Electronic Music Review

No. 6 April 1968

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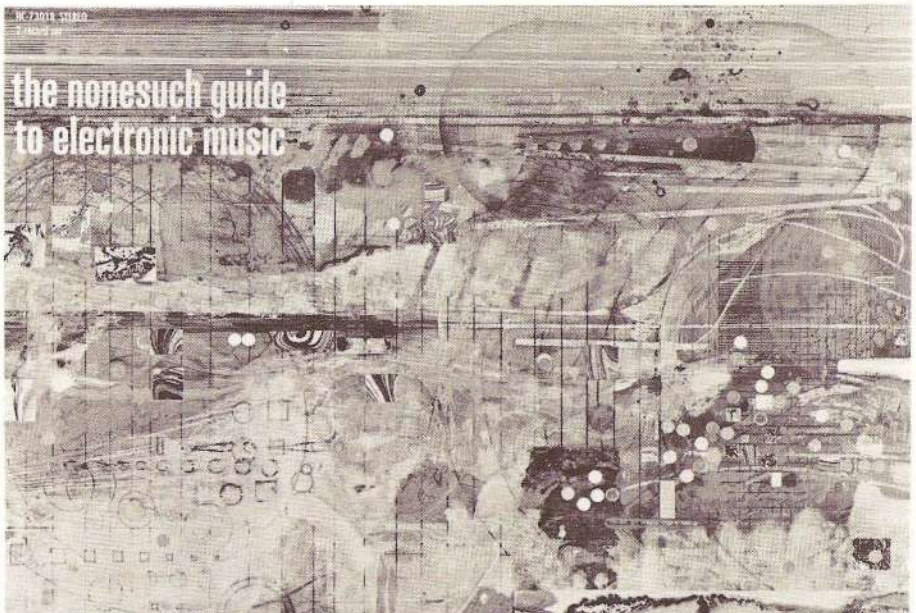
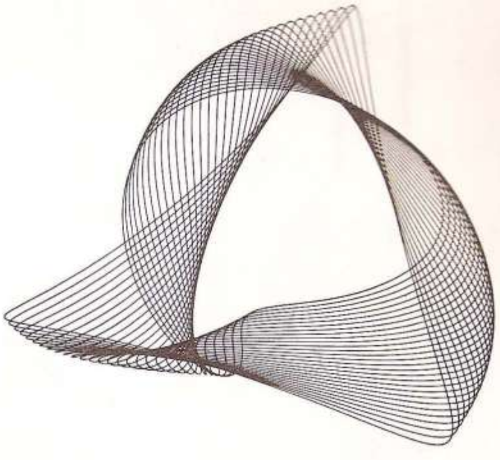


Electronic Music Review



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EMR is published quarterly by the Independent Electronic Music Center, Inc. (a non-profit membership corporation), Trumansburg, N.Y. 14886. Subscriptions to EMR are available only through IEMC membership. Annual personal membership dues are $6.00. Of this amount, $5.50 is for a subscription to EMR for one year. Annual institutional membership dues are $8.00. Of this amount, $7.50 is for a subscription to EMR for one year. Members outside North America, add 50¢ per year; all remittances payable in U.S. funds. Application for second-class mailing privileges pending at the post office at Trumansburg, N.Y.

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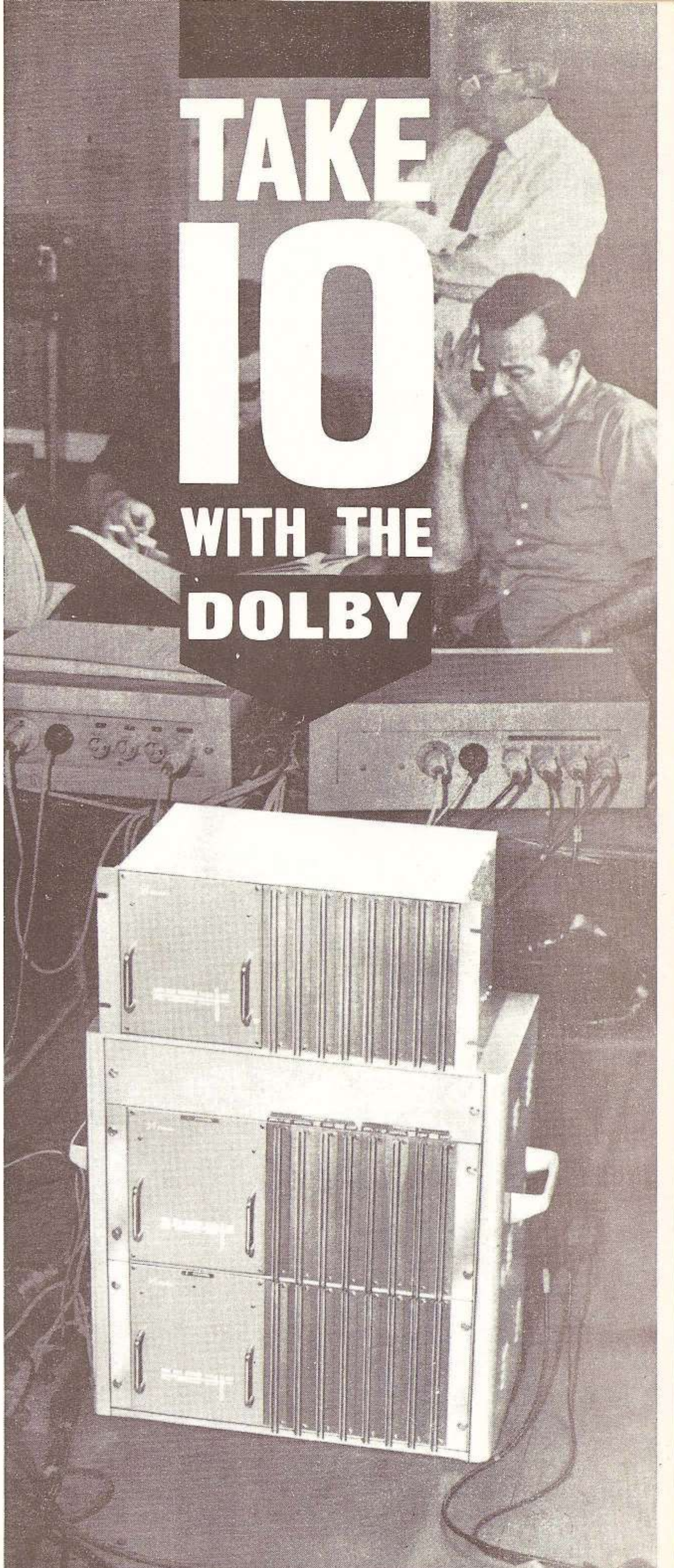

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EMscope

IN MEMORIAM

Karl-Birger Blomdahl, Musical Director of Sveriges Radio, and Member of the IEMC Advisory Council, died June 17, 1968 in Stockholm. He was 51 years old.

Mr. Blomdahl was best known for his part-electronic space opera *Aniara* (1959). This work, based on a cycle of 103 poems by Swedish poet and novelist Harry Martinson, concerns a spaceship carrying 8000 passengers that veers off course and is doomed to wander as its inhabitants die. His unfinished second space opera, *The Saga of the Super Computer*, was scheduled to be given its premiere in Stockholm during the 1969-70 season.

SUPPLEMENT TO EMR Nos. 2/3

A forthcoming issue of EMR will contain a list of corrections and additions to the *Répertoire International des Musiques Electroacoustiques / International Electronic Music Catalog* (published as EMR Nos. 2/3 and now available only from The M.I.T. Press, Cambridge, Mass. 02142). Since it would be too immense a project to document the recent rapid increase in compositions, this supplement will consist only of corrections of inaccuracies published in the original Catalog, and of listings of works which should have been listed (i.e., composed before January 1967). New disc recordings of compositions already listed will also be indicated. The compiler would be grateful for any information that can be provided, particularly in the case of omitted works. Details should be arranged as presented in the Catalog, and sent to: Hugh Davies, 26 Upper Park Road, London N.W.3, England.

WORKSHOPS, SEMINARS, COURSES, EVENTS

A recording seminar will be held at Brigham Young University, August 12-16. Further information is available from Kaye Jensen, Recording Seminar, Box 41, HFAC, Brigham Young University, Provo, Utah 84601.

The Saginaw 8mm/Super 8 Film Festival will be held August 23-24. Entries may be of any subject or length, and may be accompanied with tapes. Prizes will be awarded. The deadline for submission is August 17. Further information and entry forms are available from William Wegner, Chairman, 4373 Wayside S., Saginaw, Mich. 48603.

The Gaudeamus Foundation is establishing an International Composers' Seminar, to commence September 1. One or two composers from each country will be admitted, and such activities as participation in contemporary music festivals, concert per-

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formances of their works, and use of an electronic music studio will be organized. Further information is available from the Gaudeamus Foundation, Postbox 30, Bilthoven, The Netherlands.

Electronic music and computer composition courses will be held at the Rijksuniversiteit te Utrecht, October 1 - June 27. Lecturers will be Gottfried Michael Koenig, C.A.G.M. Tempelaars, F.C. Weiland, and J.M. Vink. Lectures will be in German and English, with English summaries. Applications must be submitted by September 1. Forms may be obtained from the Studio voor Elektronische Muziek, Plompetorengracht 14-16, Utrecht, The Netherlands.

RECENT PUBLICATIONS

Ouellette, Fernand (tr. Derek Coltman). *Edgard Varèse*. 1968. Orion Press, New York (distributed by Grossman Publishers, 125A East 19 Street, New York City 10003). Hardbound, $8.00.

Zaffiri, Enore. *Due scuole di musica elettronica in Italia* (Con una nota di Pietro Grossi). 1968. Silva Editore, Milano, Italy. 2300 lire ($3.68).

RECENT STEREO LP RECORDS

COLUMBIA CS-9597 - The Electric Flag (*A Long Time Comin'*).

COLUMBIA MS-7139 - Earle Brown (*Four Systems*), Sylvano Bussotti (*Coeur pour batteur - Positively Yes*), John Cage (*Fontana Mix - Feed*), Morton Feldman (*King of Denmark*), Karlheinz Stockhausen (*No. 9 Zyklus*).

DECCA DL-710154 - John Eaton (*Piece for Solo Synket No. 3; Prelude to "Myshkin"; Songs for R.P.B.*).

KAPP KS-3562 - Dan Taylor / Simeon (*Silver Apples*).

NONESUCH H-71198 - Andrew Rudin (*Tragoedia*).

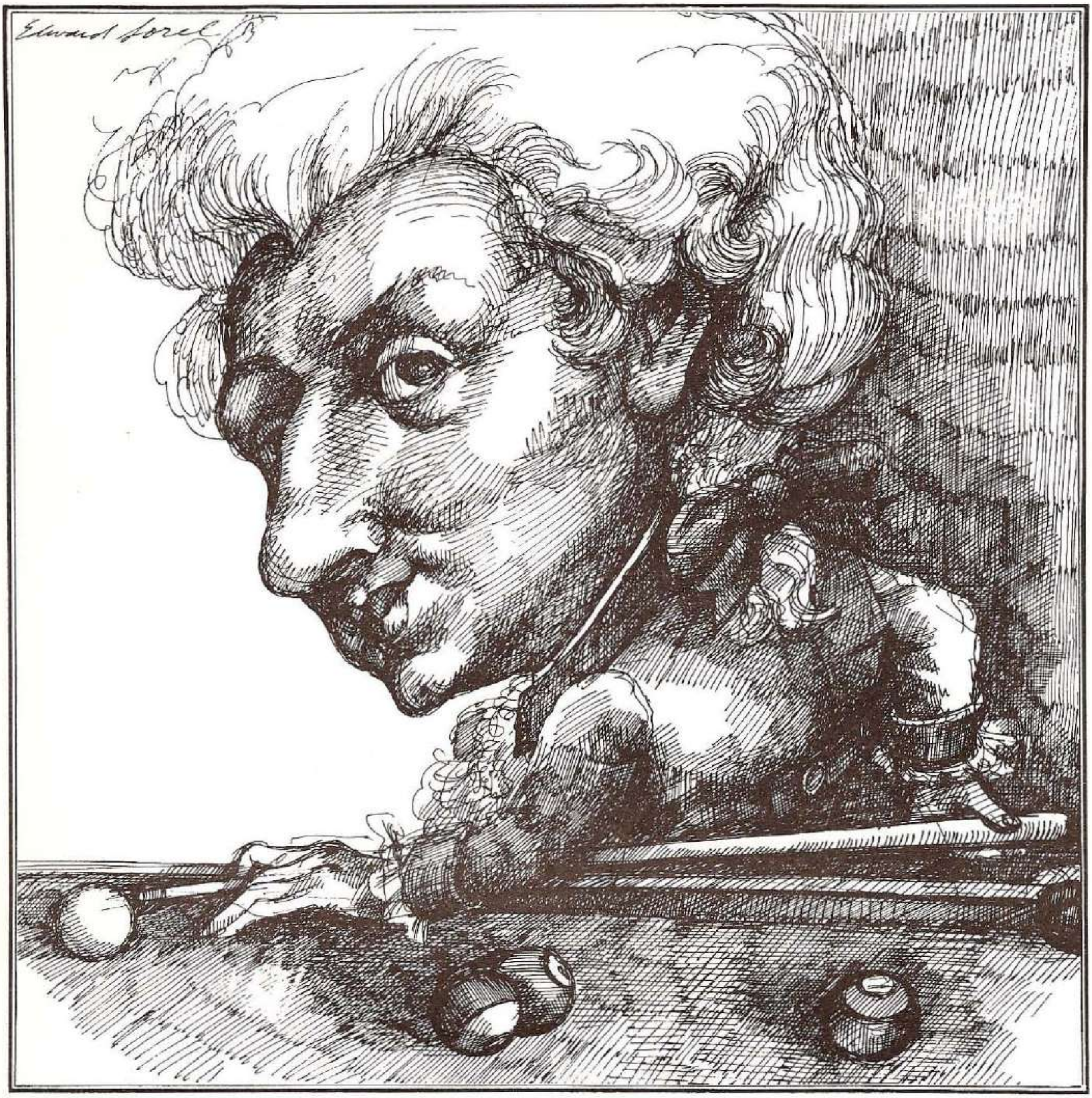
NONESUCH H-71199 - Kenneth Gaburo (*Antiphony III (Pearl-white moments); Antiphony IV (Poised); Exit Music I: The Wasting of Lucrecetzia; Exit Music II: Fat Millie's Lament*).

PHILIPS (Norway) 839250-AY - Arne Nordheim (*Epitaffio per orchestra e nastro magnetico; Response I for two percussion groups and magnetic tape*). Also released on PHILIPS (France) 836896-DSY.

