan, New York Management Center, 360 Lexington Ave., New York, N.Y. 10017. (212) 953-7262.

NOVEMBER

2-9 **Synergetic Seminar,** Washington, D.C. Contact: Don Davis, Synergetic Audio Concepts, P.O. Box 1134, Tustin, Ca. 92680. (714) 838-2288.

2-6 **Dixie Electronics Representatives Convention.** Boca Raton Hotel & Club, Boca Raton. Fla. Contact: Kimball P. Magee, Dixie Elec. Reps. Inc. 1611 Perimetter Center E., Atlanta, Ga. 30346.

4-7 **Audio Engineering Society Convention and Show,** Waldorf-Astoria, New York, N.Y. Contact: A.E.S., 60 E. 42nd St., Rm. 449, New York, N.Y. 10017. (212) 661-8528.

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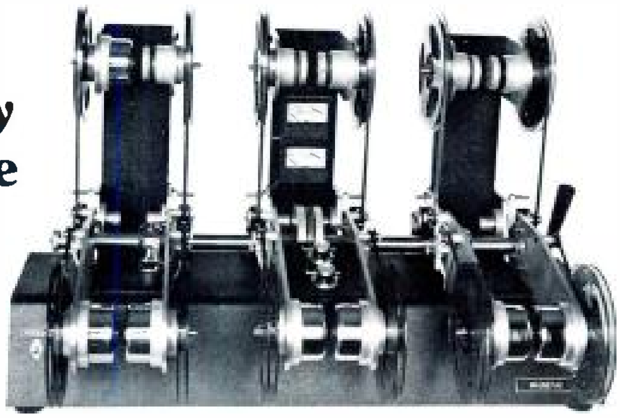

calendar (cont.)

NOVEMBER

6 **Start Your Own Business Seminar,** Chicago, Ill. Contact: Heidi Kaplan, New York Management Center, 360 Lexington Ave., N.Y.C.

7-8 **N.Y.U. R & D Seminar.** Los Angeles, Ca. Contact: Heidi E. Kaplan, New York Management Center, 360 Lexington Ave., New York, N.Y. 10017. (212) 953-7262.

10 **Society of Broadcasting Engineers, N.Y. Chapter meeting.** WQXR Presentation Theater, N.Y. Times Building, 230 W. 43rd St., New York, N.Y. 7:30 p.m. (Cafeteria dinner available.) Speaker: Ron Simon. Contact Tom Padwa.

14-17 **B&K Seminar, Acoustical Materials. Cleveland, Ohio.** Contact: B&K Instruments, 5111 W. 164th St., Cleveland, Ohio 44142. (216) 267-4800.

15-17 **Synergetic Seminar.** Nashville, Tenn. See above.

16-19 **Videodisc/Home Video Programming Conference,** Loeb Conference Facility, N.Y.U., New York. Contact: Robert Hamilton, 24 Washington Sq. N., New York, N.Y. 10011. (212) 982-5244.

22-25 **Video Tradex '77** trade exhibit and conference, Heathrow Hotel, London Airport, England. Contact: Video & Audio Visual Review, Link House, Dingwall Ave., Croydon CR9 2TA, England.

29-Dec. 1 **Synergetic Seminar.** Orlando, Fla. See above. ■

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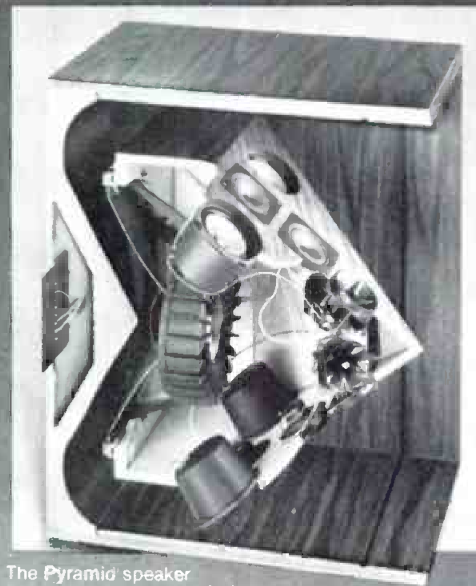

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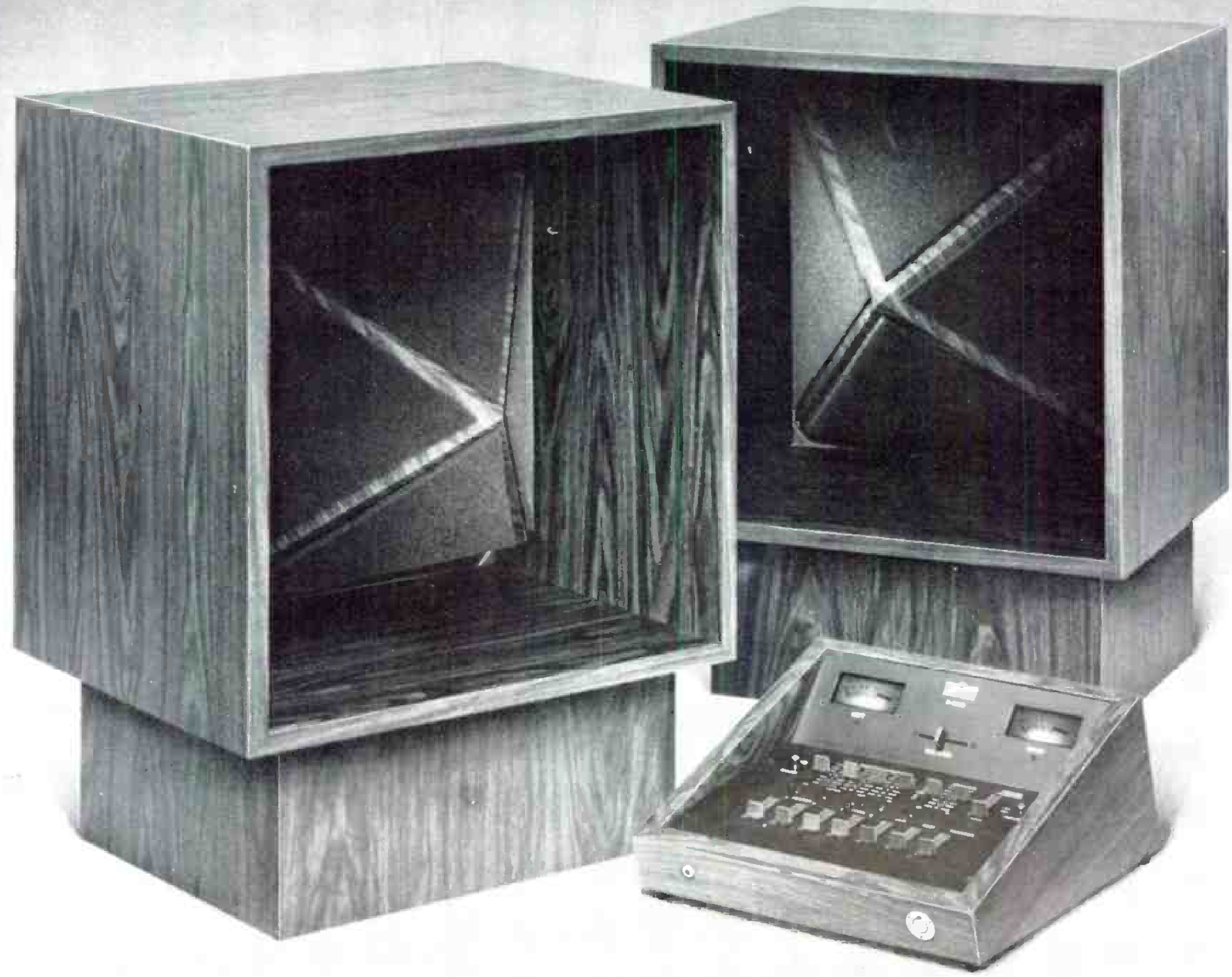

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PATRICK S. FINNEGAN

Monitoring Audio Distribution

• The audio output of the modulation monitor is an important signal because this represents the program, at the output of the station, that is now on its way to the public. Since it is an important signal, it is distributed to various places within the station where it serves a number of different purposes. This month we will discuss this distribution and some of the methods and problems involved.

SIGNAL USE

The primary function of the signal, of course, is aural monitoring, but it will be put to other important uses also. It is vital that the operator make sure that the program is on the air and *hears* what it sounds like. There's a similar need to monitor the air audio from other operational positions, so the air audio is distributed to the control room, as well as to the news room and recording booths. Besides these positions, the air audio is also channeled to various speaker locations throughout the building by a house monitoring system.

Although aural monitoring is an important function, the audio produced by the modulation monitor is often also recorded for various reasons, for example, air checks, a verification tape of a special program or speech, or by slow speed audio recorders for program logging or verification.

THE SIGNAL

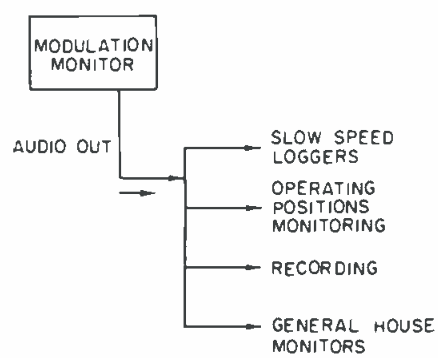
The audio which the modulation monitor provides—the station's program audio which has been demodulated from the transmitter's modulated carrier—makes the modulation monitor a very special off-air receiver.

There are no operational gain controls on the monitor; the amplitude level of the audio output is controlled directly by the modulation of the carrier wave. If, for example, the audio were very loud and distorted or perhaps very low, adjustments of the audio *ahead* of the transmitter are required—not of the monitor, since the monitor is an aural monitoring facility, not an audio amplifier. Should the announcer be busy gathering program material instead of watching the meters and there is a sudden change in the audio heard from the monitor, this *change* in level will alert him to the fact that something is wrong with the modulation and requires his attention.

OUTPUT LOADING

The audio output stage of the modulation monitor provides a signal level

Figure 1. Some typical uses for off-air audio.



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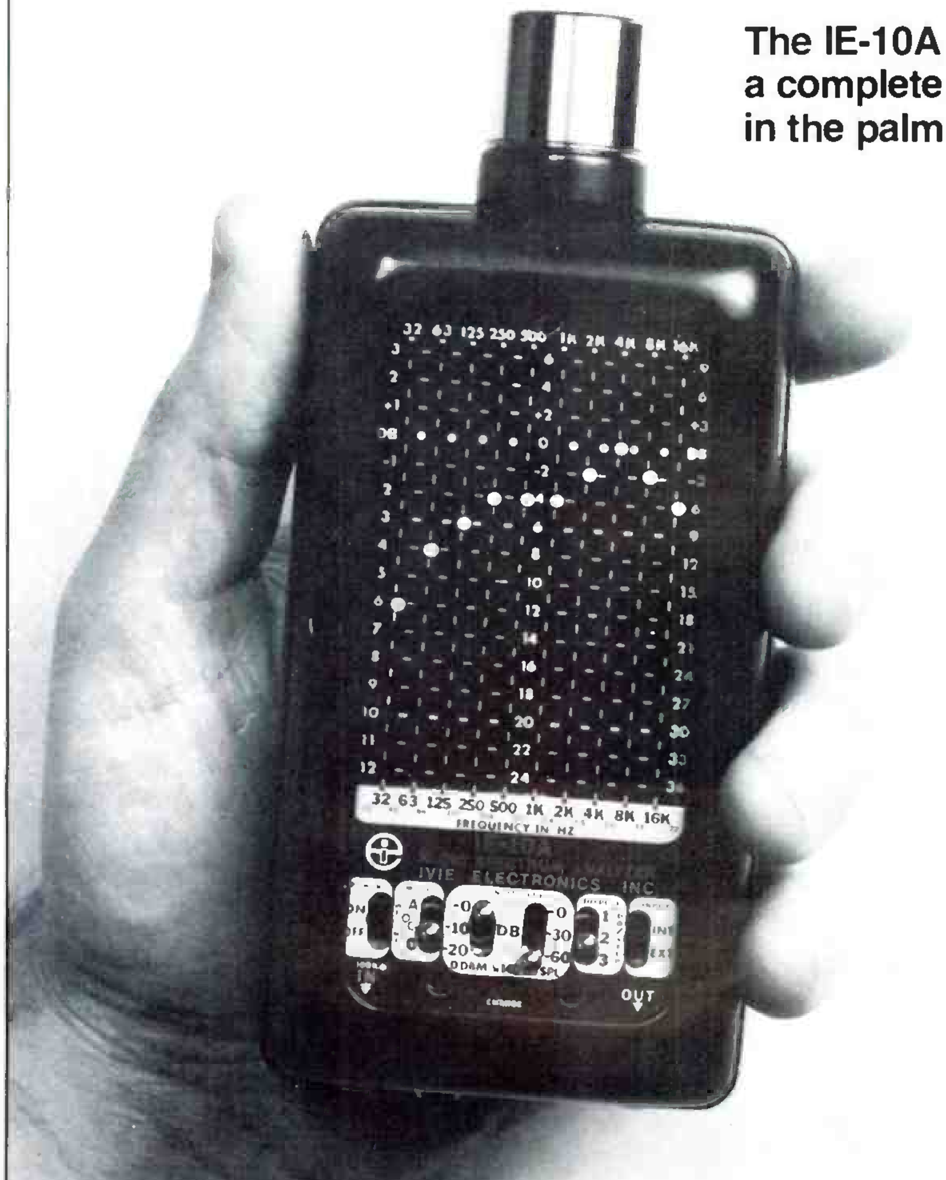

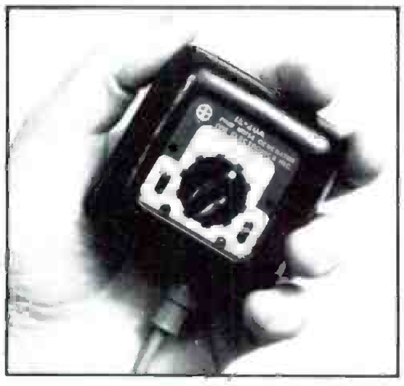

The Ivie family is growing with a powerful new set of accessories. Pictured above is the IE-20A Pink Noise Generator and the IE-15A Harmonic Distortion Analyzer is shown below.

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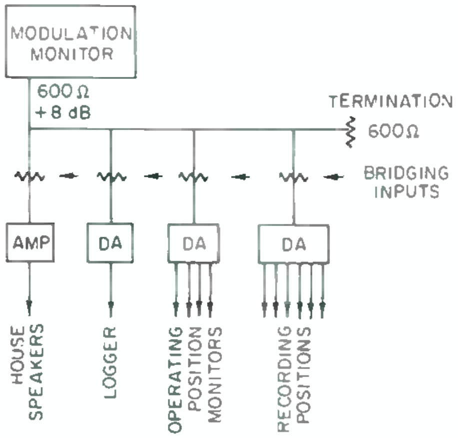

Figure 2. A typical d.a. system. The type and number of d.a.s. depends upon system needs.

of +4 or +8 dB (according to the model) into a 600 ohm load. This level is not high enough to drive a speaker directly. although it is suitable for earphone monitoring and is a standard broadcast program distribution level. As a standard level. it can be handled by normal distribution methods.