SVERIGES RADIO (Box 955, Stockholm 1, Sweden) LPD-2 [?] - Karl-Birger Blomdahl (*Altisonans*); Bengt Emil Johnson (*1/1967*).

PLEASE NOTE

Information for EMscope should reach EMR no later than one month before month of publication. In Europe, direct information to Hugh Davies, European Editor, Electronic Music Review, 26 Upper Park Road, London N.W.3, England.


Edward Sorel

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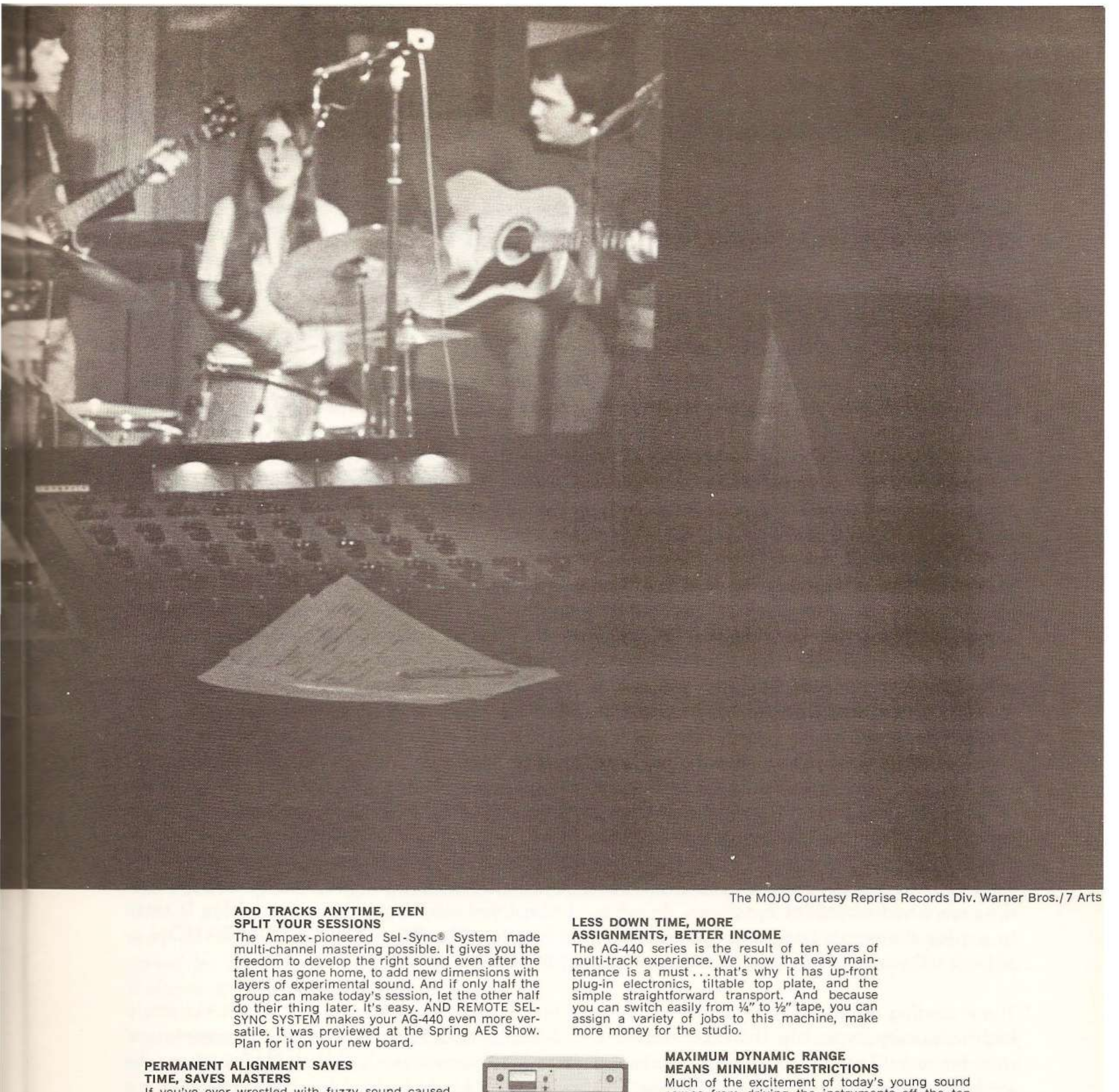

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AMPEX

Introduction to Tape Recording

Robert A. Moog

Magnetic recording tape consists of a thin ribbon of plastic (referred to as the BASE) upon which is deposited a layer of extremely fine magnetic particles (referred to as the COATING). Each of these particles can be thought of as consisting of tiny "bar magnets" embedded in a lumpy medium. Under the influence of an external magnetic field, the bar magnets will tend to align themselves in the direction of the applied field. Once the field is removed, the bar magnets will tend to remain in line and therefore will produce a magnetic field of their own (much weaker than the original applied field).

In a typical tape recorder, the tape itself moves past an array of HEADS which produce or detect changes in magnetic field. A typical head consists of a COIL of wire wound around an annular CORE of magnetic material. The core is solid, except for a very thin GAP, past which the tape moves. An electrical current passing through the coil induces a strong, localized magnetic field across the edges of the gap. Conversely, a changing magnetic field occurring between the gap edges induces a voltage (electrical force) between the terminals of the coil. The ERASE HEAD has a relatively wide gap, and is specifically designed to accept a very rapidly varying (typically 60 kHz) current. Its function is to "shake up" the bar magnets on the tape, thereby randomizing their alignment and destroying any previously recorded magnetic pattern. The RECORD head has a somewhat narrower gap (typically 0.0005") and is designed to impose a magnetic pattern on the moving tape. The PLAYBACK or REPRODUCE head has the narrowest gap of all (typically 0.0001") and is designed to produce a voltage when a changing magnetic field appears across its gap. In some inexpensive tape recorders, a single head is used for both the record and reproduce functions. In other, professional quality machines, provision is made to employ the record head as a reproducer. This is called SELECTIVE SYNCHRONIZATION or SEL-SYNC, and will be described in greater detail in this symposium.

The recording of an AUDIO, or sound, pattern onto a moving tape requires that an extremely high frequency (typically 180 kHz) current be mixed with the audio current in the record head in order to achieve low distortion. This high frequency component is called BIAS and can be explained qualitatively by recalling that the bar magnets are embedded in what is essentially a lumpy medium. (I refer here to the types of forces exerted on a bar magnet when it is undergoing realignment, and not to the physical condition of the surface of the coating.) If only a small current corresponding to a weak audio signal were applied to the record head, the bar magnets would not even begin to move past the "lumps" in order to realign. Thus, a weak recording current would have less effect in magnetizing the coating in proportion to its magnitude than would a stronger current. The bias current in effect "stirs up" the lumps and permits weak audio currents to have proportionately the same effect on the tape coating as do strong currents. Because of its very high frequency, the bias current does not leave its own pattern of magnetization on the tape.

The magnetizing of the coating is performed along the length of the gap which, of course, is perpendicular to the tape length. The width of tape covered by the record head gap is called the TRACK WIDTH. Several tracks may be recorded simultaneously. An array of heads which perform a given function on several tracks is called a HEAD STACK.

The portion of a tape recorder which provides the mechanical support and drive for the tape is called the DECK. The CAPSTAN is the rotating shaft which causes the tape to move uniformly. In most tape recorders, the capstan is driven by its own constant-speed motor. In addition, there are usually REEL MOTORS which hold the tape in tension and wind the tape; BRAKES slow down the tape motion. TAPE LIFTERS lift the tape off the head surfaces, thereby reducing head wear when the heads are not actually in use. The HEAD COVER shields the head from external magnetic fields, especially from the motors. A SOLENOID-CONTROLLED deck is one in which various mechanical components of the deck are brought into play by the action of electrical solenoids, rather than manually operated linkages.

In addition to the deck and the head assembly, every recorder contains electronic circuitry that generates or processes the various signals involved in the recording process. These circuits are known collectively as the ELECTRONICS, and consist of a RECORD AMPLIFIER which prepares the audio input signal for use by the record head, a PLAYBACK AMPLIFIER which brings the reproduce head output up to line level for use as an audio output, and an ERASE OSCILLATOR which generates the high frequency erase (and usually also the record head bias) currents. The record and playback amplifiers always incorporate EQUALIZATION — a frequency-dependent amplification which compensates for some of the inherent limitations of the recording process. Some equalization is accomplished in recording, while the rest is accomplished in playback. The NAB EQUALIZATION STANDARD defines the frequency responses of the record and playback amplifiers. The standard, determined by the National Association of Broadcasters, is used in the United States, while the CCIR EQUALIZATION STANDARD is used in Europe.

An ideal tape recorder delivers an exact replica of the signal which it has previously received and introduces no extraneous noise or distortion. The performance specifications which are generally applied to mixers[1] also apply to tape recorders. In addition, FREQUENCY RESPONSE (the frequency range in which the overall record-playback gain remains within specified limits) and FLUTTER (percent tape speed variation introduced by the deck), are required to describe the overall performance of a tape recorder. In multi-channel recorders CROSSTALK is a measurement of the proportion of the signal recorded on a given track which "leaks over" to be reproduced by the adjacent track. PRINT-THROUGH is the magnetization of one layer of tape by a signal recorded on an adjacent layer.

The articles in this symposium discuss some features of tape recorders and accessories which are of special interest to electronic music composers. Recording engineers Walter Carlos and Benjamin Folkman give an informal but highly authoratative evaluation of the relative merits of the three major American professional recorders. Gordon Mumma reports on his considerable experience with a variety of modestly-priced tape machines. Carlos and Folkman evaluate the appropriateness of multi-track recorders in electronic music composition, and describe some circuitry which they developed. Gerald S. Macdonald explains the operation of a sophisticated tape deck capable of changing tape speed rapidly and over a wide range. Ray M. Dolby describes his noise reduction apparatus, which has received widespread acceptance among professional recording engineers. Finally, Eugene M. Zumchak summarizes some features of the revolutionary Newell tape transport.

REFERENCE

1. Moog, Robert A., "Introduction to Mixers and Level Controls", EMR No. 4, October 1967, 10.

Symposium: Tape Recording

The Quality Race

A Survey of the Big Three

Walter Carlos and Benjamin Folkman

The state of the recording art being what it is, there is no such thing as a "perfect" tape machine, even on the professional level. This article will outline the various advantages and disadvantages, in our opinion, of the three American recorders most suitable and versatile for use in an electronic music or professional recording studio: Ampex, 3M, and Scully. (Thus, top-quality machines like Stüder and Nagra will not come under discussion.) These are the machines to consider if highest possible quality and durability are your primary concerns. They all average about $1500 per track. For the small studio with a tight budget, certain "home recorders" on the market, such as Sony, Viking, and Roberts, to name a few, will give acceptable quality where repeated overdubs are not required. Crown and Magnecord are " intermediate quality" machines (about half the price of professional recorders) whose advantages over home machines are greater ease of editing (highly important in electronic music), greater simplicity of operation, and better response. These do not offer either the durability or the superior signal to noise ratio typical of our "big three" (not to mention such other features as multi-track sel-sync application, and low deviation from the NAB equalization standard; the latter is especially important if several generations of tape copying are necessary).

The oldest professional machines still in general use are the Ampex 300, 350, and 351 models (employing tube electronics) which, though no longer manufactured, command a premium price on the used recorder market. The transports of the 300 and 350 are still as fine as any being manufactured today, although they lack a few of the newer frills such as scrape-flutter filters, editing buttons, and automatic tape lifters — the last is debatable as an advantage for any but remote-control applications. The 300, 350, and 351 also offered, until the appearance of iem and Norton, the finest, most durable tape heads ever constructed.

Perhaps the most important reason why one should still consider acquiring these models is that they represent the ultimate achievement in tube circuitry, and still offer, in subjective comparisons, lower noise and greater freedom from audible distortion (laboratory measurements here are often misleading) than has yet been achieved in any of the fine solid-state recorders we will discuss in following paragraphs. If you don't mind the bulky size, the nuisance of tube replacement, and heat, any of these models, particularly the last of the 351s, is warmly recommended for electronic music studio use.

Ampex had no serious competition in the professional tape recorder field until the arrival of the 280 from Scully, a company previously well known for the production of the finest American disc-mastering lathes. Borrowing several ideas from the short-lived Presto professional tape recorder series, Scully incorporated the editing button, compact retractable playback head shield ("gate"), easily interchangeable heads, more accessible tape threading path, plus several of its own innovations: solid-state electronics miniaturized to half the usual panel height, superior bias supply, convenient alignment procedure, and the scrape-flutter filter, a small idler which damps out the high-frequency flutter caused by friction in the long tape path as it passes over the heads and tape guides.

Unfortunately, the original Scully 280 suffered from a definitely annoying audible hiss, and a characteristic distortion which, though low, was strangely more audible than what we had gotten used to hearing over the years. Frequent mechanical breakdowns, such as relay contact malfunction, tape guides intolerant of all but "perfect" splices, and rapidly wearing heads plagued the early 280, while the tension equalizing arm operated so aggressively that, to many, ultra-critical editing became very difficult. One of the most irritating features of the Scully 280, and one which has not been remedied on later models, is the attractive API VU meter, whose ballistics are but one step above the magic eye of beloved wire-recorder memory. It is fatiguing to the eye, inaccurate as an averaging level device on multi-transient program material, and subject to over and undershoot. Ampex (and more recently, 3M) has always employed either Weston or Simpson meters, which have become industry standards, thanks to their fine performance. But a Scully did come up to speed faster than an Ampex, you could fit four channels of electronics where two had previously sat, and the machine had the sleek, efficient look of Swedish Modern furniture and natural wood split-level country retreats. It is not surprising that the 280 became a very popular machine in the industry.

Emboldened by Scully's success, 3M, alias Minnesota Mining and Manufacturing, Scotch, and Dynarange (choke) tape, entered the market with its own solid-state machine. The most radical innovation of the 3M is its so-called "closed-loop tape path": the smoothest, most flutter-free method of driving tape yet devised. 3M's solid-state electronics, while not as compact as Scully's, were definitely superior in signal to noise response, wide-range response, serviceability, and durability. Their "Dynatrack", employing two tracks in place of the usual one in a unique high-level/low-level switching circuit, resulted in an increase of 10 dB in the signal to noise ratio, making it (until the advent of the Dolby system) the quietest tape-mastering method in the industry. But (again that "but") Dynatrack is incompatible with standard NAB recorders, and uses twice as much tape (four channels take one inch!), so that Dynatrack (much like Ampex's AME equalization invented for the same purpose of noise reduction) has not enjoyed wide popularity. 3M's more recent models are usually exclusively NAB, or NAB with an option to Dynatrack, and utilize the excellent iem heads.

The closed-loop drive, in our opinion, has one serious drawback: editing, which, despite 3M's clever 120-degree edit-marking system, will never be as fast or convenient as on an Ampex or Scully. (That it's even possible must be regarded as a minor miracle.)

No doubt stimulated by 3M's rapid acceptance, Scully quickly revamped its 280 machine, incorporating a more durable tape transport with an automatic direction-sensing tape motion system option, premium quality iem tape heads, lower-noise modified electronics (Haeco does an excellent job renovating older Scully electronics for really low noise), and improved tape handling ease. They introduced an eight-track, one-inch recorder, and, more recently (and in a puristic sense, more regrettably), a twelve-track machine (which, sadly, doubles as a white noise generator, thanks to the extremely narrow head - gap heights necessary in fitting twelve tracks into one inch). The Scully and 3M one, two, three, four, and eight-track recorders, however, are fine machines, and have proven their worth in recording studios throughout the world.

Ampex, suddenly aware that their virtual monopoly was being threatened, retaliated with the short-lived AG 351, the more expensive AG 300 and MR 70, and finally their new AG 440 line, all solid-state machines.

The AG 351 and AG 300 are wan though well-intended attempts to update the earlier tube models which bear the same numbers to solid-state, and have nothing to recommend them over their tube predecessors except space. The MR 70 is an extravagant machine with an even more extravagant price tag.

The AG 440 is a more extensive redesigning of the 351, and sits somewhere between 3M and Scully for size, performance, and convenience. It is available in up to eight tracks, and is a potentially fine machine which will doubtless be perfected in later models. Up to the present, however, we felt that Ampex was unduly hasty in bringing the 440 line from the laboratory to the market. Quite a few studios have discovered that frequent servicing is necessary to keep the machine operating at its superb best. Bias instability, alignment slippage, and insecure plug-in head contacts are a few of the "bugs" which occasionally afflict the AG 440. Moreover, we find the automatic tape-lifter system an irritation, offering only two positions of tape-to-head contact: full or none. In the fast forward or rewind positions, you have the choice of hearing either nearly nothing at all, or the very loud chatter of full contact at high speed. With Ampex's old manual gate, an experienced operator could bring the tape into just enough contact to spot-check it without having either to blast or strain his eardrums. If Ampex insists on keeping an automatic lifter, they should consider providing a manual override, as 3M and Scully have done, and installing a delay to keep the lifters from dropping down while the tape is still screeching (literally!) to a halt (although a newer idea involves a delay on the lifters until the tape comes to a stop). The sel-sync switches, like those of the Scully 280, are located on the individual pre-amps, a position which, with their small knob size, makes them inconvenient to find, set, and check. The older method of a single master sel-sync panel with large knobs is much preferred. Perhaps 3M's "Remote Overdub Control" or Scully's "Sync-Master" are the answers here, and Ampex is sure to come up with a similar accessory soon, if not tomorrow.

Not to be outdone by 3M and Scully's multi-channel machines (particularly Scully's twelve-track), Ampex has recently made available the custom AG-1000-16 and AG-1000-24 sixteen and 24-track recorders which utilize two-inch videotape transports with industrial electronic modules, and a newer version using 440 electronics, the MM-1000, in eight, sixteen, and 24-track models. The AG-1000-24 and the MM-1000-24 indeed represent (we hope!) the ultimate demonstration (not to exclude Apple Corps' planned 72-track installation on <u>four</u> synchronized transports!) of that syndrome so peculiar to our age, <u>additio ad absurdum</u>, and will perhaps take its place one day alongside the 101-millimeter cigarette, the 70-millimeter film, the super-economy-size detergent box, and the 300-watt guitar amp in some future incarnation of the Smithsonian Institution. At least let it be said that the spectacle of three or more engineers, each madly snatching at his respective share of 24 or more faders, does not sit comfortably with the concept of producing a unified music mix, let alone a significant individual creation. We feel that somewhere between eight and sixteen tracks lies the ideal compromise dictated by the contradictory exigencies of versatility, accessibility, convenience, and low noise. (Consider that solo passage in some future 24-track composition, consisting of one active track and 23 tracks of tape hiss [or only twelve, if a superhuman engineer is really on his toes]. Computerized console control is the only real answer here — if you can afford it and have the facilities to design and construct a workable version. Or else, consider the cost of 24 Dolbys after the already ruinous expense of the AG-1000-24 and the MM-1000-24, at $32,000 and $34,000, respectively.) And already word comes that 3M is readying its new sixteen-track two-inch model tape recorder with an option of four record and sixteen playback electronics for a "budget pricing".

It is clear that the choice of a machine for an electronic music studio must still be based on a series of real compromises. If you can adapt to the editing system, or do not require great amounts of editing, a pair of 3M two-tracks and one 3M eight-track will probably provide the best example of the state of the art. The current Scully 280 is a quite respectable recorder, consistent with convenient editing, versatility, wide response, and maintenance-free operation. The Ampex 440 might provide you with better results than a Scully if you're handy with a screwdriver and an alligator clip, or if you get a trouble-free machine, and is, in our opinion, definitely superior to the first version of the Scully 280. But perhaps it is worth waiting to see what improvements Ampex will make in the 440 by next year. Both the Scully and the Ampex, by the way, are physically more compact than the 3M.

Still, the maverick in us tells us that the Ampex 300 and 351, though discontinued, are by no means obsolete, and represent the finest state of the pre-transistor art. Solid-state is the wave of the future, but we venture to suggest that the industry has not yet had enough time to achieve results which take as full advantage of the transistor as Ampex did of the torrid, cumbersome tube.

ACKNOWLEDGEMENT

The authors would like to thank R. Dennis Schwarz for his invaluable assistance in the preparation of this article.

Symposium: Tape Recording

A Report on Tape Recorders

Gordon Mumma

This report is drawn from ten years of experience with tape recorders in electronic music applications, and considers studio as well as live performance conditions. With the establishment of the Cooperative Studio for Electronic Music in 1958, Robert Ashley and I decided to use the Viking 86. Our conclusions were reached because of the compact size of the Viking 86, its remarkable ease of maintenance, and ease of modification. Our modifications included continuously variable speed (via external oscillator and amplifier), and special head configurations. We used Nortronics heads and vacuum tube electronics for the basic Viking 86 decks, and had a four-channel 1/4" tape system in use for the Space Theater productions in 1960.

The lightweight Viking 86 decks required more periodic maintenance than would have the heavy Ampex 351 mechanism, but the saving in space, weight, and money, and the greater ease of maintenance justified this sacrifice. It would have been impossible to achieve some of the unusual head configurations with the Ampex that we established with the Viking units.

Over the past decade I have worked with Ampex, Concertone, Crown, EMI, Ferrograph, Magnecord, ReVox, Sony, Tandberg, and Telefunken equipment under similar studio conditions. In spite of certain advantages which some of these units have over the Viking 86, the ease of maintenance and modification were still greater with the Viking, and I would likely make the same choice again today.

The Viking 86 is mechanically operated, with mechanical linkages, and thus is difficult to operate remotely. We bypassed this problem by using human labor. The more recent Viking 87 (or 88) decks are an evolution of the 86. Hyperbolic heads are now used, thus eliminating pressure pads. This offers, perhaps, some advantage for recording quality, but makes the modification of the recent models more difficult. After nearly a decade of heavy use, all of our Viking 86s are still in operation.

Outside of the studio, on the road, portability is a rather more critical factor. Unfortunately, there is still no lightweight stereo machine, battery or line operated, at any price, which stands up well to the rigors of the road. The superb Nagra is monaural only, with no stereo model in the foreseeable future. A rumored Tandberg has not yet appeared. The Uher 4400 is lightweight and apparently of high quality, but is limited to 5" reels.

My road experience includes theater, modern dance, and live electronic music. I still like the Viking 86 for these applications. The critical factor here is that on the road, in live performance, time for maintenance is often non-existent. If repairs must be made, say, during the intermission of a performance, they must be easy to achieve. The Viking is generally excellent in this respect. The Wollensak is the most difficult.

One of the potential requirements for live performance tape equipment is adaptability to different line voltages and frequencies. It is difficult to find a machine that accommodates 110 and 220 VAC, 50 and 60 Hz in a single model. On occasion one will find 140 VAC (at the Venice Theater, for example). An ideal solution would be a unit which contains its own oscillator and amplifier, or a digital-servo system. This is quite feasible now with integrated circuit technology, and Sony, ReVox, and MRS make such recorders.

The most flexible and rugged tape machine I have ever used on the road is the ReVox. The Cunningham Dance Co. has used ReVox machines in remote parts of Portugal, in France, Sweden, and England since I have been performing with them. These were all borrowed machines, and some looked as though they had previously seen service with oil prospectors or military commandos. These battered ReVox units were absolutely reliable. I am unable to comment on the ease of repair because I have never needed to repair one. They handle 10 1/2" reels, which is often an advantage, and seem to be adaptable to various line power situations. Their only disadvantage on the road is their large size and weight.

When quarter-track stereo first appeared I thought it was a disgrace. I still don't like it, but I must admit that a number of recent systems have been excellent, and indistinguishable from some half-track stereo equipment. The prime disadvantage for the electronic music composer is that he cannot edit a quarter-track stereo tape if it is recorded on both sides. Also, the signal to noise ratio is not as good in general because the track width is narrower. The incompatibility of half-track stereo tapes on quarter-track machines is a nuisance. Unless the quarter-track stereo head can be mechanically shifted to ride in the center of the two half-track stereo channels, the signal loss on one of the tracks is severe.

Of course, quarter-track four-channel tape is another matter. Now it is even possible to work with eight tracks on 1/4" tape, all tracks useable at the same time.

Finally, I would like to suggest some efforts for the future. It is about time that certain technology from instrumentation recording be applied to audio recording. The size of tape equipment could be decreased by use of co-axial reel mountings. Closed-loop systems (already used in the 3M professional recorders) offer many advantages. FM recording can extend the use of tape recorders into the area of programmed control, that is, recording control signals on magnetic tape with greater reliability, and perhaps simplicity, than is possible with AM recording. I have already mentioned the use of servo-controlled equipment using integrated circuitry for operation of the capstan and reel drives. A reliable tape recorder which could be operated independently of line power would be a significant achievement.

Multi-Track Recording in Electronic Music

Walter Carlos and Benjamin Folkman

To any but monodic electronicists, the problems of combining synchronized sound events without the loss of sound quality have been some of the most pressing of any in the electronic music field. In the early days of the art (pre-stereo), electronic events were compiled on individual, single - track tapes which were then laboriously synchronized and combined section by section into a final electronic ensemble. With the usual tape speed-instability-drift common even in professional machines, only segments up to about 30 seconds long could be predictably and dependably synchronized, unless, of course, perfect synchronization was not part of the concept of the piece, in which case some drift was permissible, if not preferable.

The advent of two-track stereophonic recorders altered this technique little, necessitating only the addition of routing of individual elements and events to the two channels during the synchronizing-mixing process. Stereo, of course, provided a greater clarity of individual elements, so that many more events (with, however, consequent increase in synchronizing-mixing time required) could be perceived as individual and distinct voices. The advent of four-channel recorders merely multiplied the process, with all its credits and debits, although, of course, the multi and now multi-multi track machines also introduced the possibility of "super stereophonic" electronic music playings/performances, the mixing being aural.

In the early sixties, Ampex inaugurated its new "sel-sync" (selective synchronization) option in three and four-track machines. This provided a different way of approaching the problem of synchronizing and combining electronic voices. While the electronic composer still relied (and continues to rely) heavily on individual monophonic track elements, he now had the option of real-time "performance synchronization". The sel-sync system enables any of the individual tracks to be played back through that track's record head while the next track is being performed and recorded through one of the other record gaps in the same head stack, maintaining temporal coincidence. At first glance, it would seem that sel-sync implies, and indeed requires, a real-time electronic music performance instrument, or live <u>concrète</u> sound source. Actually, many of the electronic events we had been in the habit of considering non-real-time-performable are, in fact, "performed" by the composer synchronously in real or multiple-real time as he twists the dials, depresses the necessary buttons, and pulls appropriate patchcords in sequence. While it is true that such a performance may last only a matter of seconds and requires considerable post-editing, the result justifies the use of sel-sync for macro-modular sound-element juxtapositions. The component sounds are directly placed on the tape as synchronous master tracks, thereby eliminating, most of the time, the extra tape generation of basic monaural tracks; these juxtapositions are then neatly spliced together to form larger sections, a process at which the electronic composer should already be adept.

Other decided advantages accrue from the skillful application of the sel-sync principle. These include: total control in the positioning of individual events according to the <u>expressive</u> needs of the material; separating the heretofore simultaneous functions of mixing and synchronizing;

allowing greater flexibility in the dynamic-volume contouring of ensemble voices; and, an opportunity for re-evaluating at every step of this phase of the composition. Faute de mieux has become vieux jeu.

Thanks to these considerations, the synchronizing / output times ratio more nearly approaches $mn(r+1)$, where m is the average number of necessary complete retakes per track, n is the number of tracks (usually three or four, until recently) and r is the average number of sel-sync-remixed track elements contained within each of the physical tape tracks. This last point requires some discussion. A track that is programmed to play back cueing information (i.e., a pre-existent earlier program track(s) or properly prepared skeletal guide track) is not only to be made audible to the composer, but in the first instance may be premixed-in along with the currently produced musical element(s). Such a premix, which may entail as few as two to as many as x-1 tracks, where x is the number of available blank tracks, is generally considerably less restrictive in its demands of balance, loudness-shaping, and combinatorial difference-tone products (a possible source of distortion more normally most significant in the final assembly-mix) than that final assembly-mix itself. This process assures a recurrent audition of modular elemental sub-homogeneities within the compositional frame, rendering (particularly when the whole has been intelligently sub-setted), in practice a final homogeneity greater than that resulting from the simultaneous audition of the same number of synchronized but unintegrated elements.

So, to repeat, it is preferred that:

$$m > r \geq \frac{m}{z}$$
$$\text{where } 5 \geq z \geq 2$$

z being an empirical figure. In practice, we find an optimum z at about 3, though each composer must, of course, adapt this figure to his own sound-esthetic and available hardware, belying his own musico-technical priorities in the matters of tape-generation loss and fossilization of sub-homogeneities.

In our work, we have established the stringent, albeit arbitrary, demand that no originating electronic event source be further removed from the final two-track mix than three generations. Since the final mix-down exhausts one of these generations, it will be seen that the number of parallel event-sequences, e, shall be at all times less than $(m-1)!+1$, assuming that maintenance of the skeletal guide track through all but the final step best guarantees the integrity of the realization. All factors of quality being equal, it can be easily deduced from the above that a strong argument should be advanced in favor of maximizing m.