The manner in which the distribution is done will have a direct bearing on both the quality and amplitude of the signal available at various locations. Here we are talking about the load presented to this output stage by the various distribution circuits connected to the monitor. Unless this is done with care, too many low impedance loads may be connected across the output stage so that it is looking at a near short-circuit. This would severely overload the stage. cause it to draw heavy current (and possible create damage), resulting in a signal level at various locations that is so low as to be unusable.

CROSS TALK

When monitor audio is routed throughout the studio system for various purposes, this must be done carefully so as to avoid crosstalk problems. The monitor level is a high level signal, so its routing should avoid microphones or other low level circuits. Particularly when the audio has been amplified to speaker levels for distribution, extra special care must be taken since this is a very high level and it can crosstalk into normal high level program channels.

Crosstalk is undesirable in any audio system, but the monitor audio is also the output audio of the station and so it has some additional factors of phase

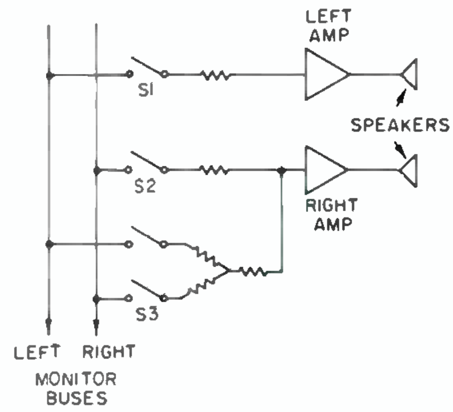

Figure 3. A switch arrangement can be set up to monitor left or right channel alone, in normal stereo fashion, or bridged together for a SUM or mono signal for detecting phasing problems.

and time delay. When this audio couples to earlier sections which carry the same audio. the delay can produce an echo in the resulting audio signal. If the crosstalk is in phase with this earlier audio, then we can have plain old fashioned feedback oscillations.

DISTRIBUTION

The distribution of the air audio depends upon the station and its needs. A very small station, for example. may only have one or two speaker locations, so the audio may be simply routed to the control room and to one or two speaker locations. But a larger station may be dispersed over a wide area and will also require the audio for many other purposes. This requires some type of distribution system.

When a considerable amount of distribution is required, the best arrangement is a system made up of d.a.s (distribution amplifiers). There are several commercial models to choose from when designing a d.a. system. so the station should have little problem in selecting those that will fit its needs. Individual amplifiers are available in a variety of configurations. for example. one-in/one-out isolation amplifiers, one-in/multi-out amplifiers. some with gain and others as unity gain. Most of these will provide for both a bridging input or a terminating input.

An important consideration in the design of a d.a. system is the output driving stage of the modulation monitor. If all the d.a.s in the system are to perform adequately, their input levels must be consistent. The best way to handle this is by using the output of the monitor to drive only a single 600 ohm-terminated bus—nothing else. All other distribution. whether by d.a.s or through other amplifiers or loads. should be bridging connections to this bus. With all connections bridging, am-

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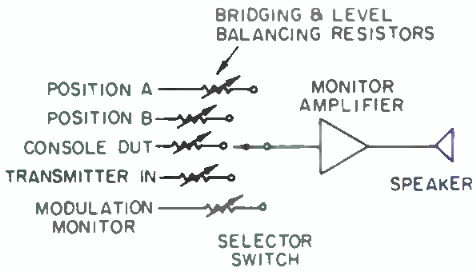


Figure 4. A multi-switch monitor test arrangement. (May be part of a console or added to a console.)

plifiers or loads can be connected or disconnected from the bus at any time without affecting the signal levels on the bus, or the rest of the system.

HOUSE MONITORING

Distribution throughout the station for general house monitoring is usually done with a power amplifier driving a speaker distribution system. A number of locations, such as the control room, have their own monitor amplifiers. These monitor directly from the air monitor bus. The house monitor feeds speaker locations throughout the building which have less importance than the operating positions.

A simple speaker system that requires only one or two speaker locations can simply connect the speaker by running directly to the power amplifier output terminals. The impedance tap should match the speaker or speakers. Remembers that when more than one speaker are in parallel, the output tap must be selected to match the combination impedance. If two 8 ohm speakers are parelleled across the output, use the 4 ohm tap of the amplifier.

For a larger system of many speakers, either the 70.7 volt or the 25 volt constant voltage distribution is normally used. This is not a difficult system to design and the component parts are readily available. The design parameters for the system are these: the distribution bus is a constant voltage bus (either 70.7 or 25 V)—the amplifier maximum power rating is divided up among all the speakers of the load. Each speaker connects to the bus by a transformer which matches the speaker to the bus and, through primary taps, channels the desired power to the speaker. Power distribution does not have to be equal, but the total of the power distributed must be equal to the maximum power rating of the amplifier.

STEREO

A station in stereo distributes the monitor audio by stereo and sometimes by a SUM (monaural) signal. There can be a number of locations where the stereo is not needed, so the left and right are properly bridged together to provide a monaural feed.

For testing and other critical listening, there may be at least one monitor position which can monitor the left or right channel separately, in normal stereo fashion, or SUM the two for checking on phase conditions. Such a test position may be at the transmitter, or perhaps in the shop. By the use of a stereo amplifier and speakers, and by a suitable switching arrangement at the monitor's inputs, these various tests can be performed. By SUMMING the channels, a tape recorder that has the head leads out of phase, for example, can be easily detected, for as soon as a tape that was made on this machine comes on the air, the signal will suffer a serious drop in level at the output of the SUMMED amplifier.

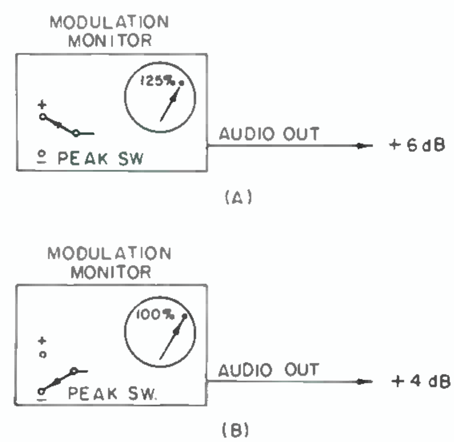
The important factor in stereo distribution is retaining proper identity of the left and right channels and maintaining the correct polarity of each of the runs.

TESTING

Any large audio system will have a test arrangement so that audio from various parts of the system appears on a selector switch to feed a monitor amplifier and speaker. The modulation monitor output should be on one of these switch positions. An arrangement such as this allows for "switching through the system" and gives an excellent before and after observation of the program over the program path. For troubleshooting problems of distortion and poor response curve, such an arrangement can help quickly to isolate the problem to a particular section of the system.

To be most effective, the audio from each of the sources should be at the

Figure 5. Asymmetrical modulation is about 2 dB difference between positive (A) and negative (B) modulation peaks.



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We also make two 90° radials for use with one inch and screw-on drivers —the RH90 and the SRH90. Both have the same flare rate, but the SRH90 (Small Radial Horn) has a smaller mouth, and is usually used as the high end in three way systems.

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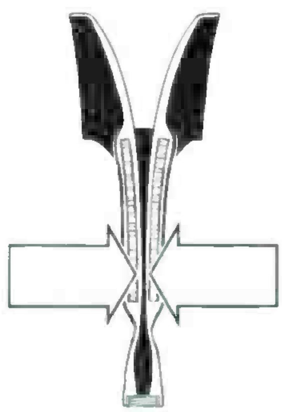

	BRH90			RH90			SRH90		
Flare Rate	240Hz			345Hz			345Hz		
Operating Range	500Hz up			600Hz up			1,000Hz up		
Size: H.	11 1/8"			12 1/4"			6 1/2"		
W.	33 5/8"			30 3/8"			24 3/4"		
D.	21"			20 1/2"			18 3/4"		
Weight	25 LB.			20 LB.			12 LB.		
Finish	Black, High Gloss			"			"		
Horizontal Dispersion	KHz	-3dB	-6dB	KHz	-3dB	-6dB	KHz	-3dB	-6dB
	6	85	95	6	80	90	1 2	95	100
	2	90	90	2	90	100	3	90	95
	10	80	90	10	85	90	10	85	100
Vertical Dispersion	KHz	-3dB	-6dB	KHz	-3dB	-6dB	KHz	-3dB	-6dB
	6	50	90	6	55	100	1 2	50	70
	2	35	50	2	35	50	3	40	65
	10	20	35	10	20	35	10	20	30

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same level as the switch. This will not require changing the amplifier gain each time. All inputs to this switch should be a bridging arrangement and also use these resistors to balance the audio from different busses so that the output of the switch is of the same amplitude in each case.

ASYMMETRICAL MODULATION

A situation peculiar only to the a.m. station is the asymmetrical modulation technique. With this technique, the negative modulation peak is limited to 100 per cent, while the positive peak is limited to 125 per cent modulation. The audio output from the a.m. modulation monitor depends upon which peak is selected for observation by the monitor. If the modulation peaks are hitting 100 per cent respectively, there is about a 2 dB difference in the audio output signal between these two. For normal system operation, the station should decide which peak will normally be observed by the monitor and the switch left in this position. If the engineer happens to notice that the air monitor bus seems to be low but the modulation appears correct, he should check out the position of the monitor switch. Someone may mave forgotten to place the switch back into the correct monitoring position.

SUMMARY

The off-air audio is an important signal that will be distributed to many places in the station for monitoring and recording purposes. This should be done by a properly designed distribution system that will deliver the signal to where it is needed and at the correct levels, but watch out for cross-talk into program channels. ■

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db Theory & Practice

How Loudspeakers Work

● In the last two issues, I have discussed analogs. One of their important applications is in examining how loudspeakers are operating. This involves the recognition of the way sound waves are transmitted, influenced by two properties of air, or any other medium, through which they pass. Mass, or density of the medium, gives it the property of *inertia*, the tendency to persist in its state of rest or of uniform motion. Elasticity, or *compressibility*, makes the medium "springy." In wave propagation these two properties interact to cause the waves to move forward at a velocity natural for the medium involved—a little over 1,000 feet per second for air.

To generate these waves, which is what loudspeakers have to do, the elements of the speaker are designed to deal separately with the two properties, density (inertia) and compressibility (springiness). For example, the diaphragm, or cone, of a loudspeaker should be as rigid as possible, with minimal springiness while the parts supporting it, the surround and the centering spider, should be as springy, at least in the desired direction, to facilitate back and forth movement of the cone, as possible.

While various parts of a speaker are designed with the idea of having one property or the other, in fact all parts possess both properties to a degree. The complete loudspeaker must also be designed to transfer as much as possible of the energy delivered to it to the air in the form of radiated sound waves.

LOUDSPEAKER EFFICIENCY

You will recognize that I am now talking about the efficiency of a loudspeaker. With most engineering devices, we think of high efficiency as meaning something like 80 or 90 per cent. Some devices may even deliver higher than that. But in loudspeakers, the best ever built ran around 50 per cent efficient. What is more commonly called a high efficiency loudspeaker will probably have an efficiency between 10 and 20 per cent, which would be pretty poor in other kinds of mechanical devices. A low efficiency loudspeaker often has an efficiency of far less than 1 per cent. That gives you an idea of what we are talking about.

But now, why is this? Had we been born fish, or dolphins, with an interest in making sound equipment to radiate sound under water, we might have come up with much higher efficiencies. From this you might conclude that

Table 1. The table of mechanical analogies.

TABLE 1

Mechanical system		Analogy I Impedance Diagram		Analogy II Admittance Diagram	
force	f	voltage	v	current	i
velocity	v	current	i	voltage	v
impedance	z	impedance	z	admittance	Y
mass	m	inductance	L	capacitance	C
compliance	c	capacitance	C	inductance	L
elastic energy	$\frac{1}{2}cf^2$		$\frac{1}{2}Cv^2$		$\frac{1}{2}Li^2$
kinetic energy	$\frac{1}{2}mv^2$		$\frac{1}{2}Li^2$		$\frac{1}{2}Cv^2$

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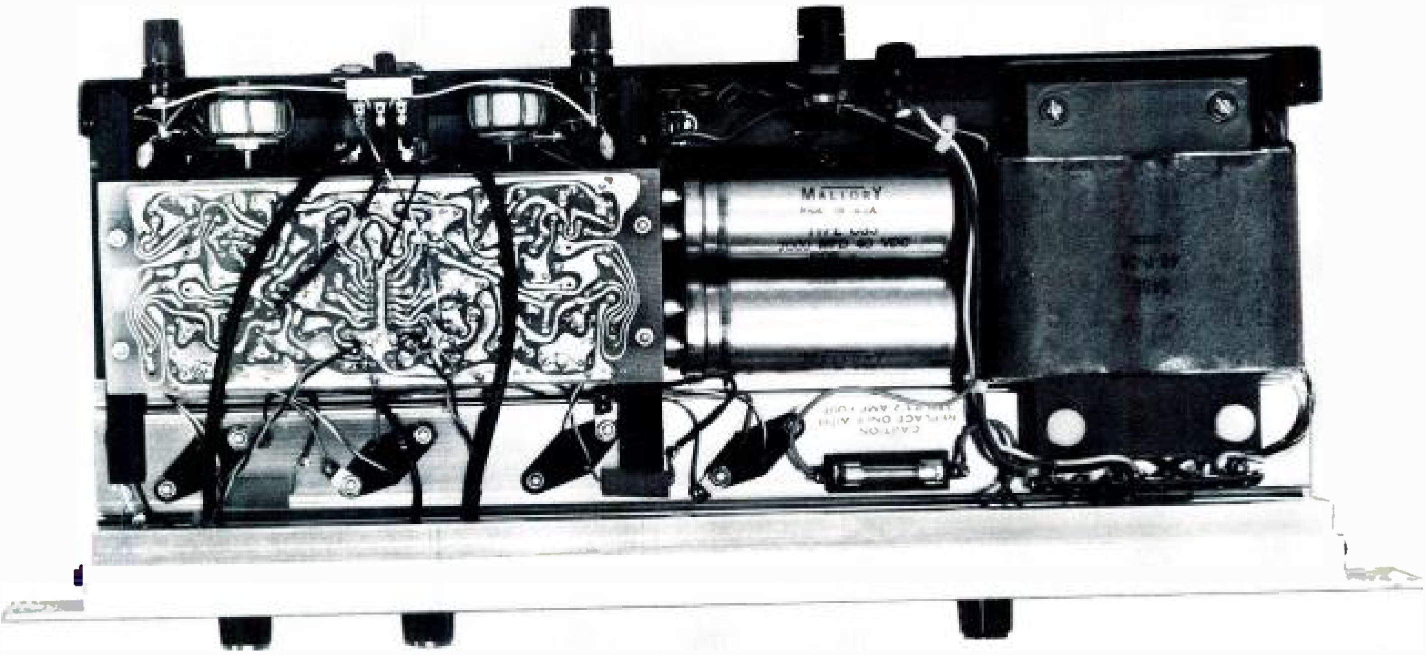
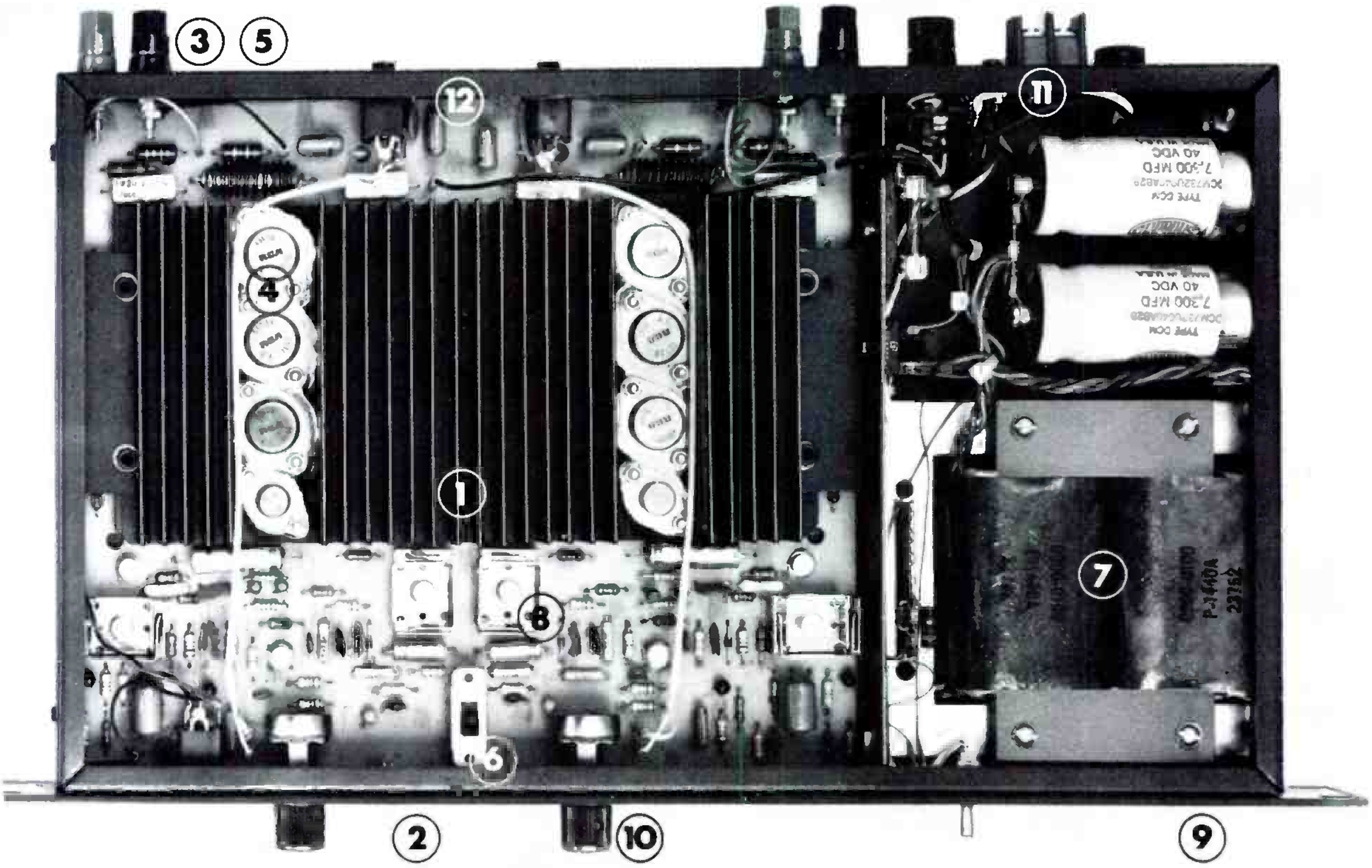


WHICH ONE



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underwater loudspeakers, for use in swimming pools, are more efficient than speakers for use in air. That is not usually true, because underwater speakers are just modified speakers originally designed for use in air, not necessarily designed for maximum efficiency in water. But why is loudspeaker efficiency so low in air?

MATCHING

Primarily, it is a question of matching. Air is light and everything that you might ever use with which to move it is relatively heavy. By using a thin diaphragm, made as rigid, as well as light as possible, you will improve the efficiency of a direct radiator loudspeaker. Use of the well-known conical shape gives rigidity, as does the introduction of ribs and other shapes which reinforce without adding weight.

Although, when sound waves are propagating freely in space or across a room, the mass and elasticity of the air perform an equal function in the transmission of the wave, in proximity to a loudspeaker, one or the other property invariably becomes the more important in various positions around the loudspeaker. The air in front of the cone exhibits mass more than elasticity. The air inside the box, whether it be infinite baffle, bass reflex, or some variant of either, such as acoustic suspension, or port loaded reflex, behaves more like a spring, and its mass is unimportant.

How come that different properties of the same air assume importance, according to where the air is? The air does not change just by being in a different place. What changes are the parameters of the parts of the loudspeaker that are adjacent to it, which makes different properties of the air become important. The air in contact with the front of the cone moves with it, or that is what the cone tries to have happen. As well as moving its own weight, the cone has to move a weight, or mass of air, in contact with it. This action starts the sound wave.

This, primarily, is where loudspeaker efficiency disappears. Too much of the drive energy is spent moving the cone, and too little moving the air that ultimately becomes the sound wave.

The air inside the box does not move so much because it is compressed and expanded by movement of the cone. This is true whether the box is of the so-called infinite baffle type, sealing in the back of the cone, or whether it is of a reflex design, in which air

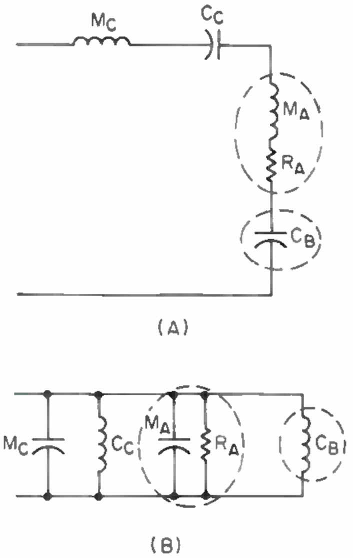


Figure 1. Alternative equivalent diagrams for infinite baffle enclosure. (A) impedance diagram. (B) admittance diagram. Symbols: M_C=mass of cone; C_C-compliance of surround; M_A= mass of air moved by cone; R_A= acoustic radiation resistance; C_B= compliance of air inside box.

escapes from the box at some point to augment the sound wave at certain frequencies.

Immediately adjacent to the back of the cone, the air moves with the cone, and thus its mass is of some importance. The mass of air in a port or duct, or adjacent to a drone cone, if one is used, which moves with the generation of sound waves, is also of some importance. But in most of the box, this movement causes the air inside to be alternately compressed and expanded, which means its important property is its *compressibility*, or elasticity.

CONTROLLING CONE MOVEMENT

So what controls the movement of the cone, and thus the generation of the sound wave it eventually radiates? On the driving side, the force is the electrical voltage and the current delivered to it by the amplifier. On the driven side, the properties of the cone and its suspension, which cannot be eliminated, as well as the properties of the air in contact with the cone influence the sound wave.

On the drive side, current provides the driving force, and voltage represents the motion associated with it. If the cone is artificially locked in place so it cannot move, no sound will be radiated and the voice coil will possess a purely electrical impedance, consisting of a resistance and an inductance. In that condition, the electrical impedance will determine the relationship between voltage and current that the loudspeaker takes from the amplifier.

But to have a loudspeaker work, its voice coil and cone must be free to move. This movement modifies the electrical impedance, or the relationship between voltage and current used from the amplifier. Let us look at what this modification means in terms of the electrical impedance the amplifier has to feed with voltage and current.

A constant current from the amplifier, as frequency is changed, will result in a constant driving force at the voice coil, but not necessarily in constant movement of the cone. This depends on what induces the opposition to movement. At higher frequencies, the opposition is caused mainly by the mass of the cone and of the air it drives to cause a sound wave. The higher the frequency, the less readily will the wave keep reversing its movement and the less its movement will be.

At lower frequencies, the opposition will be due to the restraint caused either by the mechanical suspension of the cone, by the compressibility of the air inside the box, or by both acting together. This is what will limit movement as frequencies get lower.

At some frequency, called the *resonance* of the loudspeaker, the two causes of opposition balance one another. This means that the springiness of the air inside the box, and of the cone suspension, will act in conjunction with the combined mass of the cone and of the air that moves with it to produce a resonant effect, like a spring and a weight. Very little force, at this frequency, will produce quite large movement.

What will resonance look like in the electrical circuit? A big movement accompanied by a big voltage and small force will be accompanied by small current.

Now if, in the way most amplifiers are designed, the voltage output represents the frequency content of the audio wave, rather than current, what stays put as frequency is varied will be cone movement. The current needed to produce that cone movement will vary according to the force needed at each frequency.

So far, so good. But uniform cone movement achieved in this way would depend on using a much higher efficiency than any loudspeakers possess, so we have to consider what that cone movement actually does. By the way, before we go any further, what is uniform, is not the distance of movement, but the rate of movement.

If the cone moves at the same maximum rate, or velocity, as frequency goes up, the distance it moves will go down because it travels for a shorter time in each direction. That agrees, in general, with what the sound waves require. A low frequency wave requires a larger air movement because the waves are so big. A high frequency wave requires a much smaller, more rapid air movement because the waves are much smaller.

SMALL/FORCE LARGE MOVEMENT

Now we need to take a look at what happens to all the other parts of the loudspeaker. This is where the analogy gets difficult. Take the loudspeaker's resonant frequency as the starting point. At this frequency, a relatively small driving force from the voice coil produces much larger cone movement than at other frequencies. This happens because there is resonant interchange of energy between the moving mass of the cone, with the air in contact with it, and the springiness of its suspension, including the compressibility of the air inside the box.

A small force resulting in a large movement at just one frequency can be represented as an analog by a series resonant circuit. The applied voltage is the force, the current is the movement, the inductance is the mass, and the capacitance is the compliance, or springiness.

ELECTRICAL VIEW

But that is not what the loudspeaker looks like electrically. Movement translates to voltage and force translates to current. So a relatively small current produces a relatively large voltage at this one frequency. It looks like a parallel resonant circuit. But if you think of it that way, how are you going to get the other elements into the "circuit," such as the port, if you use a bass reflex, and so on?

You could use the other analog in the set I introduced in the July issue (see reproduced TABLE I). But as you probably understand by now if you have been following this series of columns, neither analog is completely satisfactory. Each can only go so far.

There is another factor. Perhaps you could make an analog of this by using mutual inductance, but that is difficult because it changes phase with frequency. In the bass reflex, both movements—that of the cone and that of air in the port—interact. Because at resonant frequency the air movement from the port supplements the sound wave radiated, the air pressure fed by the cone is increased. This is equivalent to increasing the mass of air that the cone has to move at that frequency.

When you go to a lower frequency, where air just shuffles through the port, from the back to the front of the cone, as it does around the edges of an open baffle at low frequencies, the release of air from behind reduces the apparent load on the front of the cone. And at higher frequencies, movement of the cone, as well as radiating a sound wave from the front, merely compresses and expands the air in the back, too quickly to allow much movement to take place in the port.

Now, to complete the perplexity about how you apply analogs, think about this: how do you represent the fact that opposition to cone movement is the combined effect of air against it, in both front and back: does that look like a series, or a parallel combination?

Actually, you can have you pick, according to which analog you prefer. I have included both of them in FIGURE 1 in the accompanying illustrations of an infinite baffle-type enclosure. ■

JOHN M. WORAM

db The Sync Track

• Since this issue of **db** features several articles on various aspects of the tape-to-disc transfer process, it might not be a bad idea to spend some time here exploring the subject from the point-of-view of the small studio operator. For every studio that does its own disc cutting, there are very many that don't. Consequently, there are a lot of mixers around who have not had the opportunity to get involved in transferring their master tapes to lacquer. This can be unfortunate, since there is a lot that can happen at the cutting lathe to make or break the production. If the recording engineer doesn't know a little something about the process, he may not get the best possible finished product.

First off is the question of whether the tape-to-disc transfer is the last step in the creative process or the first step in the production process. Depending on to whom you talk, it's definitely one or the other. But actually, it's probably a little bit of both.

Some companies cut their lacquers right at the pressing plant. That means you'd better make very sure your tape is ready for transfer before you let it out of your hands. Here, the job is "stage 1" in the production line.

It's probably more common—especially in the United States—for the disc cutting facility to be near the studio (in the same building, down the block, or perhaps across town). In this case, the tape is often sent out for transfer along with the producer, who may then spend hours driving the tape-to-disc engineer out of his mind.

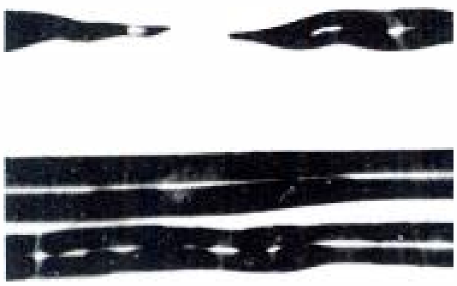


Figure 1. What goes down must come up. Excessive vertical modulation has caused the cutting stylus to lift off, perhaps due to some out-of-phase components in the master tape.

Each method has its arguments. For the former case, there is some evidence that the lacquer disc deteriorates somewhat during the interval between cutting and plating. Consequently, it should not be subjected to the rigors of a long voyage between the cutting room and the pressing plant. Also, if the pressing plant has plating problems, a new lacquer can be cut without delay.

However, if the transfer facility is reasonably near the studio, the producer can take advantage of all the gadgets that are availabe to help him make a better product. Here, it becomes vital to know what can—and what can't—be done, since disc mastering engineers get paid by the hour too.

Begin by regarding the cutting lathe as a giant transducer, for—like the microphone and the loudspeaker—it is converting one form of energy into another. And, as with other transducers, there are limitations to consider.

For example, playing time versus dynamic range. On tape, these variables are completely independent; neither has an effect on the other. Not so on the disc, where each revolution takes up space, and therefore, time. So, as required playing time is increased, the spacing between grooves must be decreased. However, as the cutting stylus swings back and forth, space must be allowed so that adjacent grooves do not run into each other. In other words, the louder the program, the shorter the playing time. Every time a loud passage comes around, the spacing between the grooves must be widened at least one revolution in advance. The wide spacing must then be retained for at least one more revolution, so that the

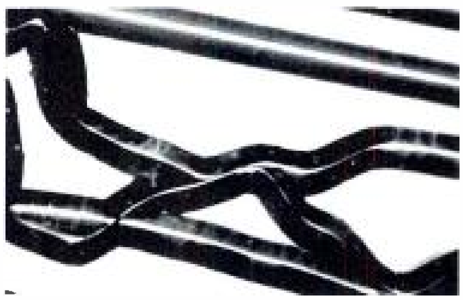


Figure 2. The ultimate test for playback stylus tracking? Not quite—it's just an example of what may happen when the mastering engineer gets some misleading test tones up front.

next groove does not cut into the previous one. And, when you get near the label area, the program is over, whether you like it or not.