It can be easily demonstrated that m is determined by the relation:

$$m = \frac{w + s}{h + s}$$

where w is the tape width in mils, h is the gap height in mils, and s is the spacing between tracks in mils. Using currently available forms of magnetic oxide tape (CrO_2 tape is still in the experimental stage and thus cannot be considered in the present discussion), h must be greater than or equal to 70, if a signal to noise ratio of 60 dB (following the Ampex standard definition of weighted noise) is to be maintained, forgetting such expensive (for multi-channel work) crutches as the Dolby. The current mechanical limitations on head construction consistent with an adjacent crosstalk rejection ratio of 55 dB minimum is found, in practice, to set the limit on s to $\geq$ 60. Excepting such costly implementations as converted videotape transports, no available tape-drive system safely allows w to exceed 1000. Combining the above optima, a figure for m of 8.15 is obtained, or 8, since a fractional track in a recorder must be considered a logical absurdity. Thus, in our work, E $\gtrsim$ 28 (or $\gtrsim$ 36, if the skeletal guide track is discarded during the initial premix) except by use of special techniques too elaborate to be mentioned here.

Table 1 displays a hypothetical evolution of a sonic organism, from the elemental stages through the production of sub-homogeneities (paradoxically, each sub-homogeneity is less complex than its predecessor as the density of complexity of the ultimate compositional postulate more closely approaches realization) to the final assembly, which alone of all the steps operates totally above the elemental level.

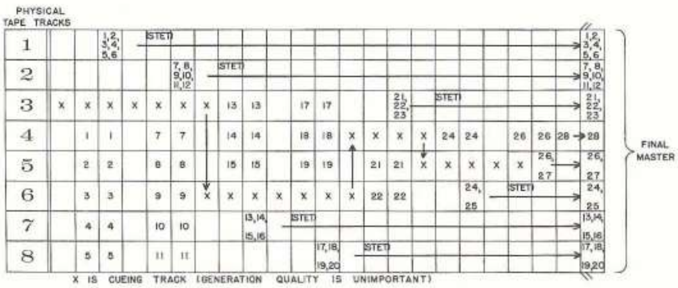

TABLE 1. 28 FINAL TRACKS FROM 8 TAPE TRACKS, NOT EXCEEDING SECOND GENERATION.

	NORMAL PLAYBACK HEAD	1 MIL UNEQUALIZED RECORD HEAD	1/2 MIL UNEQUALIZED RECORD HEAD	1/2 MIL EQUALIZED RECORD HEAD	FINAL (1/2 MIL) RECORD-PLAY SYSTEM RESPONSE
15,000 Hz	0 dB	−15	−5	+1/2	+1/2
12,000	+1/2	−20*	−3-1/2	+1/2	0
10,000	+1/2	−13	−2-1/2	0	0
7,500	0	−7-1/2	−1-1/2	0	0
5,000	0	−3-1/2	−1	0	+1/2
2,500	−1/2	−1	−1/2	0	0
1,000	0	0	0	0	0
700	0	0	0	0	0
500	0	0	0	0	0
250	+1/2	+1	+1	+1	+1/2
100	+1	−1/2	−1	−1	+1
50	+1/2	+4-1/2	+3	+3	0
30	+2-1/2	+2	+1	+1	+2

(* AT A POINT JUST ABOVE 12K Hz A NULL OF −60 OCCURS)

TABLE 2. MEASURED RESPONSE OF 1 AND 1/2 MIL RECORD GAPS.

It will be seen from Table 1 that seven of the steps entail coincident superimposition, necessitating that the range of signal reproduction of each elemental track undergoing second-generation be limited by the response and noise characteristics of what, in the pure sel-sync process, amounts to a response and noise sufficient for cueing only. The remainder of this article will present our solution to the limitations of the SYNC position in playback.

During the monophonic and two-track era of tape recording, Ampex determined the optimum record head gap width to be 1 mil. This permitted a maximum utilization of the bias and record power available from circuit designs then current. Unfortunately, the 1 mil gap functioned with decidedly less efficiency when used for playback in the sel-sync mode: when the recorded wavelength on the tape approaches a dimension as small as the playback head gap, the gap becomes unable to resolve the wavelength, and a sharp frequency null, sounding like lowpass filtering, results. At the professional tape speed of 15 ips, all frequencies below about 3 kHz are safely larger than this critical wavelength, but 15 kHz has a 1 mil wavelength, and is squarely on the null of the 1 mil gap. The range 3-15 kHz is characterized by an extremely rapid drop in output level, proportional to frequency, from 0 dB (= flat @ 1 kHz) to minus infinity. Since the full depth of the tape is not in microscopically intimate contact with the surface of the tape head, the null in practice is, in fact, shifted to an even lower frequency, in our experience approximately 13 kHz. This is a most unsatisfactory condition for reproduction of any signals containing useful energy in the upper frequency region, i.e., any complex waveforms. In normal electronic music applications, an extended upper-frequency response is desirable. Some method was therefore critically necessary to mitigate this limitation.

The obvious answer was to reduce the size of the record gap, an answer itself limited by the consequent demand of greater record and bias currents necessary to produce the same resultant flux on the tape. Both a lower and an upper limit are thus placed on the size of the record gap. A 1/2 mil record gap size provides an ideal compromise, as it places the null at 25 kHz or higher, well above the audible spectrum, but consumes only manageably higher bias and record levels.

It will be appreciated from Table 2 that the response of the 1 mil gap is unsalvageable for high-fidelity purposes. The 1/2 mil gap is still a compromise with flat response (down 3 dB at 10 kHz and down 5 dB at 15 kHz). Should we further reduce the gap size in order to optimize playback response at the expense of record and bias currents, with the distortion inevitably thus produced? If we closed-mindedly consider only the Ampex method of sel-syncing with its transformers for impedance matching and switches to control the proper function, it would appear that we must be content with a somewhat "muffled" high end in the SYNC position.

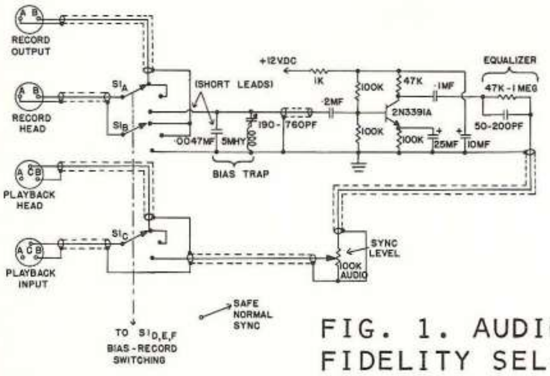

FIG. 1. AUDIO CIRCUITRY OF A HIGH-FIDELITY SEL-SYNC APPARATUS.

We decided that a fresh approach to the problem was in order. A single-transistor stage pre-amplifier (see Fig. 1) was designed with an input impedance characteristic matching the record head (nominally 3000 ohms at 1000 cycles) and an output impedance and gain sufficient to drive an RC equalization circuit whose values are selected to produce a boost at the high end complementary to the problematic roll-off, including a sufficient margin to permit an output potentiometer to control the signal level, and permit matching it to the normal playback head output characteristic. Since the output of the record head is nominally higher than that of the narrower gap playback head, and since a selected, ultra-low-noise transistor is employed, the response characteristics in SYNC and NORMAL positions become essentially indistinguishable. About the only audible difference occurs when the tape is at rest, at which time the SYNC position exhibits a slight hiss of rather high frequency, a hiss which is effectively masked by the normal dynamic hiss of the recorded tape, not to mention masking by much of the program.

While our intention is not to limit this article to the scope of a construction project, we feel that a few of our mechanical solutions to the physical organization of our synchronizing panel should be mentioned.

Our eight-track machine is a conversion of a recent three-track Ampex 300. We discarded the three-track head assembly, the 1/2" tape guides and capstan flywheel assembly, and the Ampex 300 sel-sync panel. The heads were replaced with a complete head assembly manufactured by iem, which included all the necessary head hardware, and the 24 head cables. 1" tape guides, a taller pressure roller, and a longer capstan drive assembly were purchased from Ampex. An hour of careful shimming brought the tape path into proper alignment. Reeling tensions were increased, as was the holdback tension, the latter necessary for maintenance of intimate tape-to-head contact with the wider tape, especially the critical tracks one and eight. The three original electronics (modified by larger bias-adjustment capacitors) now operate on tracks one, two, and three, the top three tracks on the eight-track head. A 5' open-backed telephone-type equipment rack contains the five new electronics (also with modified bias-adjusts) for tracks four through eight, a jack-strip, and a Fairchild reverberation chamber, and sits at the side of the 300 cabinet.

The usual nuisance and possible quality degradation of input transformers (commonly found on Ampex multi-channel equipment) was obviated by the use of high-impedance playback heads. While this necessitates shorter lead cables and more critical hum-shielding, we feel that the excellent response we have obtained justifies the greater care involved. Also, sel-sync pre-amplifier equalization is simplified by the high-impedance inputs.

We were able to fit eight channels of sel-sync into 3 1/2" of the 5 1/4" occupied by the discarded Ampex panel (see Fig. 2). The remaining space was nicely filled with an input-output panel. Eight switches determine which of the two mixer outputs feeds the various tracks. If other than the console outputs are necessary as input sources, there are eight additional input jacks on the abovementioned jack-strip, which connect with the input switches in their CENTER-OFF positions. The output portion of the panel consists of eight potentiometers which feed a cueing-mixing buss from the monitor output jacks on the back of each of the individual Ampex electronics; thus the system is isolated from the main electronics outputs, which are normaled directly to the faders on the console. The shafts of these potentiometers also activate push-pull switches, so that a track can be turned off or on without varying its pre-set level.

It is obvious that a more compact layout was required to fit eight sel-sync channels into a smaller space than three had previously occupied. Physically, our unit consists of a 3 1/2" "bathtub" chassis mounted on 1/8" thick 3 1/2" x 19" rack panel. The panel was engraved for eight switches on 2" centers. Each switch has three positions: SAFE (for normal playback of masters, record function disabled), NORMAL, and SYNC. The entire panel was anodized to increase its surface durability and make it physically stronger. Eight six-pole switches were adapted so that the two steatite wafers, each containing three of the poles, could be isolated from one another by a thin, grounded aluminum wall. The front wafer, which lies between the wall and the front panel, contains the wiring for bias-, record-, and common record-start-defeats in both SAFE and SYNC modes. In the NORMAL mode, the channel's electronics functions normally. A terminal strip was installed between the aluminum wall and the front of the panel to route the common power-feed from the transport to all eight electronics.

The remaining wafer controls the playback and record head routing (see Fig. 1). It ties together the input and output connectors mounted on the back of the bathtub chassis with the single-stage preamp-equalizers located on a long narrow circuit board that runs the entire width of the bathtub. Presently, the +12 voltage for these preamps is supplied by two 6-volt lantern batteries sitting in the base of the transport. Aside from the occasional inconvenience of replacement (once every 8 months to a year), one could not ask for a finer, more ripple-free source of DC. The knobs on the input-output panel are lined up beneath the knobs on the sel-sync panel. The location of these two panels immediately above the transport, and the selection of the large teardrop knobs (made by National and used until recently by Ampex) created what we feel is the fastest, least error-prone, most convenient, most versatile, and most cybernetically engineered sel-syncing tape recorder in existence (see Fig. 3). It is unfortunate that Ampex, following 3M and Scully, has decided, for reasons of expandability and simplicity of cabling, to discard the master sel-sync panel concept in favor of miniscule, hard-to-locate switches on the individual preamps (see our other article in this issue). Synchronization selectors should be readily at one's fingertips, and should be in one place, since it is usually necessary to set all of them at any stage of the assembly operation.

For the composer who has never worked with sel-sync, the tendency to make do with older classical techniques is very strong. But with a multi-channel machine equipped with a convenient, wideband syncing apparatus similar to that described in this article, a new generation of electronic musical techniques is inaugurated, one which brings us closer to the ever-present goal of complete compositional and realizational musical control.

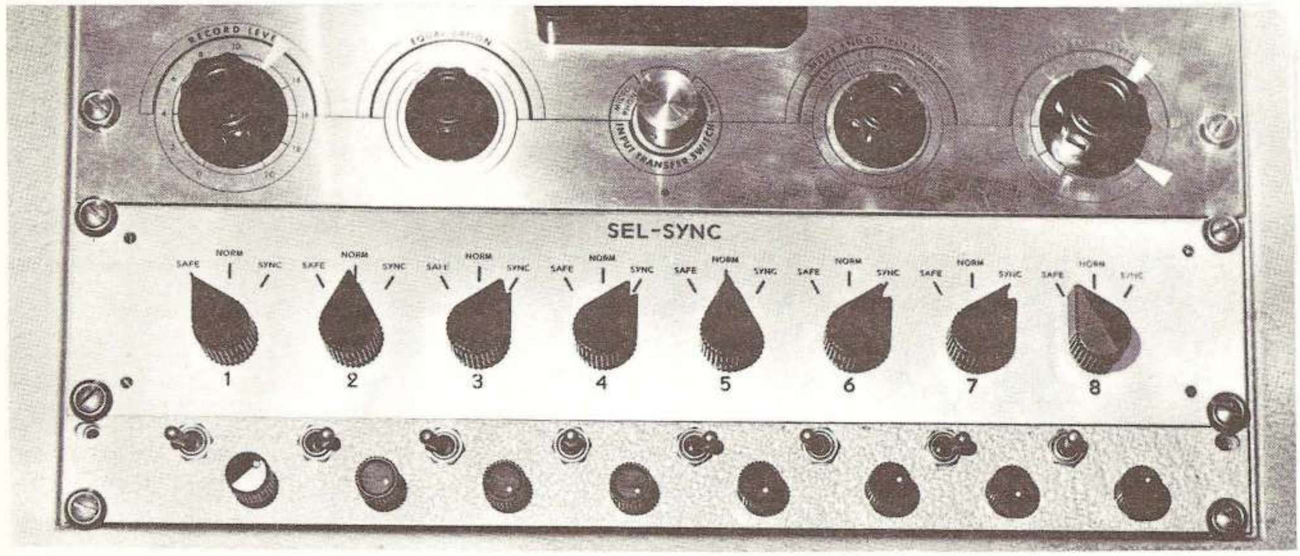

FIG. 2. COMPLETED 8-TRACK SEL-SYNC PANEL.