PREPARING A TAPE FOR DISC MASTERING

White leader is great stuff for visual identification of the beginning and end of a complete musical program: that is, one side of an lp or a 45 rpm single. However, between cuts on an lp, it is probably better to use recorded (but blank) tape instead. If leader tape is used, the sudden cut into total silence between songs can be audibly distracting.

Contrary to popular belief, the disc mastering engineer does not need white leader tape to see when to make spirals. What he does need is *accurate* timing information, such as:

	Elapsed time:
"Song #1"	ends at 3:48
spiral	(:05)
"Song #2	starts at 3:53
	ends at 6:14
spiral	(:02)
"Song #3	starts at 6:16
	etc.

The elapsed time data allows him to anticipate the spirals. Writing out the time between songs (in parentheses, above) just makes it that much easier to get the spirals placed where they belong. And remember that spirals are made by rapidly advancing the cutter head. That means that although the pause between songs may be only a few seconds in duration, each spiral may "eat" about 25 seconds' worth of available playing time.

If your tape is anything more than a collection of standard-type songs with obvious beginnings and endings, let the transfer facility know what to expect. Many disc mastering engineers have become prematurely gray from contending with abrupt endings, segments of backwards program, channel imbalances and other assorted strangeness. If strange is part of your production, let the engineer know about it. Otherwise, he may try to make corrections that you don't want made.

TEST TONES

And even if your tape is riddled with strangeness (creative, of course), make sure the test tones at the head of the tape are not in the same category. One reader wrote in recently to describe how he prepared his tape for disc mastering. ". . . record the following tones at 0 dB on the left track. 15 kHz, 10 kHz, 1 kHz, 50 Hz. Then rewind the tape and do the same thing on the right track." Wrong!!

If you do it this way, there will be no phase relationship whatever between the tones on the left and right tracks. The disc mastering engineer will go beserk trying to get his system's playback head azimuth aligned to your tape. Give the poor guy a break, and record your test tones simultaneously on both tracks. Also, clearly indicate what sort of meter readings should be expected. For example: "1 kHz test tone at head of tape. Set tape recorder output level to read 0 VU = +4 dBm. Frequency response (or 10 kHz, or whatever) follows, recorded x dB below 0 VU."

If you've used a noise reduction system, don't forget to pass along that information too. In fact, you might even want to mention which one.

In short, anything you can do to make things easier for the disc mastering engineer will pay off in reduced expenses, and probably in a better sounding record. ■

MARTIN DICKSTEIN

Sound With Images

• 'Tis the season to rejoice—for some parents, that is. The kids are back in school! The youth, however, can't quite figure out what happened to all the time they had this summer and some are even complaining about going to school again. After all, didn't they go last year? In either case, the responsibility is once again in the hands of the educators to try to present their subject matter so that as many students as possible will gain something from their efforts.

To assist the educators, the school systems make use of many (if not most) of the audio-visual aids available. In fact, the educational field especially colleges and universities, is one of the largest users of audio-visuals. Auditoria are specially designed in the newest schools to permit use of some of the most sophisticated equipment made. Older schools are adding equipment and quite a few are redesigning present facilities or adding new ones to make use of the latest equipment on the scene.

Schools at the high school and elementary levels are also making use of much of the equipment that can be found. Generally, slide and film projectors, overhead (transparency) projectors, and film strip projectors are employed. It is not very difficult to set up a projector with a wall or ceiling pull-down screen, or even a tripod unit, and everyone knows that a picture is worth—whatever the rest of the cliche is. There is no doubt that using transparencies or films can make a subject, a lesson, a fact, come to life. or at least add some interest so the students (and the teachers) will stay awake, and the material will get across better with greater retention.

PURCHASING KNOW-HOW

The widespread use of audio visual equipment is a good thing, of course, but it raises many questions. How do schools decide on what equipment to buy? Not only what type. but also what brand? Is it always wise to buy more of the same type that is already on hand when additions are to be made? Knowing how school budgets work, is there some way that those responsible for the selections can be better informed on what to look for. what to look out for, or even what questions to ask?

Now there is. Actually. there has been a guide around for the past eleven years, but only a small number of people knew of its existence, and not many educational institutions have made all the use of it that is available. The answer is EPIE, an acronym that comes from Educational Products Information Exchange Institute. Based in New York City. it is a completely non-profit. non-commercial. and non-biased service organization.

In November of 1966 the U.S. Office of Education provided a planning grant and thus made it possible for the foundation to be laid for the organization of EPIE. It is chartered by the University of the State of N.Y. Board of Regents and was officially established in June of 1967. The National School Boards Association is one of the more than 25 educational organizations nationwide that gave EPIE its blessings at the start. and still serves on the EPIE National Advisory Board. The *American School Board Journal.* a publication of the National School Boards Association. has called EPIE a "Consumers Union" for education.

Its function is to protect and advise schools, school districts. and all the rest of its members in the matter of selection and use of any material of any kind to be used by an educational institution. EPIE has become the watchdog of the educational field. Manufacturers of educational products of any kind—publishers. and material producers. respect the opinions expressed by the organization. and even look for the results of the independent research EPIE carries out.

It performs its function in part by operating its own research laboratory that can run extensive tests on a wide variety of items. and by gathering information provided by educators, students, experts in various fields. state boards of education, publishers. etc. This data is then checked out as much as possible whenever necessary. filed and collected, and then passed on in distilled form to members. or subscribers, in their newsletters. As new information keeps coming in. readers are kept up to date. In several subjects, very extensive reports have been published with in-depth type of information on the subject. A very brief look at some of the many things with which EPIE has become involved will indicate the vastness of the field and the value of the work performed.

PRODUCT TESTING

During the past few years, EPIE has undertaken projects that involved reviewing as many as 2,000 products being sold to educational institutions. The study covered such items as the quality of color reproductions, the instructional design of materials, and whether book bindings were sturdy enough to last as long as five years. One particular project they undertook was an effort to provide guidelines to educational agencies on mandating procedures for Learner Verification and Revision of many of the materials marketed to schools. A 39-member task force which included teachers as well as students, administrators, researchers, school board members, and producers looked at whether various items used in the classroom (such as workbooks, for example) really helped students learn what they were supposed to, and whether revisions have or should be made to those features which hindered rather than helped the learning process.

Another project involved a National Survey and Assessment of Instructional Materials. This was a first-of-a-kind and included a study of the effectiveness of instructional as well as curriculum materials that are available. They even became involved with instructional software such as tapes and filmstrips meant to assist the education process in the lower grades. Some of the software failed because they were never tried on children of the particular age for which they were intended, and the youngsters did not even comprehend some of the instructions. It was also found that what worked in some areas of the country did not do well in others.

In the educational materials area, EPIE become aware of products used for gluing, for example, and ran tests to determine if the products do what they claim, are harmful in any way, if the cost generally was worth the purchase, and if it was wiser to buy in bulk or small quantity at a time. EPIE has checked on learning kits, programs for various subjects, cassettes for video systems, and even consumer education materials.

HARDWARE

When it comes to hardware, EPIE again runs full tests on as many items in question as possible to determine a series of answers related to value, operating cost, safety, ease of operation, and whether items meet published specifications. For example, a series of tests were run on projector bulbs several years ago. It was found that the same bulb made by three different manufacturers had a wide variance from their specified life spans. One manufacturer was far better than spec (as much over 100 per cent better), while the other two were less than 50 per cent of spec. The matter was brought to the attention of the faulty-bulb makers and the poorer products were brought closer to spec. This in no way reflected on any other type of bulbs made by them, just the one model under test. The laboratory investigation was run under strictly controlled conditions.

In the audio-visual field, with which this corner is usually most concerned, EPIE has obtained some valuable information which is probably not available through any other source. Much of the information they receive, as well as inquiries, comes to them from members on *EPIEgram* feedback forms. A short series of questions on the form requests that certain information be provided. Sometimes complaints, many times technical questions, and very often requests for advice and information give EPIE the subjects in which the members are most interested and which require the most study and further investigation.

SAFETY

In the matter of safety of electrical devices, numerous questions came to their attention on the subject of double-insulated equipment and the 3-wire electrical power grounding system. EPIE went into some detail to explain the differences and examined where each type is most likely to be used. They also went into why it can be unsafe to use the common 3-to-2 prong adapter, and why, in audio-visuals, where equipment is usually interconnected (as differentiated from items such as drills or office equipment which are used singly and independently of any others) there can be problems and safety hazards in the use of the two methods of power wiring, when hooked together.

One of the most valuable studies undertaken by EPIE was an evaluation of the cost-effectiveness of a.v. equipment. Some interesting results came through. For example, they ran surveys on lifetimes of various types of equipment, checked manufacturer specs of the life of lamps, and costs of electricity in different sections of the country, finding an average value, and measured projector outputs in the lab.

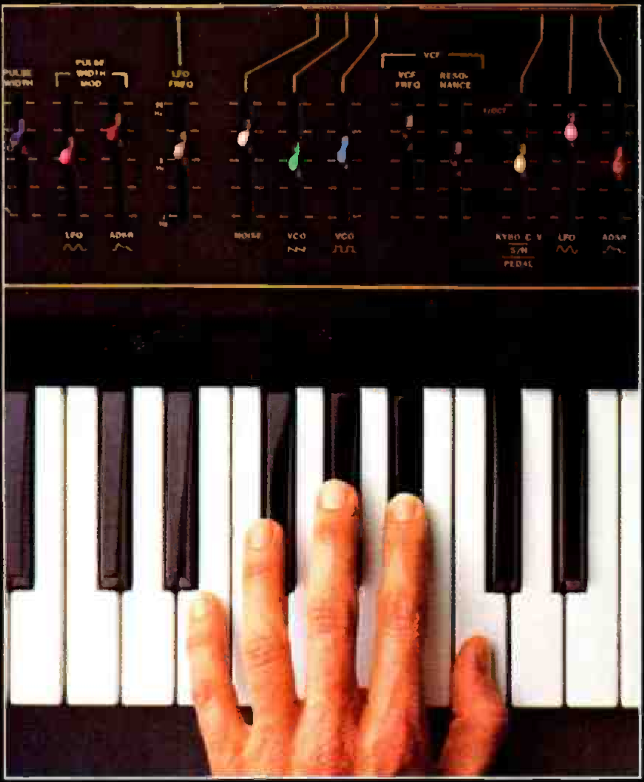
Following that, they charted the information and got some fascinating results. For slide projectors, as one example, they found that the use of one type of bulb could cost the user as much as almost $4,000 in replacements during the expected 3200-hour life of the unit. With another lamp, the cost over the same span could be as little as $200. As another example, one type of overhead projector, priced $27 less than another in original purchase cost actually ran over $250 more in operating costs over the life span of 3,400 hours. Quite a difference when one considers the individual items in relation to future budget allocations.

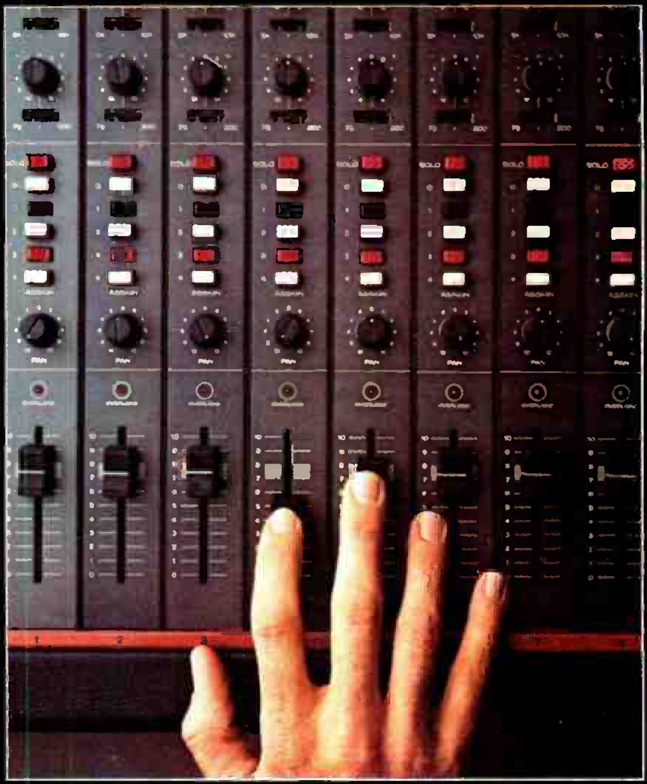
Another subject for much discussion is the use of the ¼-in. jack on some film projectors, and the 0.206 in. on others. It was explained that there might be some advantage to the smaller diameter jack which prevented naive users, such as young students, from putting a headphone plug into the output of a film projector with the level set fairly high, thus avoiding the possibility of hearing damage. Counter complaints came that in some areas it was not possible to find the smaller plugs and thus prevented the output from being fed to either other speakers or through other audio systems. The discussion and study continues.

EPIE has also published in-depth reports on a multitude of subjects. One was a how-to handbook on writing equipment specifications. Another covered the subject of *Materials for Individualizing Math Instruction*. Still another was on the subject of electrical safety in schools. In the field of hardware, they wrote on the *Life Expectancy for AV Equipment: A User Report*, *Heavy Duty Audio Cassette Recorders*, and evaluations of 16mm motion picture projectors and 35mm silent filmstrip viewers. And these are only a few of the topics. And in both the EPIEgrams and the full-length reports, EPIE mentions names.

There are just too many topics and subjects to mention in this limited space with which EPIE has dealt, and with which they still plan to get involved. It seems only right that more people, both in the educational field and those associated with them in any way, should get to know what the organization has to offer. Even educators could learn something, save money at the same time, make their work a little easier and safer, and find that it might even be the season for them to be jolly—er—or at least a little jollier than they have been.

EPIE has just moved to new quarters, and can be reached at 475 Riverside Drive, N.Y. 10027. We would appreciate your mentioning us in your correspondence. ■





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DIRECT BOX

● Direct box PS-9 is equipped with a noise fader with an adjustable sensitivity to accommodate various input levels, ranging from microphone to professional amplifiers or to create special effects. High frequency input is retained by providing a very high input impedance which avoids loading down the instrument pickup. The direct box's +9 dBm output is sufficient to drive professional amplifiers. When long cable runs are required, very low output impedance reduces loss of high frequency and pickup of hum and noise. All of this works with the guitar amplifier even if no interface with professional equipment is used. Phone jack and 3-pin XLR connector included.
Mfr: Tycobrahe Engineering Co.
Circle 51 on Reader Service Card

DISCO CONSOLE

● Oriented to disco use, D.J. Disco consoles incorporate electronic music synthesizer techniques. DC-300 features voltage controlled stereo mixing, switchable headphone monitor, stereo metering, automatic voice-over for microphone, slide cue control with l.e.d. indicators and master equalizer. There are two turntables with magnetic cartridges and diamond styli with a four-pole synchronous motor. The console has three separate stereo line outputs for power supplies, as an amplifier with pre-amp, and a third for stereo reproduction. The unit is modular, comes with a transporter cover.
Mfr: Earth Sound Research
Circle 52 on Reader Service Card

SPEAKER ENCLOSURES

● Made for the road and its onslaughts, Series A 1917 monitors are enclosed in husky low resonance wooden carrying cases (in 5 colors) and pampered with foam linings. The panel holding the speakers is suspended, so they are protected from direct contact with outside impact. The units incorporate electronic tweeter-protector circuitry. They have three usable angles: 70 degrees, 30 degrees, and 90 degrees.
Mfr: Amanita Sound Co.
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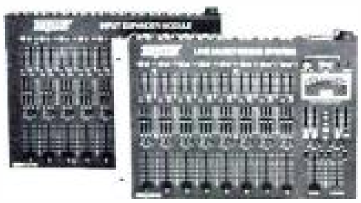
INSTANT RECORDING

● Loss of material through blank leaders is eliminated in the IRC line of cassettes. Leaders are of 1.5 mil. tape recording tape, accepting material the instant the recorder is switched on. The body of the cassette is composed of 1 mil tape, in recording capacities of 30, 60, and 90 minutes.
Mfr: 3M Company
Price: $1.50-$2.50.
Circle 54 on Reader Service Card

ECHO/REVERB UNIT

● An endless tape loop is featured on Echo 200 echo and reverb. The motor speed is electronically controlled and the echo delays are continuously adjustable from 100 μsec. to 380 μsec. Included are one record head and one playback head, universal input with switchable and adjustable input sensitivity, echo channel with echo duration, echo tone and echo return controls. There is a connector for amplifiers. The unit is portable, with carrying case, measures 17 x 13 x 3 in.
Mfr: Dynacord, Inc.
Circle 55 on Reader Service Card

LIVE MIXER



• If you mate an output control module with eight inputs with a ten-input expander, Trouper I puts eighteen inputs on the road. Each input stacks up with the following features: low level balanced input, high Z input, in/out jack, 20 dB of mic attenuation, monitor send, echo send, three band graphic equalizers, solo switch for individual channel monitoring. The vu meter follows the solo system. The output control module also features house and monitor outputs, echo send/receive jacks, headphone jack, solid state vu meter, echo send master to the built-in reverb, headphone level control, house/monitor echo receive, high/low cut filters, and house/monitor level controls.
Mfr: Uni-Sync, Inc.
Price: Output Control Module: $749. Expander: $698.
Circle 56 on Reader Service Card

RECORD TRANSDUCER SYSTEM

• Two transducers, directly coupled to the stylus system by a tiny rubber ring system, are employed by model 9210SG. This enables the device to pick up vibrations of ultra-sonic frequencies (20 kHz-50 kHz). R.I.A.A. playback equalization is accomplished mechanically at the transducer. The cartridge incorporates a semiconductor strain gauge element that utilizes the variable resistance effect of semiconductor materials when deflected. The electronics provide the source current for the cartridge and the additional amplification required to supply a high level input to any auxiliary preamplifier. Frequency response is 5 Hz to 20 kHz ± 1 dB, with claimed less than 0.1 per cent thd, dynamic range in excess or 70 dB from 20 Hz to 20 kHz, R.I.A.A. accuracy within 1 dB.
Mfr: Ram Audio Systems, Inc.
Price: $299.00.
Circle 57 on Reader Service Card

New Literature

MAKE-IT KITS

400 electronic kits are listed in this catalog. Mfr: Heath Company, Benton Harbor, Michigan 49022.

PROFESSIONAL EQUIPMENT

A 100-page catalog contains complete fact sheets on the manufacturer's entire line of products. Mfr: Community Light & Sound, 5701 Grays Ave., Philadelphia, Pa. 19143. (Christine Kofoed)

AUDIO CONNECTOR

The Quick Ground Professional Connector, especially suited for rigorous entertainment settings, is described in a four-color brochure. Mfr: Switchcraft, 5555 N. Elston Ave., Chicago, Ill. 60630.

SWITCHING TRANSISTORS

XGSR series high voltage switching transistors are described in an 8-page data sheet. Mfr: General Semiconductor Industries, Inc. P.O. Box 3078, Tempe, Az. 85281.

TEST INSTRUMENTS

More than 40 test instruments and their accessories are described in a 48-page presentation. Mfr: Leader Instruments Corp., 151 Dupont St., Plainview, N.Y. 11803.

SKEW AND TENSION

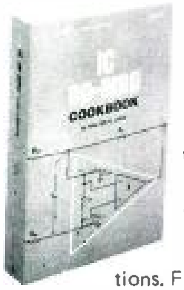
How to eliminate skew or tension errors in video is revealed in a two-page publication. Mfr: 3M Company, P.O. Box 33600, St. Paul, Minn. 55133. (Clark Duffey)

AUDIO/VISUAL AIDS

290 products for the aid and comfort of a/v presenters, such as storage, retrieval, security, and mobility equipment, are detailed in a color catalog. Mfr: H. Wilson Corp., 555 W. Taft Dr., S. Holland, Ill. 60473. (Kathi Jenin)

OUTLET STRIPS

The conversion of one electrical outlet into many is achieved through outlet strips. This catalog shows how, as well as giving information about wheeled carriers. Mfr: Waber Electric, 300 Harvard Ave., Westville, N.J. 08093.



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PETER "PETE SKYE" DWORSKY

The Audible Effect of Disc Center Accuracy

For critical musical reproduction, precise centering of a disc requires exact measurement.

THE PROCESS of creating the center hole in a phonograph disc starts when a "lacquer" is cut on a lathe, usually from a master tape. A hole, to be used in centering the lacquer on the lathe, has been placed there by the manufacturer. During cutting, the center hole is ignored—the lacquer is held down by suction—so it makes no difference if the hole is too big for the lathe's spindle, as long as the lacquer does not shift during the cutting process. The outside edge of the lacquer is also ignored during this stage, so if it is not true to the center hole, it makes no difference.

The first error may occur during the plating process, in which one or more "stampers" are made. These stampers need center holes and one must be placed in each. The stamper is placed in a punch press, which has a die in a round rotating table. The operator examines the grooves in the stamper with a stationary microscope, much like on a mastering lathe, while he spins the table. By tapping lightly on the edge of the stamper with a small steel bar which with each tap moves the stamper slightly, he centers the stamper by causing the grooves to move evenly in one direction across the face of the microscope. Then he pulls the punch press lever, which punches out the center hole in the stamper. The center hole size is specified by the pressing plant which will get the stampers.

Now the stamper is placed on a similar rotating table fitted with a spindle and similarly examined. If the hole has not been punched accurately enough, it is tapped on with a metal hammer which moves a slight amount of metal into the hole and scraped with a sharp-edged instrument until the hole's accuracy is acceptable.

At the pressing plant, the stamper is mounted into a record press. This requires the use of brute force and a wooden mallet if the hole is too tight; some of the hole's accuracy can be destroyed in the mounting operation. The actual hole in the record comes from a permanently mounted spindle die in the press. Since the stamper hole and the mounting die in the press are much larger than a spindle hole, the accuracy of the hole's position here depends on two things, the accuracy of the stamper's hole and the accuracy of the spindle die in the press.

MEASURING THE ERROR ON A FINISHED DISC

A setup similar to the one used in the processing plant is suggested. The spindle should fit very snugly, so that the pressing does not slide slightly from side to side. If the spindle is slightly beveled, mounting and dismounting the pressing will be facilitated. The lockout groove near the center of the disc should be used for the measurement since, hopefully, it will not move across the calibrated microscope's face as the turntable is revolved. When making a reading, divide the distance between the lockout groove's excursions by *two* to get the error from true center.

STAMPER STRETCH

My attempts to measure differences caused by "stamper stretch" were inconclusive. I could not find any changes in the distance from true center to any selected musical passage in either of two pressing runs of 275 copies each. I did, however, find that e, the actual center hole's error from true center, increased in varying amounts; in one case it reached nine mils on the last copy. This could indicate that the stamper sometimes shifts while in use in the record press.

CALCULATING PERMISSIBLE ERROR

If we forget about warped records and work in two dimensions, and if we ignore the slight changes created by today's computerized lathes, there are only three parameters to work with: f, the shift in frequency (as a ratio) caused by the inaccurate center; e, the distance from the true disc center to the erroneous center; and r, the radius from the true center to the point on the groove under investigation. Note that the speed of rotation is *not* a parameter.

We have the following relationship:

$$f = (r + e)/r$$
$$\text{or, } r = e/(f - 1)$$
$$\text{or, } e = r^{*}(f - 1)$$

The best musicians can sometimes hear a three-cent error in a musical note.[1] A cent is taken to mean one of

TABLE 1
ACCEPTED DISC DIMENSIONS IN INCHES

Groove Dimension	33	45
Starting diameter	11.5	6.5625 (6-9/16)
Starting radius	5.75	3.28125
Ending diameter	4.75	4.25
Ending radius	2.375	2.125
Lockout diameter	4.125	0.796875 (3-51/64)
Lockout radius	2.0625	0.3984375

"Pete Skye" Dworsky is the chief engineer at Watermark Studios, Inc. in N. Hollywood, Ca.

one hundred equally ratioed intervals of a half-tone. There are twelve equally ratioed half-tones in an octave and an octave is the interval which is bounded by two frequencies having the ratio 2. Thus, a half-tone would have the ratio of $(2)^{1/12}$. A cent would have the ratio $(\text{half-tone})^{1/100}$. Thus, three-cents would be the ratio $(((2)^{1/12})^{1/100})^{3} = (2)^{3/1200} = (2)^{1/400}$.

This is approximately 1.001734370. So we will assume that the best musician could, for example, sometimes hear a change in frequency from 1000.0Hz. to 1001.734370 Hz, but could not hear the change if it was less than that.

If we take e1 as the radius error which will just cause the $(2)^{1/400}$ pitch change between the fastest and slowest groove velocities, we can calculate e1/r, the maximum permissible error for any groove radius. Take f.high as the highest pitch, f.low as the lowest pitch. From the above relation,

$$f.high = (r + e1)/r$$
$$f.low = (r - e1)/r$$
and we want $f.high/f.low = (2)^{1/400}$

Find e1/r: $((r + e1)/r)/(r - e1)/r) = 2^{1/400}$

$$(r + e1)/(r - e1) = 2^{1/400}$$
$$(r + e1) = (r - e1) * 2^{1/400}$$
$$e1 * (1 + 2^{1/400}) = r * (2^{1/400} - 1)$$
$$e1/r = (2^{1/400} - 1)/(2^{1/400} + 1) = \frac{0.001734370}{2.001734370}$$
$$= 0.000867$$

Example 1: Suppose we have an lp being pressed and we grab a sample off the line. We find the error at the lockout groove to be 5 mils (a 10-mil total excursion), or 0.005 in. We measure the distance from the center to the closest musical groove and on this disc get r = 2-13/32 in. = 2.40625 in. Can this error be heard?

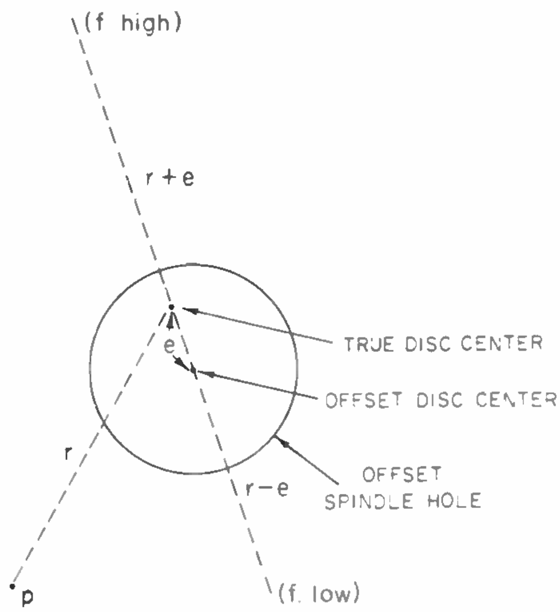

*Figure 1. We are attempting to find e1, the largest value of e which will not be heard. This value is calculated to be 0.000867*r.*

Solution: $f = (r + e)/r$
$= 2.41125/2.40625$
$= 1.002077922$

The frequency shifts both up and down by this much. The actual ratio of the two frequency extremes is

$f^2 = 1.004160162$, which is greater than our 1.001734370.

Thus the error could be discerned by some people.

Example 2: How far away from the center must we get for our 5-mil error to be undiscernable?

$$el/r = 0.000867$$
$$r = 0.005/0.000867$$
$$= 5.767012687$$

On a typical recording, this means that perhaps the first two minutes of each side would be okay for everyone.

Example 3: How much error should we allow? If we allow music no closer than 2.375 in. from the center (the lockout groove is at 2.0625 in.), then

$$r = 2.375, \text{ so}$$
$$el = 2.375 * 0.000867$$
$$= 0.002059125$$
$$\cong 2.06 \text{ mils.}$$

For critical music, very tight quality control should be exercised on each pressing run. The acute listener might want to consider purchasing a calibrated microscope so that he could center his discs on his turntable before playing.

The ending groove dimensions are minimums. Mastering engineers may end a side further from the center if possible to reduce discernible program changes caused by lower groove velocity.

The foregoing background on how the center hole in a phonograph disc is placed there is based on my observations at only three cutting rooms, one processing plant, and one pressing plant. Operations may be different elsewhere. ■

REFERENCE

1. "Build a Pitch Reference," *Popular Electronics*, September, 1968, p. 47.

STAN RICKER

Half Speed Disc Cutting

The author, with much experience at this subject, views the value of half-speed cutting in the production of disc masters.

ALTHOUGH half-speed cutting has recently received some attention in connection with the production of CD-4 quad records, it is by no means a new technique. In fact, its advantages for regular stereo disc mastering have been well known since the early days of the lp. English Decca used the technique up until 1968, since they felt it gave them a superior-quality disc.

In this country however, many mastering facilities were using the Westrex system, and real-time tape-to-disc transfers seemed to satisfy producers most of the time. Yet at least one major label resorted to half-speed from time to time as a problem-solving technique, especially on sibilance-prone recordings.

Given the current state of the art tape-to-disc transfer systems, half-speed cutting may now seem (at first glance) to be more trouble than its worth, but let's take a closer look before putting it in the CD-4-only category. Here are two questions frequently asked.

QUESTION ONE

Doesn't bass response suffer? Theoretically, perhaps, but for all practical purposes, no. Measurements at the JVC Cutting Center show that the cutting system's low frequency output is flat down to 7 Hz, and is down 3 dB at 4.5 Hz. In real-time, these frequencies move up an octave to 14 Hz and 9 Hz. With the addition of peripheral equipment (tape deck, noise reduction, transfer console, signal processing devices, etc.), the total system response begins to roll off at 14 Hz, and is down 3 dB at 11 Hz. In other words, the real-time response of the total system is flat down to 28 Hz, with a 3 dB roll-off at 22 Hz. These limits impose no practical restrictions on the low frequency response of practically any record produced today.