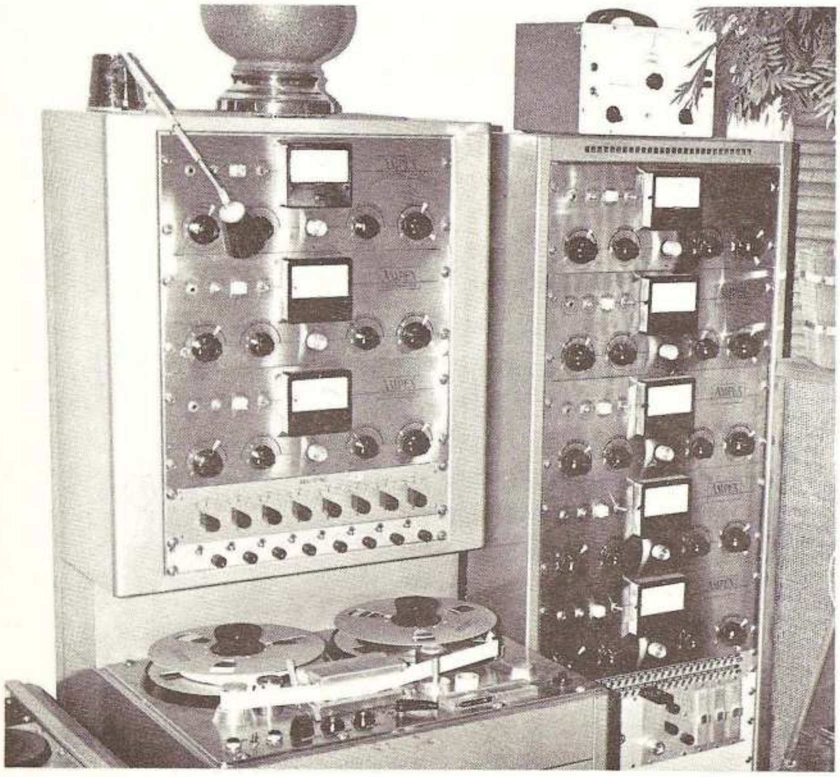

FIG. 3. 8-TRACK AMPEX ASSEMBLED BY R. DENNIS SCHWARZ AND WALTER CARLOS.

Symposium: Tape Recording

The MRS Recorder

Gerald S. Macdonald

Introduction

The utility of a variable speed tape recorder in electronic music composition cannot be underestimated. Despite the inherent limitations of the tape recording process, tape manipulation is still an indispensable aid to electronic music composition. One of the most valuable types of tape manipulation is speed change. Minor speed changes are used to provide small corrections of the pitch or timing of a track, while large speed changes produce great modifications in the tone quality, as well as in the pitch and timing of the recorded material. The MRS recorder adds two entirely new dimensions to the speed-changing capabilities of conventional recorders: speed variation over a five-octave (32:1) range and extremely rapid action (typically under 0.1 second). The wide-range operation of the MRS permits speed changes of up to five octaves without re-recording, and the composer can create rapid variations in the recorded material. For instance, a pitch inflection characteristic of a given traditional musical instrument can be imparted to any recorded material of steady pitch by appropriately varying the MRS recorder speed.

Although the MRS recorder was developed to fulfill the needs of a wide range of applications in both the audio and instrumentation recording fields, it is especially suited to electronic music applications. The design approach incorporates some of the techniques generally reserved for the more sophisticated instrumentation recorders, including digital and linear integrated circuits for low level control, and power transistors for motor control. These low-cost electronic components, and careful consideration of the inevitable technical compromises, have made it possible to design a transport of relatively modest cost, although still somewhat high by professional audio standards.

A meaningful discussion must necessarily lead the reader into some technical areas. However, in describing performance features which hopefully will suggest some unusual applications, technical involvement will be kept to a minimum level. Of primary importance is that the recorder is controlled from a source of DC power; the three motors are printed circuit type DC motors, and while a conventional 115V AC power supply is normally used to provide the required DC voltages (±12V), two batteries of suitable capacity may be used just as readily. Each of the three motors is controlled by an independent servo system, and it is principally this feature which allows both versatility and high performance.

The transport is easily portable and weighs (less power supply) about 28 pounds. The front panel (Fig. 1) is standard rack size (14" x 19") and the depth behind the panel is 5". Both 7" plastic and 10 1/2" NAB reels may be accommodated. All the electronic components, except the power transistors, are grouped by function and mounted on nine readily accessible plug-in circuit boards (Fig. 2). The power supply is mounted separately, either in a rack, or, for a console type installation, in any convenient location behind or under the machine, as desired.

FIG. 1.
FRONT PANEL OF MRS RECORDER.

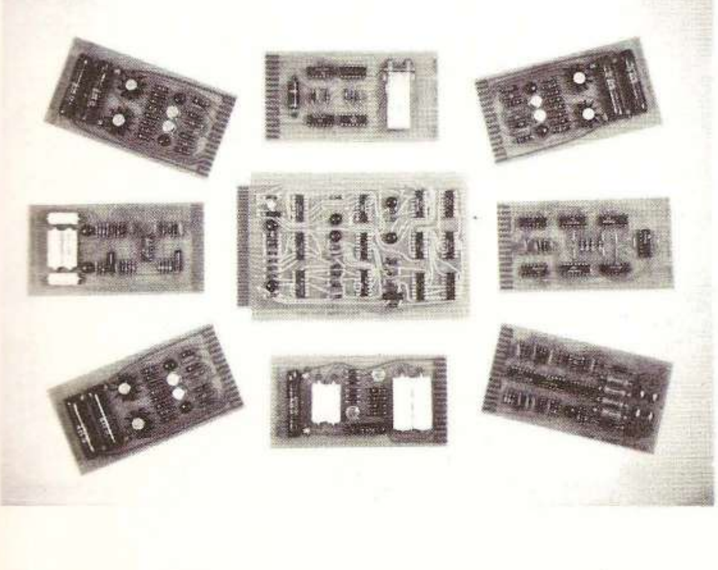

FIG. 2.
CIRCUIT BOARDS. LEFT THREE, REEL SERVOS; CENTER, (TOP) CRYSTAL REFERENCE FREQUENCY GENERATOR, (MIDDLE) PUSHBUTTON LOGIC CONTROL, (BOTTOM) POWER SUPPLY REGULATOR; RIGHT THREE, CAPSTAN SERVO SYSTEM.

The Capstan Servo

The heart of the transport is the capstan drive system, but the approach used here constitutes a radical departure from the conventional AC hysteresis-synchronous motor, now used almost universally in high quality audio transports. The fact that the conventional AC motor is normally locked synchronously to the power line frequency (which controls the speed of the motor), and the nature of the motor itself, impose certain limitations on the user of electronic music devices, who desires high accuracy and flexibility in his equipment. First, the instantaneous accuracy of the 60 Hz frequency source occasionally leaves something to be desired, and may adversely affect flutter performance. Second, the motor is inherently somewhat loosely coupled (locked) to the line frequency and often exhibits the phenomenon known as "hunting", which also affects flutter performance. Third, and perhaps most significant, is the basic limitation of this type of motor which permits, at best, two or three speeds with limited torque, and precludes, for most practical purposes, continuously variable or modulated tape speeds over wide speed ranges. Therefore, in order to improve accuracy, reduce the effect of external torque disturbances on the capstan motor, and provide a wide and readily controlled range of tape speeds, the DC drive motor in this recorder is used together with a synchronous phase-locked servo system in a direct drive configuration which, while electronically quite complex, is mechanically simple and straightforward, and provides superior performance.

In principle, these requirements are met by coupling to the motor a "pick-off" device, or digital tachometer, which provides a fixed number of output pulses per revolution of the motor shaft (making frequency of the output pulses directly proportional to motor speed), and by providing an electronic means for "locking" this signal, on a pulse-for-pulse basis, with a similar reference frequency signal generated by a stable oscillator.

From a "black box" point of view, this is also a synchronous motor, but quite unlike the AC type in that: (1) If the frequency of the reference oscillator is altered, the motor speed will follow, thus providing a simple means for changing the tape speed either in discrete steps or continuously. (2) The useable range of reference frequencies can be made quite high — on the order of 100 to 1 or more if required. For a typical recorder, the actual range (which is a function of the number of pulses on the pick-off wheel, the capstan diameter, and the desired tape speed) is approximately 3 kHz to 100 kHz for standard tape speeds between 1 7/8 and 60 ips. (3) The torque available from the capstan motor is quite high (on the order of 30 ounce-inches) so that speed changes are rapid. For example, the time required to change speeds from 7 1/2 ips to 15 ips is approximately 1/10 second. (4) The "tracking rate", which is defined as the rate of change of tape speed possible without losing synchronism with the reference generator, is on the order of 100 rpm in 25 ms. Since the motor speed at 7 1/2 ips is approximately 400 rpm, the tracking rate for various conditions of reference frequency modulation may be readily calculated. It should be emphasized that the figures given in (3) and (4) are not design limitations, but rather a set of parameters selected for a "standard" recorder — much faster acceleration and deceleration rates are possible in special cases by altering the pick-off wheel inertia and other related factors. (5) When running at a given speed, the capstan servo is critically damped; there is no overshoot or hunting and the full 30 ounce-inches of torque is available on an instantaneous basis to maintain true position (phase angle) integrity between the pick-off and reference generator signals. (6) The above drive system characteristics combine to reduce flutter caused by the capstan motor itself almost to the vanishing point; flutter contributed by external conditions (reels, tape tension, etc.) is discussed in a subsequent section.

In practice, the capstan motor pick-off device is a brass wheel fastened to the rear shaft extension of the motor. On the outer rim of the wheel there is a magnetic coating which is sprayed on, and when cured, has properties equivalent to ordinary magnetic tape. By means of a special fixture which includes conventional record and reproduce heads, a track of pulses (2000 in all) is very accurately recorded on the coating around the wheel. This, together with a pick-off head and suitable electronic circuitry to amplify and shape the signal from the head when the motor is turning, provides the continuous signal information required by the servo amplifier as to the average and instantaneous speed of the motor. The aforementioned reference oscillator generates a similar continuous signal so that there are two frequencies fed to two inputs of a digital frequency and phase comparator.

This comparator determines, by digital rather than analog means, whether the motor speed, as determined by the frequency of the pick-off output signal, is above or below that of the reference generator. If below, the motor is accelerated under full power; if above, it is decelerated under full power. This is the frequency control. At some instant, when the two frequencies are precisely equal, the comparator locks them together, and its function is changed to one of continuous linear phase control, where the servo tends to maintain a constant phase angle between the two signals. If the reference frequency is changed (switched), the comparator reverts to the non-linear frequency mode and the process is repeated. If the reference frequency is continuously varied up or down (rather than switched), the motor speed will track, maintaining synchronism and phase control, within the system limitations outlined earlier.

The output of the comparator is a width-modulated rectangular wave which is converted to a DC voltage, amplified, and fed to the capstan motor. The magnitude of the DC voltage is continuously changed in accordance with the instantaneous requirements of the capstan motor to maintain constant speed. Thus, any tendency of the motor to speed up or slow down (even minute amounts over very short time periods), is met with very large opposing forces (bi-directional current through the motor as required), which tend to correct this action.

For the more technically inclined, it should be pointed out that although we are ultimately concerned with accurate tape speed control, the system is actually a continuously moving (rotating) <u>position</u> servomechansim (as opposed to a <u>velocity</u> servomechanism), since we are constantly monitoring and correcting the phase angle (position) between the reference and pick-off signals. Thus, for purposes of detailed servo analysis, the standard ground rules for phase shift, stability, gain, etc., peculiar to position systems apply.

<u>The Reel Servos</u>

The controls of the reel drive systems are also unlike those found on more conventional equipment. The normal approach for 10 1/2" reel transports is to employ frictional or electrical braking on the supply reel motor to provide tape tension across the head area, and reduced power to the take-up reel motor to wind the tape as it comes from the capstan-pressure roller area.

In addition, some sort of mechanical filter or stabilizer is usually used between the supply reel and the head area. This device is most often a flywheel coupled to a shaft and roller, the roller being driven by frictional contact with the tape, and the assembly rotating in a set of precision bearings. This is a lowpass mechanical filter which tends to reduce tape motion disturbances on the input side of the capstan assembly by virtue of the stored energy in the mass of the flywheel. These disturbances may be caused by: internal electrical or mechanical torque disturbances in the reeling motor, uneven or eccentric winding of the tape on the reel, mechanical disturbances in the braking system, and splices or sticky tape.

While this overall reeling system approach has proved quite successful over the years, there are problems inherent in the basic method, particularly in changing or modulating the tape speed rapidly under controlled conditions. These problems are: (1) If rapid speed changes are called for, the mechanical stabilizer by definition cannot respond, and is therefore rendered practically useless. (2) Drastic and sudden speed changes require proportional torque changes in the reeling motors in order to maintain smooth tape control and prevent spillage at worst, and large tension bumps at best. (3) Average tape tension varies as much as 4:1 as the diameter of the tape on the reel changes from beginning to end of reel. (4) The tension changes in (3) are further aggravated if small (or dissimilar) size reels are used, thus requiring "reel size" switches which modify the motor torques by a fixed amount. (5) Mechanical filtering, by what amounts to a passive network, cannot "anticipate" (by rate correction) any dynamic disturbances which may appear even at "constant" tape speed. (6) There is no provision for controlling tape tension at fast wind speeds or when braking to a stop. This problem is also more significant with small reels.

Fortunately, the tendency towards despair when considering these design problems is greatly alleviated if independent closed-loop servos are considered for the reeling systems. Indeed, if the additional costs involved can be held to a reasonable level, the servo approach appears to be the only practical way to reduce to a minimum, if not completely eliminate, all of the above problems.

In order to incorporate reel servos in the transport under discussion, several approaches were considered. The final selection included the use of small spring loaded tension arms coupled to "cams" which, when the arms move, progressively alter the amount of light allowed to impinge upon photocells suitably mounted near the arms. The photocells, in turn, are connected to amplifiers which supply power to the DC reeling motors. The mechanical assemblies and amplifiers are adjusted so that with the arms approximately in the center of their travel, there is zero power to the motors. If either arm is then moved in one direction or the other, a current proportional to the amount and rate of arm travel will flow through the corresponding motor, the direction of current flow (polarity) depending upon the direction of the arm travel.

In operation, since the arms are spring loaded, they always tend to move to a position which sets up a state of equilibrium between tape tension and motor torque. If the tape tension starts to change for any reason, one or both arms, depending on the conditions, will move to a new position which alters the motor current in a direction to restore the original tension. Neglecting friction, the absolute tape tension is a function only of the spring tension in the arms. Technically, these independent controls are also in the position servomechanism class, and are fully proportional and bi-directional.

Some discussion of the reel servos in operation will shed additional light on the significance of their use in this recorder. When placed in the RUN mode, for example, the pressure roller engages the capstan, which accelerates and brings the tape up to speed. During the acceleration period, there are two essential conditions: the take-up motor current must increase in order to wind up the tape coming from the capstan without throwing a loop; and the supply motor must unwind the tape to supply it to the capstan in a controlled manner without any jerks and tension bumps. In the first case, as the tape starts out from the capstan, the tape tension on the take-up side starts to reduce, allowing the tension arm to move out, which supplies large amounts of current to the motor as required in order to restore the normal tension. On the supply side, the tension starts to increase, causing that arm to move in, supplying currents (of opposite polarity) to its motor as required. Since operation is dynamic, and power is supplied in a manner governed by the situation, it can be seen that in changing tape speeds rapidly up or down, or even if the tape speed is continuously modulated, the arms will respond continuously as just described, maintaining relatively constant tape tension and thus very smooth operation.

Under normal conditions of constant tape speed, the tape motion disturbances on the input side of the capstan, referred to earlier, are greatly reduced by the servos, since these disturbances are actually tension changes which, therefore, initiate the self-corrective reaction. The absolute amount of this error correction is, as with any position servo, a function of the servo gain and the nature of the disturbance. It should be pointed out, however, that although these are relatively high gain servos, it still behooves the designer to reduce to an absolute minimum, at the source, any predictable disturbances which might be present. This is the only way to take full advantage of the very tight control over the capstan motor and thus realize the excellent flutter performance of which the equipment is capable.

It should also be noted that the diameter of the tape on the reels is of no significance, due to the servo action, and that different size reels may be used on either side of the machine indiscriminately, without any electrical or mechanical changes.

Since the capstan and pressure roller, in the RUN mode, effectively divide the transport into two mechanically isolated sections as far as the tape is concerned, the need for two independent servos is clear. There are other conditions, however, such as fast wind, coming to a stop, and stopped, where the system is not divided in the same manner, and thus the need for and the use of independent systems is not so obvious. As a practical matter, when the tape is stopped, the friction which exists in the motors and along the tape path between the reels is sufficient to allow virtually independent action of the two servos and thus equalize the tape tension on each side. Under dynamic conditions, however, such as when the tape is in a fast wind mode, or is coming to a stop from fast wind, there would be interaction between the servos if they were both left operating, which proves to be an undesirable situation for proper tape handling.

In order, then, to initiate the fast wind mode (either FAST FORWARD or REWIND), the appropriate servo is disabled, and a fixed voltage is applied to the motor associated with that servo. For this mode of operation, the tape is not merely pulled through the system as with more conventional drives; since the remaining servo is still activated, the trailing reel actually unwinds the tape as dictated by the changing position of its associated tension arm. This action automatically ensures that tape tension is monitored and held relatively constant during all fast wind conditions, a control feature which is highly desirable, particularly when using different size reels.

In order to come to a stop from fast wind, it is only necessary to remove the fixed voltage from the leading motor. The friction in the system and the action of the trailing tension arm provide the conditions necessary to bring the tape to a smooth stop, still under controlled tension. An electro-magnetic circuit is used to sense the situation at the instant (or slightly before) the reels come to a stop. This re-energizes the previously deactivated servo, so that the tape is now at rest with both servos on.

Although the foregoing describes the basic operation of the reel servos, it is oversimplified to the extent that there is necessarily some fancy footwork buried in the details of the electronic circuitry, to accommodate transient conditions sometimes present during starting and stopping, and to ensure extremely smooth and gentle tape handling under all operating conditions with either large or small reels, where differences in inertia and therefore stored energy may be great.

Operating Controls

Tying together all the functions described up to now is a digital logic system using illuminated momentary contact pushbuttons and integrated circuits which replace the more usual relay controlled systems. This "miniature computer" is completely interlocked and contains memory circuits which ensure that the mode of operation initiated is that dictated by the last button pressed, regardless of the sequence or timing that the operator may use in pressing buttons. For example, if the tape is in REWIND, and the RUN button is pressed, the tape will come to a stop, the pressure roller will then engage the tape and the capstan, and the tape will run forward at the selected tape speed. In short, it is not possible to "trip up" the system by any predetermined or random sequence or timing of button pressing. The logic system may be operated by remote control if desired.

Tape speeds are controlled by a rotary switch which selects a frequency derived from a master crystal oscillator. Standard speeds are from 1 7/8 ips through 60 ips. There is also an EXTERNAL switch position which allows the use of any external fixed or varying frequency source, within the prescribed limitations of the system, at the discretion of the user.

Associated with the fast wind mode of operation is a panel mounted control (potentiometer) which allows the operator to adjust the wind speed from zero to "very fast" (about 60 sec for a 10 1/2" reel with 2400' of tape). This feature, together with a 4-digit revolution counter which is provided, is very convenient when searching for a particular passage recorded on the tape. Due to the action of the tape tension arms and reel servos, acceleration and speed in the wind mode is approximately the same at any point on the reel with a given setting of the speed control knob.

When the tape is placed in the FAST FORWARD or REWIND mode, an automatic tape lifter removes the tape from contact with the heads. However, this action can be manually defeated if desired, by means of a panel mounted knob. This knob may also be used to manually lift the tape from the heads at any time when not in fast wind.

In order to load tape on the machine or otherwise move the tape by hand without opposition from the action of the reel servos, a LOAD pushbutton is provided which disables both servos. Pressing the dual function STOP/READY button will reactivate the servos, providing tape slack has been taken up and both tension arms are off their stops. The switches which are activated when the arms (or either arm) are on the stops at the end of their travel are also used to shut off the reel servos and return the circuitry to the LOAD condition if tape is absent for any reason, such as at the end of a reel, or if a splice gives out during operation.

Symposium: Tape Recording

Noise Reduction in Electronic Music

Ray M. Dolby

Introduction

In conventional recordings, acoustic background noises arise from traffic, people, aircraft, musicians, and other identifiable sources. This background noise, or ambiance, as it is often known, is not altogether a negative quantity. Without it, many listeners feel that music seems to have an artificial, sterile quality. Noises are expected and accepted, provided they appear to have arisen in some normally explicable way.

Such noises are a boon to the recording engineer. In the absence of musical signals, they tend to mask the hiss, hum, print-through, and other noises arising in the magnetic tape recording process. Moreover, because of the complex nature of musical sounds — especially those from instruments having a significant content of wideband noise, such as strings — a high degree of noise masking is provided by the signals themselves.

In the production of electronic music, these naturally occurring masking conditions are largely absent. Without the signal, silence is total. Any intrusion is immediately identified as a product of the deficiencies of the recording process. Hiss cannot be excused as the "air" around the sound, print-through can hardly be attributed to an over-abundance of hall acoustics, and rumble and hum have a decidedly electronic quality.

The types of signals which are generated and assembled to make electronic music are often simpler in structure than those of instrumental music. This feature not only results in greater noise audibility at low signal levels, but in the evidence of modulation products — in the worst case, obvious extraneous tones — at high levels. Such intermodulation distortion can be reduced by recording at a lower level, but this approach is at best a compromise. With several generations of dubbing, equalizing, mixing, frequency shifting and splicing envisaged, it is clearly an advantage from the noise point of view to start with as high a level as possible.

The splicing aspect by itself is a hazard; a disturbing change in noise results if a first generation recording is spliced directly to third or fourth generation material. The difficulties are compounded by the fact that the higher generation recording will in all probability have a higher noise level than can be accounted for by a simple generation by generation buildup of tape hiss. Intermediate operations on the signal, especially high frequency boost and compression or limiting, can result in a significant increase in noise. Similarly, in mixing the signals from several tracks, the resultant noise level is often greater than expected, because of the frequent necessity of mixing in one or more tracks at a higher gain setting than was used in the original recording.

The increasing complexity of electronic music and its associated production processes necessarily requires a general tightening of quality standards, especially in the recording system — undoubtedly the weakest link in the production chain. The more ambitious and complex a recording project, the more important are level frequency response, low distortion, and low noise. It is becoming increasingly unsatisfactory to rely on the attenuation of high frequencies as a means of bringing hiss down to a tolerable level and to accept non-linear distortion as an unavoidable feature of the recording medium — or, indeed, to embrace the unpredictable esthetic consequences of such effects as necessary ingredients of the creative process.

Clearly, it would be of some significance to have an improved method of recording and, if desired, to be able to deal with each of the side effects normally associated with recording on an individual basis. If wideband noise is required, it can be added by a generator; if a non-linear characteristic is desired, it can be produced in a controlled way by appropriate networks. Such idealization of the recording process is one of the many required steps in bringing all of the parameters entering into the creation of sound under the control of the composer.

Noise Reduction System

Since 1966 a new technique, noise reduction, has become available for professional audio recording applications. A commercially manufactured noise reduction system (Dolby Laboratories A301), shown in Fig. 1, is now being used in the record industry for the making of master tape recordings. With regard to the application of this new studio tool to electronic music, it may be useful to outline the principles of operation of the system and to indicate something of its range of applicability, as well as to point out its limitations.

Principles of Operation

The design philosophy and technical details of the system have been discussed in previous papers[1,2,3]. The incoming noise-free signal is treated by a recording processor unit before being recorded on tape. During playback, the signal is fed into a complementary processor unit which restores the signal to its original condition and at the same time reduces any noise acquired during recording by 10-15dB. The overall treatment may be thought of as a special dynamic equalization process which automatically optimizes the signal to noise ratio.

In the recording processor the incoming signal is split into four frequency bands, each of which is fed to a low-level compressor circuit. The outputs of the four compressors are then recombined with the main signal, the effect being to increase the amplitudes of low-level signal components (30dB or more below 0 VU) but to leave all high-level signals substantially unaltered.

During reproduction, a filter and compressor network with characteristics identical to those used in recording is connected in the negative feedback loop of an amplifier. The transmission characteristic produced is thus complementary to that used in recording, with the result that the dynamics and frequency response of the signal are restored to normal. Being complementary to the recording processor, the playback unit attenuates low-level signal components, thereby reducing noise from the tape and tape recorder. The system is designed to reduce hiss by 10-15 dB (depending on the frequency) and to reduce crosstalk, print-through, hum, and rumble by 10 dB.

Operational Aspects

It is important to visualize the noise reduction system as part of the recorder and not as a normal studio tool such as an equalizer. Referring to Fig. 2, the system is inserted at normal line level between the mixing console and the tape recorder. The recorder should be operated with a gain of unity (±2 dB) and level frequency response (±2 dB). Moreover, the input and output gain settings of the recorder should be adjusted with reference to the level on an internationally recognized standard test tape (Ampex or DIN), which will ensure that tapes made with the noise reduction system will be fully interchangeable. Recent production units include meters (Fig. 1) to assist in setting recorder gains.

Although the noise reduction system and tape recorder must be operated under standardized gain conditions, all of the usual studio facilities may be used normally either before or after the system. If the signal is to be modified between tape generations, it should be replayed through a playback noise reduction unit, manipulated as desired, and then fed into a recording noise reduction unit for re-recording. One thus deals with normal signals in the mixing console and other studio facilities, while the tape itself is always in the noise reduction processed mode.

It may be remarked, however, that if the above precautions are not observed, the result is often satisfactory anyway. For example, if two processed signals are mixed together and then de-processed, the result will normally be indistinguishable from the case of the signals first being de-processed and then mixed. But in principle this is an incorrect procedure and in some low-level situations it is possible to detect a modulation of the level of one signal by the level of the other. However, non-standard use of the noise reduction system is a matter for experimentation.

Splicing is a notable exception to the rule that the tape signal should not be operated upon while in the processed condition; tapes may be handled and spliced normally. For editing, the signal should ideally be monitored after it is restored to normal. However, it is also possible to work

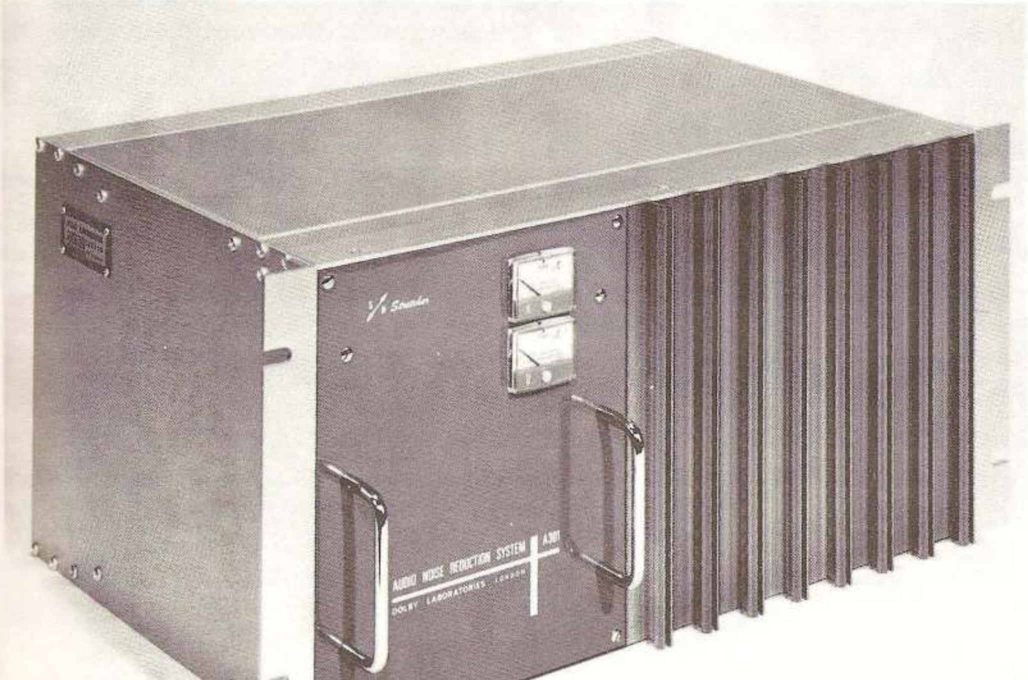

FIG. 1. DOLBY LABORATORIES AUDIO NOISE REDUCTION SYSTEM A301. ONE UNIT COMPRISES TWO INDEPENDENT SIGNAL PROCESSORS, EACH OF WHICH CAN BE SWITCHED INTO EITHER RECORDING MODE OR PLAYBACK MODE. CONSTRUCTION OF UNIT IS PLUG-IN MODULAR.

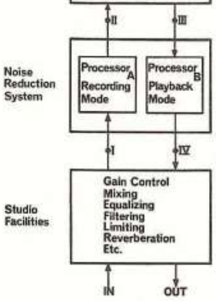

FIG. 2. USE OF SYSTEM IN AUDIO CHAIN (ONE CHANNEL).

with the raw processed signal. Although the sound then has a bright, breathy quality, it is close enough to being correct to enable routine editing to be done. In fact, some recording engineers use the processed mode as a means of obtaining a sharper, more critical impression of the sound and as a method of detecting noises and other low-level flaws.