Stan Ricker is chief engineer of the JVC Cutting Center, Inc. in Hollywood, Ca.

QUESTION TWO

What about the low per-unit-time lacquer production rate? In the very real-time world where production is more important than quality, this is a definite problem. On the other hand, it is not uncommon to spend many months (and many dollars) to produce that final master tape. When it is finally ready for transfer to disc, doesn't it deserve more than a half-hour or so of the disc mastering engineer's time and attention?

If you don't think so, then half-speed cutting is probably not for you. On the other hand, if you are interested in a better-quality record, consider some of the arguments *for* half-speed cutting, such as:

1. More accurate high frequency phase response.
2. Better transient response.
3. Less high frequency cross-talk.
4. Lower distortion within the total transfer system.
5. Smoother groove cuts, and therefore better electroplating at the pressing plant.
6. Less noise and better high frequency response at inner diameters.

The first three points are closely related, so we'll examine them together, as behavior patterns of cutter heads in general. Cutter head systems are classified as dynamic motional feedback systems; that is, for each channel, there is a driving coil and a feed-back coil. The feed-back coil could probably use some explanation.

Like the driving coil, it operates within a strong magnetic field, and generates an EMF corresponding to the motions of the cutting stylus and connecting rod. This EMF is fed back to the drive amplifier through some sophisticated circuitry, and is compared with the input signal. Deviations in either amplitude or phase indicate that the cutter is not doing precisely what is desired of it. Therefore, the phase and amplitude errors are "seen" by the motional feedback circuitry, and proper voltage and phase corrections are made, with the corrected result fed to the drive coil.

Although the operating theory may be reasonably straightforward, in practice there are at least a few "variations on the theme."

FEEDBACK UNIFORMITY

For example, the amount of feedback control available is not uniform across the audio frequency bandwidth, as seen from the chart in Table 1. We find that, while feedback control at the primary resonance point (about 900 Hz) is somewhat in excess of 35 dB, control in the upper registers is marginal. A quick glance at the chart shows that if we cound bring the troublesome upper frequencies down by one octave, we could have much more feedback control available at the cutter head.

A high pitched voice, close-miked by a condenser microphone with a rising high end (it happens all the time, folks), can create tremendous energy clusters on the tape in the 8 kHz vicinity. As most cutting engineers know, this type of program will cause lots of problems throughout the system. Chances are, the circuit breakers in the cutting system will trip, due to power drain by the amplifiers on the associated power supplies. If the level is dropped to a point where the sibilance can be safely cut, the over-all level on the disc will be too low. The usual compromise solution is to use program peak limiters at the transfer console, and high frequency limiters, or acceleration limiters within the cutting system itself. Either method provides less-than-optimum transfer of the offending sibilants, with thumps and popping noises heard behind castenets, maraccas, cymbals, and such. These noises are usually traced to d.c. offsets in the power supplies of one or more pieces of equipment in the recording chain, (not necessarily within the cutting system alone).

By transferring the offending program an octave lower (that is, at half-speed) we see that we'll have over 12 dB of feedback control (at 4 kHz on the chart) as opposed to 5.5 dB in a real-time transfer. By dropping the music frequencies an octave, we are able to put more of the total music spectrum in an area where there is more feedback control over cutterhead motion available. And, since high frequency response and phase accuracy are largely a function of this feedback control, we can expect better performance in both of these areas.

RIAA PROBLEMS

Within the upper frequency area, there is yet another "fly in the ointment," and that is the RIAA recording equalization curve. Most of us know it's there, but many just aren't sure what the numbers are, so the RIAA equalization chart is printed here, as Chart 2. Note that 10 kHz is 13.7 dB above the 1 kHz zero reference level. Realizing that every increase of 3 dB is a doubling of power, it soon becomes apparent that the normal cutter system may begin to run out of "gas" in an area where it can least afford to do so.

AMPLIFIER POWER

This brings us to the fourth point listed above. Obviously, if we run a tape and lathe at half-speed, it takes twice as long to cut a given piece of music. By taking twice as long to do the job, we also find that it requires only one quarter of the power to cut the disc, since the acceleration of the cutter stylus is only one quarter of its real-time counterpart. In fact, using a 600 watt cutting amplifier for half-speed cutting is about the same as a real-time big brute of 2400 watts per channel. In fact, it's even better, since the phase accuracy at half-speed is better!

On playback, the improved phase accuracy of the cutter head and the reduced high-frequency cross talk is heard as a dramatically-improved image stability. Full

Chart I

15k	−0.6	1K	−34.0	70	−16.4
10k	−3.2	910	−35.5	50	−15.7
9k	−4.2	900	−35.0	40	−14.9
8k	−5.5	800	−32.0	30	−13.5
7k	−6.9	700	−29.0	20	−10.8
6k	−8.4	600	−26.9	15	−8.2
5k	−9.9	500	−24.5	12	−5.9
4k	−12.1	400	−22.4	11	−4.9
3k	−15.0	300	−20.5	10	−3.5
2k	−19.6	200	−18.5	8	−0.0
1.5k	−24.0	100	−17.0	7	+2.0

Table 1. The amount of feedback control available at the cutter head, indicated in dB. One channel only is shown for clarity. Resonance on this example is at 910 Hz.

Chart II

Recording dB	Frequency Hz	Halfspeed Hz
−19.3	20	10
−18.6	30	
−17.8	40	20
−17.0	50	
−16.1	60	
−15.3	70	
−14.5	80	
−13.1	100	50
−12.4	110	
−11.6	125	
−10.2	150	
−8.3	200	100
−6.7	250	
−5.5	300	
−3.8	400	
−2.6	500	
−1.9	600	
−1.2	700	
−0.7	800	
−0	1,000	500
+1.4	1,500	
+2.6	2,000	
+4.7	3,000	
+6.6	4,000	2000
+8.2	5,000	
+9.6	6,000	
+10.7	7,000	
+11.9	8,000	
+12.9	9,000	
+13.7	10,000	5000
+15.3	12,000	
+16.6	14,000	
+17.2	15,000	
+17.7	16,000	
+18.7	18,000	
+19.6	20,000	10.000
+25.6		20.000

Table 2. The RIAA Recording Equalization curve at normal and half speed operation.

left, half left, and center are instantly discernable Percussion effects panned between (or among) channels stay where they've been put. So do brasses and cymbals. There is a naturalness to voices, either solo or in ensemble, that must be heard to be believed.

OTHER FACTORS

Although many manufacturers of both hi-fi and pro hardware would have us believe that all equipment is a straight wire with gain, we know deep down that it just "ain't so."

Therefore, we find that the cutter system itself is not the only part of the transfer chain to benefit from operation at half-speed. In fact, most of the other components within the system benefit from the lengthened rise-time information being fed through the chain, as well as from the reduced power demands.

CUTTING STYLI

At this point, it might be worthwhile to look at recent developments in cutting styli, which together with half-speed cutting techniques, will lead to a finer disc master. Early on in CD-4 cutting, it was found that the standard cutting stylus was not up to the task of cutting the carrier signal that contains the difference information of the complete quadriphonic program. Even at half-speed, the upper frequency range is extended to 22.5 kHz, and the typical stereo stylus is simply too large at the cutting edges (called burnishing facets) to engrave such short wavelengths. Typically, the 30 kHz (real-time) carrier frequency wavelength at 11.5 inches is 0.00069 inches, while at the inner diameter it is about 0.000285 inches. To accommodate these very small dimensions, a new cutting stylus was developed, with a tip radius of 0.00157 inches (1 micron), and an average burnishing facet width of 2 microns. (25.4 microns = 0.001 inch.) In addition to its application for CD-4 disc cutting, the new stylus offers significant improvement in cutting any high frequency program, as well as transients and steep wave fronts in general.

This re-engineering of cutting styli, together with the parallel development of Shibata-type playback styli, permit improvements of up to 3 dB in high-frequency response at the innermost diameters of an lp record.

The length of the new cutting stylus has been shortened to 1.17 mm, as compared to 2.1 mm for a standard stereo stylus. This reduction of approximately 44 per cent greatly decreases carrier cross-talk in CD-4 records, since there is less "whipping action" at the stylus tip. And of course, this improvement applies to stereo record cutting as well.

The high degree of precision required in the manufacture of these styli, together with the slower cutting rate, produces a smoother groove wall, and consequently, less noise.

Finally, there is one more technique that may be used to ensure a better tape-to-disc transfer, and this one applies at real-time as well. Make sure there are adequate test tones at the head of the tape. Although this could be the subject of a separate article (*we're working on it.* Ed.), suffice it to say here that even the most meticulous half-speed cutting job may suffer if the transfer engineer does not have sufficient information for aligning his system to your tape.

Yes, it's your tape, so why not give it the care it deserves. In other words, give half-speed cutting some serious consideration. The additional time spent will probably pay off. ■

GEORGE ALEXANDROVICH

Quality Controlling Stampers and Matrices

Newly devised styli solve a disc cutting problem: quality-monitoring sound at the matrix and stamper stages.

WE ALL KNOW that a chain is only as strong as its weakest link. In the field of sound recording and reproduction, the chain of events which involves sound recording, mastering and disc manufacturing is long and intricate. The longer this chain is and the more stages of signal processing are involved, the more stringent the quality control requirements have to be for each individual step in the entire process. In talking about the process of sound recording, let us review in our minds the picture of all processes taking place between the microphone in a recording studio and the speaker in the home of the hi-fi enthusiast.

After the sound is picked up by the microphone, it is amplified. Then it can normally be processed through equalizers, compressors, and limiters and mixed with reverberated or delayed signals. The outputs of the mixing console where signal grooming takes place are fed into the multitrack tape machine where the signals are stored for final editing and mixdown. Then a master tape is used for tape duplication and for the production of records.

Up to this point, every step of sound processing is carefully monitored and controlled. The minute the master disc is cut, we enter the region of partial QC blackout which lasts until the records are pressed and familiar sounds re-emerge as we play the finished pressings. Just as when a spacecraft returns to earth and we keep our fingers crossed as it burns its way through the atmosphere until it splashes down safely, so we send our master lacquers through the series of plating tanks, hoping that at the end of this intricate process the sound from the records will be the exact replica of the sound heard on the master tape.

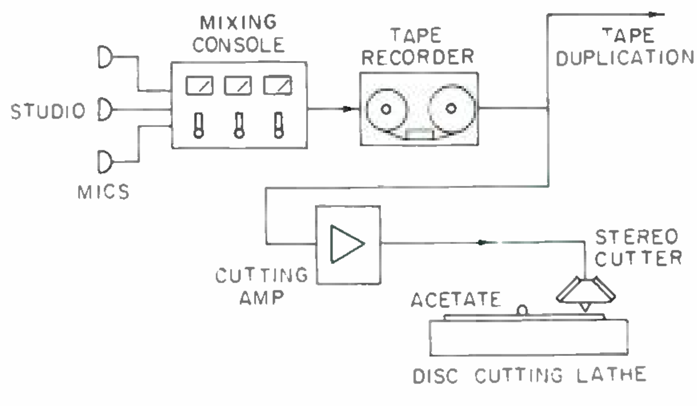

Figure 1. The signal processing chain preceding the actual cutting of the disc.

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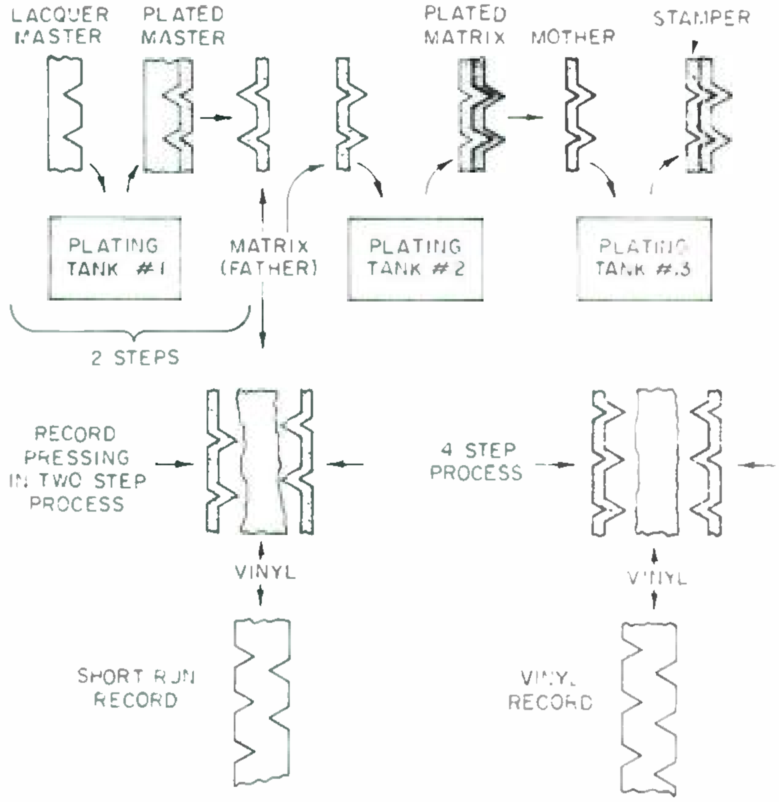

Figure 2. The plating sequence when producing the matrix, mother, and stampers from the acetate master, leading to the two-step or four-step process.

For decades, the whole record manufacturing industry operated without knowing if the quality of the vinyl pressings would be acceptable or not until test shots were made or in many cases, until the production of records had actually started. Not many people are aware of all the complicated plating processes which precede actual record pressing. Most of us know that records are cut and then they are pressed or stamped. In order to describe the procedures that lead to the manufacturing of the stamper, we have to start with the lacquer master.

LACQUER MASTER

The master disc is made of a circular sheet of aluminum covered with a thin layer of acetate lacquer which is placed on the turntable of a disc-cutting lathe and into which we cut modulated grooves. Grooves cut in the lacquer resemble grooves in the final product; you can play them with a cartridge having an ordinary stylus designed for vinyl records. However, because the lacquer is soft, if you play it, the groove will quickly wear out, resulting in the deterioration of the frequency response, and an increase in surface noise and distortion. Therefore, it is the accepted practice not to play masters. If the master were played, a reputable disc manufacturer would not use it for further processing.

There are two basic processes of manufacturing records—the two-step process and the four-step process. The first step in both processes consists of plating the master with a hard metal, such as chrome, which makes the negative impression of the record. Before doing this, the surface of the master has to be made conductive by spraying the lacquer with a special silvering solution. One side of the master is covered with insulating material and the whole assembly is lowered into the plating tank. When the thickness of the plating reaches approximately 0.01 inches, the

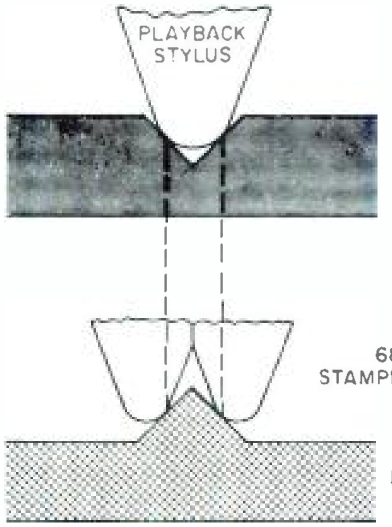

Figure 3. Locations where the bi-pointed stylus touches the ridge of the stamper should coincide with the contact area in the record groove.

master is pulled out of the tank and the metal plating is peeled off, producing a record negative called a *matrix*. (In Europe they call it the father.) The lacquer master can be plated only once. It is destroyed after the first plating when the matrix is peeled off.

The two-step process, used when a small number of records are to be produced, employs the matrix for stamping records. Records produced in this manner are also called strike-offs.

When a great many records are to be made, the four-step method is used. In this process, the matrix is plated again, producing a negative of the negative, or a positive called a *mother*. This mother, in all respects, duplicates the original master and previews the final product: therefore it can be played with an ordinary cartridge.

STAMPERS

Many negative impressions, called stampers, can be produced by plating the mother. Stampers are mounted in the record pressing machines, where they squeeze a "biscuit" or "cake" of preheated vinyl and form it into a thin record. When many thousands of records are to be produced, a great number of stampers are necessary because each stamper can produce only a limited number of vinyl pressings, a couple of thousand at the most. Impurities in vinyl slowly but surely wear down the stamper by dulling the originally sharp ridges which produce grooves in vinyl.

QUALITY TESTING

Up until recently, there has been no way to monitor the quality of the plating beyond listening to the mother before the stampers were made. Usually we could perform only an optical inspection of the matrix and stamper, which did not tell us very much. We could monitor the quality of the sound or signal at every stage of the mixing console in tape recorders and in the cutting amplifier, but nothing could be done to listen to the matrix or the stamper.

Stanton Magnetics has been instrumental in the development of a special bi-point stylus to be used to play or "ride" ridges (negative grooves) of the matrix or stamper to enable it to be heard for quality control. Because of the basic differences between records and stampers, special hardware is needed to accomplish this. The stamper or matrix is the reverse of a record in some ways. Vinyl records are rotated in a clockwise direction, the stamper in a counter-clockwise direction. The record has grooves: the stamper has ridges. It's possible to play a stamper like a conventional record, with a special stylus, but the sound comes out backwards, not too pleasing to the ear. Therefore, a turntable with counter-clockwise rotation is used with a special tone arm, which is placed to the left of the center of the record with the offset angle in the opposite direction from the one we are used to. Even the cartridge wiring is unique. The left channel becomes the right channel, so in order to keep sound coming from the same direction, the channel wiring has to be reversed.

The stylus used to play the ridge of the stamper has to have two diamond tips positioned very close to each other in the plane, perpendicular to the record surface and passing through a line joining the stylus tip and the record center. The cartridge body used to convert vibrations of the special stylus tip into electrical signals is of ordinary design. The main trick is to design a stylus which is able to ride the ridge without falling off, without touching the adjacent groove or touching the bottom or the space between the ridges and is able to track all high frequency modulation.

Playing the stamper enables one to check the quality of the plating. Many times an impatient plater increases the current during the process to speed up production of the stamper, thereby producing a "burned" or a rough surface. This in turn increases surface noise in the finished product. We can detect this by playing the stamper. Improper cleaning and silvering of the master can produce pops and clicks in the finished product. These imperfections appear either as holes or bumps on the plated sur-

Figure 4. An actual photograph of the Stanton 681 BPD/M bi-pointed stylus tracking the ridge of a stamper. © Stanton Magnetics, Inc. For comparison, a stylus is shown in the groove of a record.

face. By playing metal parts we can detect these imperfections before the final production of the vinyl pressings and take corrective steps.

Once we establish the quality of the plating and find that there are an acceptable number of imperfections present on the modulated portions of the stamper, since it is more economical to polish out a few pops and clicks rather than throwing away the stamper, we use the same double-pointed diamond tip to burnish the rough spots in plating.

REPAIR STYLI

For this we have designed two types of stylus assemblies. One we call 681 BPS-M, a light device tracking only at ¾ to 1½ grams, to play stampers and check the quality of sound. The other assembly is a heavy tracking, heavy duty assembly designated Model 681 BPS-R (R stands for repair). This stylus ssembly is designed to work with vertical tracking force from 3 to 7 grams, which we recommend to do repair work.

We suggest that the stamper be played in the area where clicks have been detected. As the first click is heard, stop the turntable, back up to the spot where the click was detected, increase force to 7 grams, and move the turntable back and forth a few times so that the stylus rides over this spot several times, burnishing it. This type of repair of metal plating is being practiced professionally by several record manufacturing companies who use the Stanton 681 AMC stylus assembly to repair metal mothers.

If there are clicks in the matrix, these clicks will appear as holes in the metal mother, which are pretty hard to polish out. In the stamper, on the other hand, the same click may appear as a bump which can be removed or flattened with much less effort. One of the main objectives in designing the 681 BPS-M (M for Matrix) and the 681 BPS-R is to cause it to rest on the sides of the ridge where an ordinary stylus would touch the walls of the groove. See Figure 3 to visualize this.

The use of this stylus may help us find a few missing pieces of the puzzle we have been working on for decades to complete, learning more about the behavior of the playback stylus as we play vinyl and metal discs and compare frequency responses, signal phase relationships, tracing problems, and measuring distortion. The styli should not only improve the quality of sound from records, but facilitate matters for record manufacturers who will be able to check the quality of the stamper without wasting many precious hours of set-up time and tying up the press to start the production run, only to discover that the stamper is bad. ■

CHARLES REPKA

A High Quality Custom Disc Mastering Studio

This article examines one of New York City's premium studios and offers significant insight into the problems of setup and operation.

CONSIDERING the enormous costs involved, it's amazing that anyone ever had the courage to start a business that specializes in just cutting lacquers. Bob Ludwig's room at Masterdisk, Corp. in New York City, for example, contains the following equipment.

One Neumann VMS 70 Disc Mastering Lathe. This is just the mechanism for supporting and moving the cutterhead and rotating the lacquer at the proper rpm. It also contains the variable pitch and depth electronics. Cost: $50,420.00.

One Neumann SAL 74 Cutterhead Drive Electronics. This includes two 600-watt drive amplifiers, RIAA equalizers, a tracing simulator computer, acceleration limiters, monitor electronics and 150 watt speaker amplifiers. Cost: $25,635.00.

One Neumann SX-74 Cutterhead. Cost: $8400.00.

One Neumann SP-77 Changeover console. The changeover console contains two sets of identical electronics (eq, limiting, filters, etc.) for each channel which are periodically used while cutting. If you are cutting a side with six bands with different eq. settings for each band. Band one would be cut using the *A* electronics. The *B* electronics would be preset for band two. During the spiral between bands, the console is switched from *A* to *B* and while band two is being cut, the *A* electronics are preset for band three and so on for all six bands. The cost of this flexibility is $42,590.00.

One Studer Preview Tape Player. The preview machine has an extra playback head positioned in advance of the normal playback head. The signal from the preview head feeds the pitch and depth computer at the proper time before the signal reaches the cutterhead. The preview signal is converted into control voltages that determines the proper change in pitch and depth. Cost: $8,000.00.

Then there are the accessory items such as: Dolby A type noise reduction at $750.00 per channel; dbx noise reduction at $250 per channel (using K9 cards); ITA parametric equalizers at $750 per channel; and an NTP Limiter at $1100 per channel.

I've given these prices in per channel prices because it is necessary that the preview electronics see a signal identical to the one presented to the cutterhead. This means that any changes made to the signal (noise reduction, eq. limiting, etc.) must also be made to the preview electronics and so a separate duplicate set of electronics is required. As Bob Ludwig remarked. "Sometimes there is as much as $10,000 worth of accessory electronics in use whose net effect is a d.c. control voltage that moves the cutting stylus a few mm."

MONITORING

The final part of the cutting room is the monitor speaker system. Here is where Bob's room (and custom cutting studios in general) differs greatly from the cutting rooms at the major record companies. Up to this point, all the equipment listed can also be found at RCA, CBS, or Capitol, but their monitor systems usually consist of a modest stereo amp and a small pair of bookshelf speaker systems. Monitoring levels are kept low because all the mastering rooms are clustered together on one floor with a minimum of sound isolation between rooms. This is not the case at Masterdisk. Bob's mastering room contains a monitor system that would gladden the heart of any hi fi nut. The system consists of a stacked pair of QUAD electrostatics per channel, each coupled to a Pioneer ribbon tweeter and Hartley 24-inch woofer. This elaborate speaker system is driven by a Mark Levinson preamp via a Levinson electronic crossover and Marantz, Neumann, and McIntosh power amplifiers. Total cost: approx. $6,000.00. All of this is not just to impress the client. Bob evaluates his own work from the viewpoint of the highly critical listener. To do this, he feels he must have the finest monitor system available.

The total cost of all this equipment is in the neighborhood of $150,000. This is just for *one* cutting room, and there are four such rooms at Masterdisk. While all the rooms are not as elaborately equipped, one can easily see where, in equipment alone, the studio represents an investment of over $500,000! And that's not including such items as rent, utilities, salaries and raw materials (lacquers, cutting styli, etc.) Disc cutting is *definitely* not a low budget operation.

MAINTENANCE

Fortunately, because of the great care (and expense) with which disc cutting equipment is made, it is inherently

Charlie Repka is a recording engineer with the Vanguard Recording Society in New York City.

Figure 1. One of the mastering chains at Masterdisk. The equipment is by Neumann.

stable and trouble free. I should say here that I am speaking of modern transistorized equipment. While it's always been relatively easy to build a lathe that turns quietly at a constant rpm, building stable electronics is another story. In the days of tube equipment, the electronics had to be allowed to warm up for at least an hour before cutting and even then tended to drift with heat and age. System checks had to be made daily. With modern equipment, checks are made about once a week and usually nothing has changed from the week before.

Any possible change is usually discovered by tape/disc comparisons. These are made frequently during the course of a normal day's worth of cutting. The human ear can hear very subtle changes in the sound of a music program: this is also another good reason for having a high quality monitor system in the cutting room.

CUTTING STYLI

The one area that is subject to change is the cutting stylus. This must be checked frequently, about once or twice a day, and is done by checking the high frequency response at inner diameters. Installation and alignment of the new stylus is very critical and must be performed with great care using a microscope. Once the stylus is installed, the cutting system must be adjusted with respect to noise, frequency response, and operating level. Noise is checked by making test cuts (with no modulation) at outer and inner diameters and adjusting the stylus heat for minimum noise with the least possible heating current. Too little current will increase noise, while too much current will scorch the lacquer.

FREQUENCY RESPONSE

Checking frequency response can be done by either (or a combination) of two methods and introduces the problem of reference standards. One method is to make a frequency response test cut on a lacquer and check the results with a phono cartridge. But the response of the cartridge must also be known and can only be determined by using a test record. Unfortunately, the various test records can differ from each other by several dB (at high frequencies). This is even true of different pressings of the *same* test record. Cartridge aberrations can be determined, however, by using the two speed test (the same test record played at two different speeds) developed by Bernard Jacobs of Shure Brothers.

The second method is a purely optical one using a Buchmann-Meyer collimated light source. Here, one makes test cuts at various frequencies and looks for the proper pattern when viewed under the light source. The first method is easier to use but has possible inaccuracies. The second method requires greater skill and accurate optical measuring equipment, but it is the only truly accurate way to measure high frequencies on a disc.

Level checks (0 VU = 7 cm/sec lateral cut at 1 kHz) can be made easily with either method. Regardless of the alignment method used, the final check is always a tape *versus* disc comparison. If there is a significant difference, the alignment procedure must be repeated.

THE TAPE PLAYER

The piece of equipment that sees the most re-alignment is the playback tape machine. It must be realigned to the tones on each client's tape. If no tones are present, a standard alignment tape is used (and one hopes that the client's tape machine was aligned using a similar tape). If a noise reduction system and/or a four channel matrix encoding system was used and no tones are present, a call is made to the client before proceeding. The tape machine must also be capable of being adjusted to the various tape speeds and equalization standards that have been used over the years. This includes 7.5, 15, and 30 in/sec. and the NAB, CCIR, IEC, AES, AME curves (just to name a few) plus a variety of custom eq. curves used by different studios.

OPERATING PROCEDURES

It is beyond the scope of this article to give the step-by-step procedures that would be taken during the cutting of a typical lacquer. Nor can I cover all the possible problems that could develop. Therefore, what will be presented is a list of items that must be considered by the cutting engineer putting stylus to lacquer.

- Length of side. This is used to roughly determine the groove spacing (minimum and maximum lines per inch) on the disc. Groove spacing is also a function of:
- Program level. The signal level the client wants on the disc. The actual level on the tape is not important because the over-all gain of the cutting system can be adjusted as necessary. If the average level is high, more space will be used per line. (Automatic variable pitch is not of much use in this case because it will just stay at the maximum LPI setting) If the dynamic range is large and the side timing is long, extra care must be taken to prevent overcuts and pre and post echo, although here the variable pitch and depth computer (fed by the preview head) helps a great deal.
- Phase content. This can be observed either with an oscilloscope or a phase meter. A large amount of out-of-phase (or difference) components in the recorded signal (as is the case in any four channel matrix recording) will result in greater vertical motion in the cutter stylus. This will, in turn, limit the maximum possible level that can be cut (because of the finite coating of acetate on the lacquer). A large amount of vertical modulation will also use up a big space per groove.
- Spectral content. A very wide bandwidth can cause its own special set of problems. Strong low frequencies produce large stylus motions and use up more space per groove as well as increasing the possibility of overcuts. High frequencies at high levels can cause the cutter head to overheat, resulting in damage to the head or, at least, activating the thermal protection circuits. There is also the possibility of making a perfect cut that cannot be played back with the average phono cartridge.
- Space allocation. As a general rule, cutting engineers like to stay as far from the center of the disc as possible. This minimizes high frequency distortions which increase with decreasing radius (caused by a variety of factors in both cutting and playback and more thoroughly explained in the technical literature). Unfortunately, many

Figure 2. The Neumann SP-77 changeover console.

Figure 3. Masterdisk's sophisticated monitoring system.

producers are under marketing pressure to fill the disc. Although the average pop record with five three-minute tunes per side would sound better if cut using only half the space per side. many clients will insist on cutting right up to the label because it is believed that the consumer would otherwise feel cheated. This is not as much of a problem with classical music where musical content and sonic quality have a greater influence.

The good cutting engineer must be able to juggle all these factors along with the client's demands (usually for more level). There are several solutions to each of these problems (usually involving a compromise of some sort) but only a great deal of experience will enable the cutter to choose the best solution for each situation. Usually the custom cutting studio is brought the problem tapes that contain all the above problems to excess. Someday someone is sure to bring in a tape containing a 30 minute, matrix encoded recording of an Emerson. Lake & Palmer arrangement of a Mahler symphony!