Another feature of importance in electronic music is that noise reduction processed tapes can be replayed in reverse through the system without detriment. In principle, small dynamic errors are generated in this process, but it has been proven in a wide variety of program situations that such errors are inaudible in practice. (In such tests the program is returned to the original direction by means of a normal tape recorder, the resultant sounds then being monitored in context.) This bi-directional facility is attributable to the fast response time of the compressor circuits and to the fact that their operation is confined to very low-level signals.

The related matter of speed changing is also of significance in electronic music. As with the replay of reversed sounds, a change of speed introduces, in principle, low-level dynamic and frequency response errors. However, the quality changes which occur as a direct result of the speed change override errors introduced by the noise reduction system. Speed changing thus can be done without modification of the system. Nevertheless, a fact deserving mention is that all frequency dependent parameters in the system can be changed simply by replacement of one module per channel. Special modules are available for half-speed tape to disc transferring; module availability is also planned for 2, 4, 8, and 16 times full speed, primarily for application to the mass production of pre-recorded tapes.

While the noise reduction system was originally designed for use with high quality live signals, it is also of some usefulness when old normally recorded material must be revived and used as the program source. The old recording is operated upon as desired and then fed into the noise reduction system for re-recording. Played back through the system, the signal will not represent any improvement on the original material, but neither will it be any noisier. Thus, while the system cannot be used to reduce the noise on old normally recorded tapes, it can successfully minimize any further degradation of the material; the same principles also apply to the signals from discs and other sources. It may be mentioned that if a normal signal is fed into the playback noise reduction unit a significant reduction in noise can be achieved, but only with accompanying low-level dynamic errors and loss of high frequency response.

A further operational aspect which should be appreciated is that noises in unprotected portions of the audio chain will combine with the signal in the usual way. Without a noise reduction system, such noises, arising in mixers, compressors, reverberation devices, and so on, are normally swamped by tape noise; with noise reduction, it is often found that some effort must be expended on improving the performance of these other facilities.

Conclusion

With this new type of noise reduction system, a 10 dB reduction of tape noise can be obtained, a matter of particular significance in the creation of electronic music. The signal is generated and manipulated as desired in the usual way and then fed into a noise reduction processor unit before being recorded on tape. During playback, the signal is processed in a further noise reduction unit which has complementary characteristics. The signal is thereby restored to normal, but tape noise is reduced in the process.

Use of the system is simple, but certain rules should be observed. The recorder should be adjusted in a standardized way, and the signals should not be operated upon by the normal studio facilities when they are in the noise reduction processed condition. With these precautions, the system does not produce any overall alteration of the signal itself.

A considerable improvement in operational flexibility is gained by the resulting 10 dB increase in dynamic range. The system may be utilized as desired for reducing noise, obtaining lower distortion, or for increasing the number of tape generations which can acceptably be used.

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Symposium: Tape Recording

The Newell Tape Transport

adapted from a paper presented by C.W. Newell at the Audio Engineering Society Convention, Los Angeles, April 30, 1968, by

Eugene M. Zumchak

No one needs to dwell on the importance of a good tape recording system in the creation of electronic music. Tape is the medium, and it's unlikely that it will be replaced in the near future. Fortunately, then, we may be witnessing some dramatic breakthroughs in the area of tape transports.

Many of the limitations imposed on tape recording derive from the mechanics, rather than the electronics, of the system. Although numerous elegant refinements have been introduced in the head/tape system, the tape web handling system has remained virtually unchanged for 25 years.

In the conventional tape handling system, the tape performs two roles. First, it bears the magnetic coating and thus the electromagnetic signal information, and second, it serves as an energy coupling element in its own transportation. A system that eliminates the mechanical role of the tape (that of transmitting power) can be expected to yield significant improvements to the electromechanical recording system.

The tape transport developed by C.W. Newell of Newell Industries accomplishes just that (see Figs. 1 and 2). This tape drive eliminates the energy coupling role of the tape. All power is induced at the roll periphery, rather than at the tape web itself, and since the tape is entirely supported throughout, it is not allowed to absorb short-term energy which, of course, results in flutter. Since the drive behaves as three solidly interacting rollers, the tape filament behaves as a magnetically coated drum of several thousand feet circumference, rather than as an imprecise, unstable, energy coupling belt. A prototype tape deck is shown in Fig. 3.

In a conventional roll of tape, air is trapped between the layers as the tape is wound. This air, when subjected to radial forces, escapes, leaving inner layers in a zero tension, or a compressed condition. The result, of course, is an unstable, loosely packed roll. In the Newell transport, elimination of air through the "squeegee effect" of capstan-to-tape roll, coupled with a tension program, eliminates the problem. Rolls of tape thus transported are virtually solid discs of plastic. They can be wound without flanges. One can literally pound such a roll on the edge of a table without the tape separating. Yet, this solidity is not accomplished through unusual tension. Actually, the tension is only a few ounces. Tape elongation after hundreds of passes is typically less than one part in 10,000.

The advantages of a Newell transport are exciting. Tape winding is virtually independent of tape velocity. In fact, controlled velocities of several thousand ips have been accomplished in the labs of Newell Industries. In a high-performance instrumentation machine, perfect head/ tape contact has been maintained at speeds up to 1000 ips.

Because of the rapid acceleration/deceleration provided by the tape system, it is possible to cue a given sound event and get up to speed virtually instantaneously. The precise presentation of the tape to the head, coupled with rapid acceleration/deceleration capability, enable note-by-note editing in a manner not possible with a conventional tape handling system.

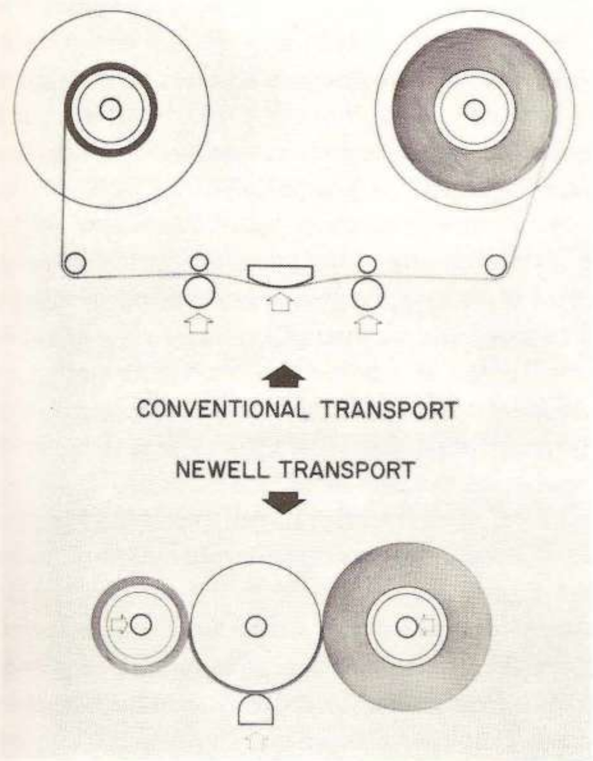

FIG. 1. CONVENTIONAL TRANSPORT COMPARED TO NEWELL TRANSPORT.

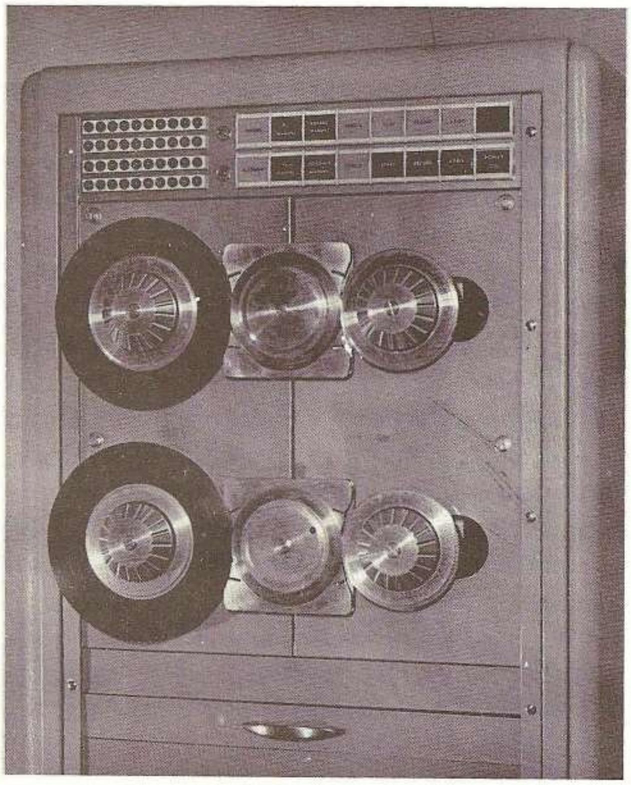

FIG. 2. NEWELL TRANSPORTS.

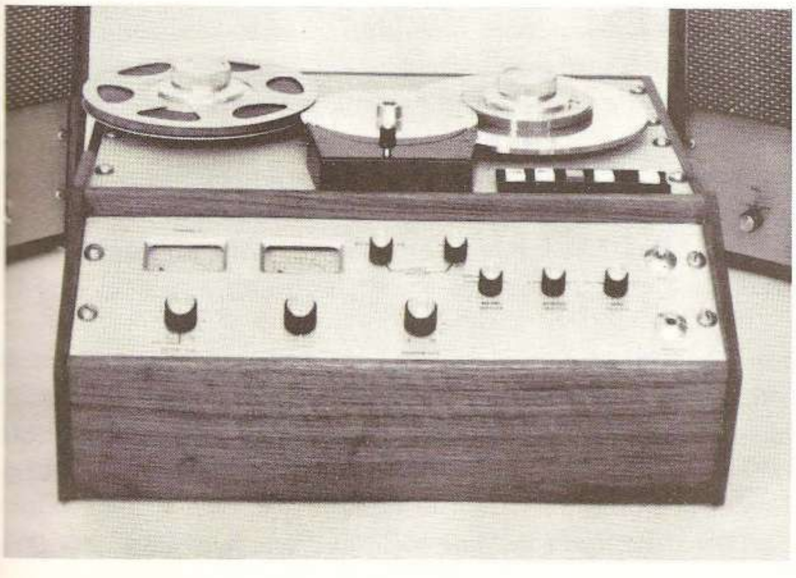

FIG 3.
PROTOTYPE TAPE DECK.

Electronic Music and Music Education

Wayne Barlow

The difficulties of attempting to place electronic music in a context of traditional music education are self-evident. The art is simply too new and still too experimental to have established any kind of tradition in its methods or any substantial body of literature that might serve as the basis for a systematic presentation of its esthetic or its structural principles. At the same time, there are a few short-term considerations and a great many more long-term ones that suggest themselves as we begin to consider electronic music in relation to the teaching of music in the various schools and departments. I think that, at the least, we can illuminate the problems even though specific recommendations for solving them may still be premature.

One of the concerns of composers of electronic music is that the development should be considered as a normal outgrowth of the general ferment of the times, rather than a kind of circus freak with no discernible connection with the world of music as we know it. It is only coincidental that electronic music makes use of a lot of complicated if not incomprehensible gadgetry that seems to have little relation to conventional music; in actuality, the science of electronics has only placed at the disposal of the composer a means of extending his expressive resources in directions which he had already begun to explore before the advent of magnetic tape.

Our first problem, then, if it <u>is</u> a problem, is to make it clear that electronic music shares some of the same features as a great deal of contemporary music, not all necessarily of the avant-garde, that is being written for conventional instrumental resources. Aside from the assorted squawks, whooshes, and general clatter that seem to mark electronic music, it is apparent that the rhythmic nature of this music is apt to be either very free or very complex, or else non-existent in any traditional sense. Yet the same freedoms and complexities exist in present-day instrumental music as well. Listen, for example, to the beginning of Stockhausen's <u>Zeitmasse</u>; the rhythmic scheme of this piece is such that the underlying periodic time-unit is nearly completely submerged.

As unsettling as the nearly total absence of a rhythmic pulse may be, the total absence in some music of anything resembling thematic content is even more bewildering to some listeners. This feature, however, is common to both electronic music and some recent instrumental music. It is quite apparent that in this music the composer's chief, if not only, concern is the nature of the sound itself, whether produced by electronic or more conventional means. It thus becomes possible, I think, to identify a kind of music which is basically <u>sound-oriented</u>, in contrast to that which is more conventionally <u>theme-oriented</u>. In the one the sound itself is the significant element, while in the other the sound is only a vehicle for projecting a thematic element, which itself is the dominant significant element.

For illustration of emphasis on pure sound in orchestral music, listen to Ligeti's <u>Atmospheres</u>; this work also shows the rhythmic freedom that was mentioned earlier. Another example of sound-oriented music, this one with chorus as well as orchestra, is Lutoslawski's <u>Three Poems</u>. In both of these works a certain kinship with the sounds and methods of electronic music is observable.

In relating electronic music to sound-oriented instrumental music I have tried to show that it is in no sense off the main trail — or at least one of the trails — of contemporary practice. It follows, therefore, that music education must somehow come to grips with the problem of defining this practice, because the problem is one that involves all contemporary music and not just the electronic variety. It is important, too, to recognize that the absence of rhythmic and thematic elements of the familiar sort does not denote a negation of these elements so much as a shift in focus to the sound-objects themselves.

Once the music educator recognizes electronic music as a respectable if somewhat eccentric member of the musical family, he is confronted with the problem of how to explain it to the uninitiated. And since electronic music is entirely a sound-oriented medium, it is obvious that the explanation must be rooted in a thorough understanding of the nature of sound itself. Music education has paid little attention to the physical nature of sound because, up to this point in time, we have been content to accept the timbres of conventional instruments as representing the totality of sound resources. Where the instrument was merely a vehicle for a thematic idea, there was no compulsion to delve into the complex properties of sound, and it seemed more important to develop digital dexterity than acoustic knowledge. With the shift in emphasis, however, sound suddenly becomes the dominant element in an increasingly large segment of music, and we find that we must greatly expand our knowledge of the physical aspects of sound before we can begin to develop a pedagogical method for studying sound-oriented music.

The first step in understanding the revolution in music comes with the realization that the role of the composer has changed significantly from a passive one as recipient of the instrumental resources of the past to an active one as a kind of alchemist with the power to create an infinite number of timbres through synthesis. Whether the new sounds come about through modification and processing of recorded sounds, or whether they are the result of electronic sound generating devices is immaterial; for the first time, literally any sound can in principle be produced.

There are a number of concepts that are important to an understanding of sound. A key concept is that of density. This is a spatial concept involving the notion that sound occupies a kind of space. Many composers work consciously with this property of sound, with minimum density being represented by the simple sine tone and the maximum by white noise, which stretches from the lowest to the highest limits of frequency that the ear can perceive. The range from minimum to maximum density is a continuum. There is a direct correlation between density, when used in this sense, and ambiguity of pitch: the more dense the sound, the more ambiguous is the sense of pitch.