CLIENT COSTS

When a tape is brought to Masterdisk. a 12-inch double-side reference lacquer is cut. a process that involves consideration of all the above listed problems. If the client approves the reference lacquer. then two single-sided 14-inch lacquers are cut and sent to the plating plant. Masterdisk charges $55.00 for the 12-inch reference and $65.00 for each 14-inch lacquer. The charges for the 14-inch lacquer are for a completed side. If it takes the cutter three attempts (*ie.*, two bad lacquers) before making a good cut. the client is still charged only $65.00 per side. With blank lacquers costing $8 to $12 each. it doesn't take many mistakes to cut into your profit margin. If the client wishes to take an active role during cutting (trying eq. and level changes. etc.) the charge is $70.00 per hour.

QUALITY CONTROL

You can never really be certain if you have made a good cut. The lacquer cannot really be played before plating and it is impossible to visually inspect every inch of groove. So there will always be a certain number (hopefully low) of returns due to a lacquer flaw, overcuts. stylus lifts and the like. Even when a perfect cut is made. some lacquers will be lost in the plating process. Some plating companies will accept full responsibility for the lost lacquer and pay for the recut. Others will pay for lost lacquers at some agreed upon discount. And still others accept no responsibilty and the question of who pays for the recut depends entirely upon the relationship between the cutting studio. client. and plating company. The plating process can also aggravate other problems such as noise. pre echo and post echo. This problem has reached the point where some of Masterdisk's clients now have their lacquers sent to Germany for plating and pressing. Different plating techniques have been developed in Europe that have practically eliminated the pre/post echo problem. It also allows a different cutting stylus shape to be used that produces a true V groove. All cutting styli used in the U.S. have rounded bottoms which can cause noise problems with certain types of playback stylus shapes. This problem may be solved in the near future with the opening of a new plating plant in NYC (Europa Disc operated by Jim Shelton) which will be using the latest Europa Film equipment and techniques. If it is successful, it will probably cause improvement in our standards, thus forcing other plating companies to meet the competition.

WHAT MAKES A GOOD CUTTING ENGINEER

The disc cutting process is one that is at the same time both simple and complex. Without a doubt, the average audio engineer could be taught how to operate a modern lathe in a few hours and be making *acceptable* cuts within a few day's time. However. the demands of the record business require that those special sounding tapes (produced and engineered by some highly exceptional and talented people) should still sound *special* when translated into disc form. This requires someone with more than just "acceptable" abilities.

Learning the skills necessary to become an exceptional cutter is a difficult process for there are no schools for disc cutting. (The Institute of Audio Research does offer a 30 hour course in basic disc cutting techniques. but one cannot expect to become an expert after 30 hours of instruction.) The real learning process takes endless practice with the experienced master craftsman instructing his (or her) apprentice. Disc cutting is a craft (in the best sense of the word) that requires great skill. ingenuity. artistry. and creativity. The person who would become a master cutter needs a high level of mechanical dexterity. a solid technical understanding of the recording process. the patience of a saint. although sainthood is *not* a requirement. and a strong musical background. Bob Ludwig. for example. is a graduate of the Eastman School of Music. These high standards make the master cutter a very rare breed indeed and as a result. keep places like Masterdisk booked solidly for many weeks in advance.

I would like to thank Bob Ludwig of Masterdisk Corporation for graciously permitting me to tour his facilities and supply a large portion of the information contained in this article. ■

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BURWEN PRO. products: Model 1500A, Model 1500D, dynamic noise filters; Model SP 5200 stereo pre amp. New units—below cost. **J. B. Parent Co., 5188 Wedgewood Rd., Medina, Ohio 44256. (216) 725-8871.**

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BUSINESS OPPORTUNITIES

RECORDING STUDIO. Professional 8-track sound studio currently operating in the Washington, D.C. area. Good location with room for expansion and good potential. $30,000 takes all or will sell equipment individually. For more information and equipment list write **Dept. 71, db Magazine, 1120 Old Country Rd., Plainview, N.Y. 11803.**

WANTED

WANTED: TRANSCRIPTION discs, any size, speed. Radio shows, music. **Box 724-db, Redmond, Wa. 98052.**

WANTED: RECORDING CONSOLE 16-in/16-out; 16-track recorder; misc. equipment. Send particulars. **LeMans Sound, Box 24, Belle Mead, N.J. 08502.**

EMPLOYMENT

TM PRODUCTIONS, largest radio commercial and ID firm, is now screening applicants for top engineering/mixing position. Must be a dedicated pro, and one of the best. Exceptional sense of organization and efficiency essential. Unlimited opportunities with the fastest growing production house in the U.S. Send resume, sample mixes, and salary requirements to **Ken Justiss, Operations Mgr., TM Productions, 1349 Regal Row, Dallas, Texas 75247. Absolutely no phone calls accepted.**

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CHIEF ENGINEER/STUDIO MANAGER with well known midwest 24-track, automated studio seeks position with studio on East or West coast, or active production house, anywhere. Heavy experience with R & B and drum recording. Expert tape machine alignment and system troubleshooting. 5 years "hands on" 16 & 24. 12 years total studio experience as musician, manager, and publisher. Studied at Institute of Audio Research, N.Y.C., 1972-3. Expect $12-15 an hour. Contact: **Bill Olszewski, (309) 347-1931 or 22 Chafford Woods, St. Louis, Mo. 63144. (314) 962-3987.**

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db People/Places/Happenings

• A newly created position, vice president of administration, at **Shure Brothers, Evanston, Ill.** has been filled by **Meyer Langer.** Mr. Langer was formerly a vice president at the **Bresler Ice Cream Company. He** also served in the Naval Reserve supply corps, retiring with the rank of captain.

• Focussing particularly on the development of advanced broadcast equipment incorporating the concepts of computers and digital processing of audio, **Neil J. Miller** has assumed the post of director of R&D for **Eric Small & Associates** of San Francisco, Ca. Mr. Miller has developed several real-time computer systems in the areas of acoustic recording, analysis, and synthesis. An interesting accomplishment was the recreation of antique Enrico Caruso recordings through the digital re-synthesis of the singer's voice.

• Of interest to producers of trade shows and conventions is the joint venture of **Andrews-Bartlett & Associates** and **L & M Stagecraft, Inc.** of Cleveland, Ohio in combining their facilities. The firm will rent, sell and service theatrical and audio-visual equipment.

• **Paul P. Hoppe, Jr.** has joined **Switchcraft, Inc.** of Chicago, Ill. as vice president of engineering. Mr. Hoppe, with four patents to his credit, is well-known in the electronics field. He was previously director of engineering at **Sierra Electric Division of Sola Basic Industries** and for 23 years held important posts at the **Amphenol Industrial Division of Bunker-Ramo.**

• Computerized television control and display expert **Thomas R. Meyer** has been appointed product manager for **Dynair Electronics, Inc.** of San Diego, Ca., in charge of new product activities. Mr. Meyer was formerly with **TeleMation, Inc.**

• Coming from **Farinon Electric, John Woods** has been named vice president, engineering, for **Catel,** a division of United Scientific Corporation, of Mountain View, Ca. 94043. Mr. Woods will be responsible for all engineering and design for existing and new products.

• **Lloyd S. Bashkin** has been appointed manager of Entertainment and Industrial Sales for the **RCA Service Company,** Cherry Hill, N.J. Mr. Bashkin will supervise and direct sales for the company's broadcast services, including video tape duplicating.

• Two appointments has been announced at **Sierra Marketing, Inc.,** of Santa Clara, Ca. **Penny Wright** has been assigned to the post of merchandising director, coming from **Chiat/Day Advertising. Rick Anderson,** coming from the **Craig Corporation,** will serve as a sales representative in the Sacramento Valley and northern Nevada.

• **Radiometer A/S,** Copenhagen, Denmark has purchased from **Katy Industries** its 80 per cent interest in **The London Company.** The London Company, manufacturers of audio test equipment, was formerly owned jointly by the two firms.

• The reorganization of its sound products division into two separate divisions has been announced by the **Altec Corporation,** of Anaheim, Ca. The commercial sound products division will be headed by vice president and general manager **Charles E. Van Liew.** This division will market the University Sound Product line, sold through manufacturer's representatives and original equipment manufacturers. Leading the sales efforts at the new Altec Lansing Sound Products division will be vice president-commercial sales **James E. Morrison.** The other new division, Altec Lansing International, headed by **William L. Fowler,** vice president-general manager, will concentrate on consumer products.

• Time flies department! **Gotham Audio** of New York and Hollywood is celebrating the twentieth anniversary of its founding by **Stephen Temmer.** Commencing with Mr. Temmer's interest in the first stereo records ever cut, by the **Neumann Company** of West Berlin, Gotham became involved, first with representing Neumann, and extending to other European firms. They then moved into leasing equipment and presently not only import foreign products but serve as an exporting outlet for a number of U.S. firms.

• **Senator Barry Goldwater** will be the featured speaker at a banquet to be held in conjunction with the **Society of Broadcast Engineers** (Kentucky Chapter) regional convention to be held November 30-December 2 at the Marriott Inn, Clarksville, Indiana. Approximately 50 exhibitors will be on hand for the free exhibit of new equipment. For information, contact **Robert J. Klein, KET TV, 600 Cooper Dr., Lexington, Ky. 40502.**

• **De Luxe Laboratories** has consolidated their video duplication and film-to-tape facilities and relocated to 1546 N. Argyle Ave., Hollywood, Ca. The firm specializes in 70, 35, 16 and Super 8mm motion picture film processing.

• Two new executive vice presidents have been elected at the **Ampex Corporation,** of Redwood City, Ca. **Charles V. Andersen,** a veteran at Ampex since 1951, has served in the international area. **Charles A Steinberg** has been with the firm since 1963, functioning mainly in the audio-video and data products divisions.

• A new 24-track state of the art studio, **Forum Productions,** has come to Covington, Ky. The sophisticated studio is designed to serve top-drawer recording artists. Forum is located at 2656 Crescent Springs Rd., Covington, near the Cincinnati, Ohio airport.

• **Robert V. "Bud" Payton** has been appointed to the newly created post of national sales manager at **Audio-Technica U.S. Inc.,** of Fairlawn, Ohio. Mr. Payton, who will oversee all field sales activity, working especially with reps, comes to Audio-Technica from **Yamaha International.**

• Well-known manufacturer's representative **Morris F. Taylor** of Silver Spring, Md., has retired after a career spanning 47 years in electronics. Mr. Taylor's firm, **Morris F. Taylor Co.,** will continue in business under the direction of **James J. Fahy, James W. Ferris, Sr.,** and **Eugene Wingo.**

• A new audio amplifier manufacturing firm, know as JRF, was recently founded by **John R. French** in Sparta, N.J. According to Mr. French, the line, commencing with their Model 2502 stereo power amplifier will consist of modular devices emphasizing simplicity. The address of the firm is P.O. Box 833, Sparta, N.J. 07871.

1976: ADC CLAIMS THE XLM MK II SHOWS "NO PERCEIVABLE WEAR OVER THE LIFE OF A RECORD." AND PROVES IT.

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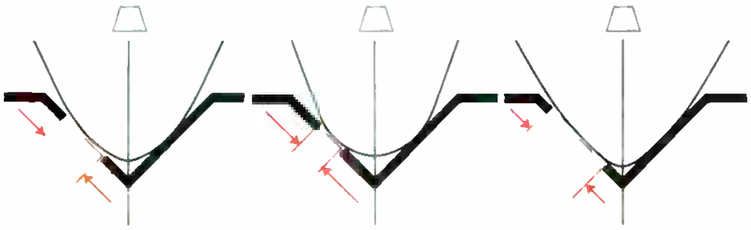

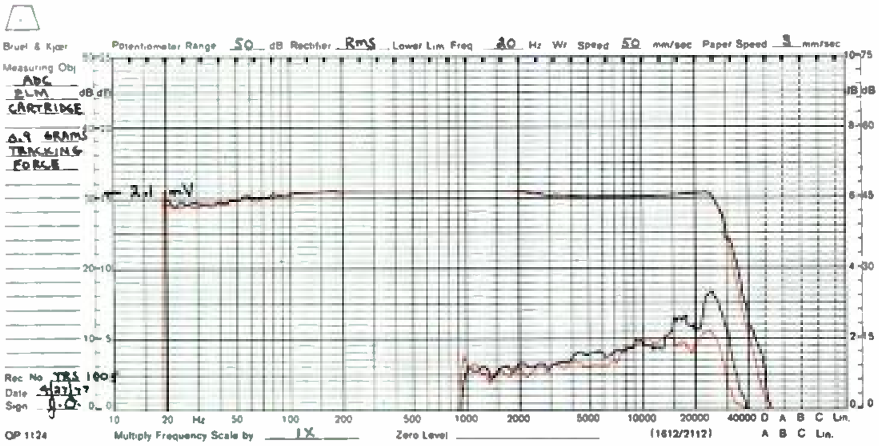

Left ——— Right ——— 20 Hz to 1kHz · B&K QR2009 · 1 kHz to 50 kHz · JVC TRS1005

Introducing the ADC ZLM cartridge with the ALIPTIC [1] stylus. It's a revolutionary new cartridge design that has taken the state of the art a giant step closer to the state of perfection.

Because of last year's XLM MK II record wear test results, we confirmed our thinking on how to design the perfect stylus tip shape. It combines the better stereo reproduction of the elliptical [2] stylus shape with the longer, lower wearing, vertical bearing radius of the Shibata [3] shape. The result is our revolutionary new ALIPTIC stylus.

And that's only the beginning. The ALIPTIC shape is polished onto a tiny .004" x .008" rectangular nude diamond shank, which has reduced the tip mass of the XLM MK II by an incredible 50%. This tiny stone is mounted on our new, tapered cantilever, which reduces effective tip mass even further.

The XLM MK II tests also proved the importance of tip polish in reducing record wear. So the ZLM is polished with a new, more expensive, more effective patented polishing method.

The ADC XLM MK II has long been known for its uncolored, true sound reproduction. The ZLM goes even further. Sound reproduction is completely open and spatial. And individual instrument placement can now be identified with even greater ease.

The ZLM tracks between ½ and 1¼ grams. Frequency response is ±1dB to 20kHz and is flat to even higher frequencies; out to 26kHz ±1½dB.

As you can see, by reducing the tip mass even further, we've come closer to the ultimate in pure sound reproduction. To prove it, every ZLM comes with its own individual frequency response curve [4], signed by the ADC technician who tested it.

This means that the ZLM cartridge will reach every sound lying dormant in your records, transmitting them faithfully through your hi-fi system without altering the sound or the health of your records.

Not only do we think the ZLM is one of the most exciting cartridge designs to come along in years, but we can prove it.

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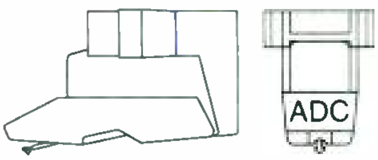

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