One of the special attractions of electronic music for composers is the control it offers over the envelope of a sound. In brief, this means that the composer can control the attack and decay characteristics of sound in a continuum between the limits of a very long period of buildup or release and the instantaneous attack and release characteristic of percussive tones. The reversed envelope of a piano tone with the slow buildup followed by an abrupt release is a simple example of envelope control resulting in a type of sound somewhat rare in conventional instruments but only one of a great number of electronic possibilities.

There are some new concepts that arise in connection with electronic music that have no counterpart elsewhere. One of these is known as <u>modulation</u>, whereby a property of a sound can be controlled by another sound or sub-sonic signal. A sub-sonic control frequency will yield a vibrato- or tremolo-like result, although the deviation of the controlled sound may be made much greater than is possible through natural methods. However, if the control signal is in the audio frequency range, essentially a new class of sounds results.

The concept of mixing of sounds is not new; it forms the basis for ensemble music of all kinds. Applied to the wide variety of new sounds in electronic music, however, it is obviously an important resource for the electronic composer. Eight- or ten-channel mixers are not uncommon in electronic music studios, and at least one has twenty-channel mixing capability. It goes without saying, of course, that electronic methods permit the mixing of sounds in any proportion at the twist of a dial, resulting in a nearly infinite range of tonal possibilities.

Finally, any thorough-going study of sound demands that a start be made toward developing a method of classifying sound types. I am confident that the vocabulary exists for describing a number of basic classes of sound within which will be found the various sound objects that the electronic composer — or the composer using more conventional means, for that matter — may decide to exploit in a particular composition. Such systematizing and ordering of sounds is vital to work in electronic music.

Along with the study of properties of sound itself that must be carried on, it is just as important to begin to investigate some of the psychoacoustic questions raised by the development of electronic music. Milton Babbitt, among others, is concerned about the need for research in this area, and I am indebted to him for some of the specific suggestions for research activity listed below.

In the comfortable days before the tape recorder, music occupied a limited portion of the auditory perception area represented by the sensitivity of the ear to pitch and loudness. With electronic means we can penetrate to the limits of auditory discrimination in both dimensions, and we frankly do not know the limits of such penetration as we approach the extremes. As musical stimuli move outside the narrow limits of the past, some interesting phenomena take place, and all of these must be studied:

a) There are distortions due to extreme loudness.
b) There are interacting relationships between loudness and the sense of pitch.
c) The simple relationships between frequency and pitch sensation do not hold for the extreme high frequencies. For example, the ratio of 2:1 no longer sounds like an octave.
d) There is a non-linear relationship between perceived intensity and the bandwidth of noise — extensively used in electronic music. This leads to real difficulties of predicting loudness in tape mixtures involving noise.
e) The familiar equal-loudness contours of Fletcher-Munson assume radically different shapes when bands of noise are used instead of sine tones.
f) There is a real "coefficient of annoyance" for sounds above 4000 Hz, but we do not know the value.
g) There is a very complex relation between perceived pitch and pulse duration, but it has not been studied.

Here are some additional areas for research opened up by electronic music:

a) How does the ear perceive timbre? Can a theory be developed for inharmonic partials?
b) What are the discrimination capabilities of the ear in detecting minute differences in timbre? We are in total ignorance of this at present.
c) What is the relationship between our sense of elapsed time and the rate of change of events in a composition?

There are enough problems here to keep a graduate department busy for years!

As the body of electronic music compositions begins to assume respectable proportions, we can make a beginning, I think, in trying to deduce some structural principles. It is likely that some of the time-honored formal precepts concerning unity and coherence will be found to be still operating, but it is certain that the new emphasis on the sound object will give rise to a new structural syntax. I foresee the evolution of new principles of variation that operate in the sphere of pure sound. I foresee transitional devices for getting from one segment of a piece to the next, and new concepts of coherence that hold exclusively for sound-oriented music. In time, I think the new methods of coping with old problems of esthetics as they relate to the new music will be identified and codified and will find their way into courses in music theory and music literature. In the meantime, it is important for both composers and theorists to speculate on possible solutions to the obvious structural problems of electronic music and, above all, to publish their speculations so that the widest possible dissemination of knowledge can be had. The time is past when electronic music can ride along on novelty of sound alone.

This leads to another concern of mine which has to do with critical evaluation of the new music that we hear. Somewhere in the process of bestowing academic respectability on electronic music there must emerge a concern for ways of developing discrimination on the part of listeners. I am well aware, of course, that this is part of a much larger problem, but it ought not to be forgotten in connection with electronic music. Critical evaluation of the many compositions emanating from the studios is becoming increasingly urgent as these compositions multiply in number. Such evaluation should be made by the various composers in the field; by the listeners, who should recognize integrity and esthetic value when they exist, and not expect that every new work of electronic music will be a masterpiece; and by professional critics with a sense of responsibility toward a new art that needs all the enlightened and informed criticism it can muster. The kind of knowledge that leads to enlightened criticism must admittedly await a great deal of further study of sound-oriented music, but the education of competent critics should have a high priority.

It is evident that the longest of the long-term objectives in relation to electronic music is its eventual incorporation into basic theory programs. On the other hand, electronic music as a method of composition is already being taught rather widely, and I can say from personal knowledge that the composers under whose guidance the seminars are conducted are opening up to discussion many of the considerations that I have touched on in this paper.

If it is too early to be able to tell educators what to do about electronic music in their classes next week, the most important short-term objective is to make a beginning at trying to find answers to some of the questions and problems raised here. Many are actively involved with electronic music composition, and many others are interested in joining the quest for knowledge about this development. I am confident that through our combined efforts we can succeed in making electronic music academically respectable.

Review

A Bibliography of Electronic Music by Lowell M. Cross. University of Toronto Press, 1967. Hardcover, $5.00.

At last a commercially issued book devoted entirely to an electronic music bibliography. Not only does it supersede the relevant section in Serial Music: A Classified Bibliography of Writings on Twelve-Tone and Electronic Music compiled by Ann Phillips Basart (which contains references up to 1959, long out of date in terms of electronic music's twenty years of existence), but it also comes at a very appropriate time, when electronic music is rapidly expanding beyond purely specialist circles. (It should be added that a few mimeographed bibliographies on the subject have been circulated privately during the last four years, and are duly acknowledged in the preface.)

Mr. Cross states that his aim was to compile "as exhaustive a bibliography as possible". One is therefore somewhat surprised to find that he has come across only 1562 items (in fact slightly less, since some of these are only cross-references to co-authors). Closer analysis shows that he has done a very thorough job as far as the United States and Canada are concerned, less so for the rest of the world. Similarly the first five years of electronic music's existence (1948-53, a period in which Mr. Cross has specialized) are extremely well documented, but the scope becomes less complete the more up to date his researches go. Before examining this in greater detail, I should like to explain the reasons for both of these shortcomings. It is impossible to obtain a coverage that is even approaching completeness in such a project by remaining on one side of the Atlantic, however many contacts one has on the other side, and however au fait they are with the subject. Since Mr. Cross's bibliography was compiled as a graduate research project at the University of Toronto, one must assume that he did not have the opportunity or funds to visit Europe. Secondly, in compiling a bibliography that should be up to date on the day the manuscript is completed, the compiler does not have the best possible chance of discovering recent publications. A delay of some years would enable the compiler to rely partially on the work of other compilers living in different places and with access to different periodicals and other source material, references quoted in other articles, and so on.

If one evaluates Mr. Cross's bibliography in terms of his own stated aims, one must regard the word "exhaustive" as being less important than "as possible". The ideal bibliography would require much more time and work than Mr. Cross could probably have afforded to spend on it. Any comments and criticisms that follow are made in comparing it with an ideal bibliography, and also, being written by a European, come from the other side of the Atlantic and thus from sources of information quite different from and complementary to those at Mr. Cross's disposal.

The writings listed in this bibliography are in fourteen different languages. To these one could add articles in Hungarian, Romanian, Portuguese, and probably a couple of other European languages. However, the only Japanese text listed (presumably because it has an abstract in English) is by four technicians from the NHK studio in Tokyo (No. 1373 — numbers are assigned to each item in the book), and one looks in vain for several articles published in issues of Ongaku Geijutsu and — less difficult to discover, also with English translations — in the two volumes Masterpieces of Contemporary Japanese Music published by Ongaku no Tomo in 1959 and 1960, respectively. Similarly, Mr. Cross lists articles from the two leading Czechoslovakian music journals (he has omitted the accent on Hudební Rozhledy, while that on Slovenská Hudba has been written in by hand — the printing is offset, of excessively uneven quality — on each occurrence), but none of the three most important Czech publications are given: Elektronická Hudba by Vladimír Lébl (Státní Hudební Vydavatelství, 1966), and the two volumes Sborník Přednášek O Problémech Elektronické Hudby (Dilia, 1964), with contributions by five of the leading figures in Czechoslovakian electronic music. There are also several useful articles published in Rozhlasová a Televizní Technika (e.g., 1964 Nos. 3 and 4; 1965 Nos. 2, 3, and 4). Further, Mr. Cross has found three separate publications of a short note on Czech electronic music (two in German and one in Polish, Nos. 631-2), but not the English version (Musical Events, August 1964). A similar situation exists with Russian writings. In the index, under "Studios, USSR", one of the three references (No. 631, see above) does not in fact refer to the Soviet Union, but to Czechoslovakia (CSSR in German means Czechoslovakia and not the USSR — this also explains why Nos. 631 and 632 are listed as if they were different articles). Two texts about the ANS (a synthesizer using optical coding methods at the Skryabine Museum in Moscow) are listed (Nos. 28 and 919); only the latter is indexed, and rather inappropriately under "Electronic musical instruments". No references are given to more recent writings on the ANS, such as Yevgeny Murzin's "ANS — elektronnyi instrument dlya kompozitorov" (Soyuz Kompozitorov RSFSR, 1965). The remaining writings on electronic music in the Soviet Union are concerned mainly with electrical instruments and computer-composed instrumental music (Rudolf Zaripov, Nos. 1553-6) — neither of which really qualifies as electronic music — but omit Zaripov's most substantial (and more recent) publication on the subject, the book Kibernetica i muzyka (Moscow, 1963). No references are given to any of the writings of Gleb Anfilov (including the book Fisika i muzyka, Mir Publishers, Moscow, 1964; translated 1966 as Physics and Music, same publishers), nor to the relevant chapter in Fred K. Prieberg's book Musik in der Sowjetunion (Verlag Wissenschaft und Politik, Cologne, 1965); and the same author's article on which this chapter was based is listed in English translation (!) of the Swedish title used when it was published in Sweden ("Experimentell musik i Sovjet", Nutida Musik 1, 1963/64), while the original German text (Magnum, April 1963) is not listed.

The above mention of the English translation of the title of an article published in Nutida Musik confirms the impression that Mr. Cross has otherwise included no references to this excellent periodical, which is the most informative and internationally oriented of all European periodicals devoted to new music. Some two dozen articles on electronic music have been published in it during the last ten years. Further important Swedish texts have appeared in other magazines (Bengt Hambraeus in Ord och Bild, and Bo Nilsson in Musikrevy). Another important periodical — devoted equally to new music and new painting — is Collage, published in Palermo.

Major publications otherwise omitted:
— Pierre Barbaud. Initiation à la composition musicale automatique. Dunod, Paris, 1965.
— Pierre Boulez. Relevés d'apprenti. Editions du Seuil, Paris, 1966 (this contains No. 154 in the original French, Nos. 155-7, and one important article "Eventuellement...", first published in Revue musicale, April 1952).
— Ulrich Dibelius. Moderne Musik 1945-1965. R. Piper & Co. Verlag, Munich, 1966.
— Francisco Kröpfl. "Prólogo a la edición española"; preface to a translation of die Reihe 1 (which Mr. Cross never mentions as a special issue devoted entirely to electronic music). ¿Qué es la música electrónica?. Editorial Nueva Visión, Buenos Aires, 1959.
— Calvin Tomkins. The Bride and the Bachelors (including a revised version of No. 1393). Viking Press, New York, 1965.

All of the above-mentioned were published before Mr. Cross's deadline of November 1966, and he does include No. 1198, which was then only just off the presses (advance information?).

As it stands this bibliography has been compiled with meticulous care, and there are comparatively few spelling mistakes and wrong or missing accents: Wuorinen is wrongly spelled in No. 213 and in the index, but correct in No. 1531; No. 456 has "technic" for "technique"; No. 537 has Tawaststjerna wrongly spelled; No. 578 has "Hodier" for "Hodeir"; No. 682 omits the accent on Kučera and spells "hubda" for "hudba"; No. 1476 omits the accent on Bruynèl and the upper case for the title Reliëf 1964; No. 1559 misspells "Vnimanie" as "Vhimanie". Another two dozen small errors can be found, mainly with French and German words. The actual references are precise, although one would have welcomed an indication of the total number of pages in each text referred to (as in Mrs. Basart's bibliography; but then it is necessary actually to see each article, which was obviously quite impossible for Mr. Cross to have done). Indications are only given when the reference is to an abstract. This is sometimes very misleading, as with No. 1483: "Computermusik" by Fritz Winckel is indexed (reserved only for the "more significant items") under "Computers", but turns out to be a 140-word review (or rather an account of the contents) of Nos. 552 and 555 (which are published as a single volume under the title Informationstheorie und Computermusik, and actually comprise its entire contents, neither of which is apparent from the way in which they are listed).

A few final notes: No. 64 should read "...for the IBM 7090 electronic..."; No. 102 refers only to the Italian-language edition of Ricordiana for the date given; No. 401 is a score of an electronic music composition, and none of the other scores that are published have been listed (this particular score, Evangelisti's Incontri di fasce sonore is, ironically enough, the only one at present out of print!) — Mr. Cross has assumed that this title is the name of a periodical, and that the work's subtitle (Studio elettronico) is the title of an article in it; a similar confusion exists with No. 402, where the article "Verso una composizione elettronica" has been taken as referring to Evangelisti's composition Ordini (actually an instrumental work), while Ordini in this instance is the name of a periodical produced in Rome (and, following a distinguished tradition, it never reached a second issue); No. 816 "...see Strasser, Bruce E." (he is nowhere to be found! This is probably a reference to the introductory booklet included with a record Music from Mathematics produced by the Bell Telephone Laboratories); No. 1476 has been reprinted in English and German in Sonorum Speculum, Winter 1965; No. 1507 is a French translation of No. 1491.

In spite of all these observations, Mr. Cross's bibliography is a very useful investment for anyone involved in any aspect of electronic music, and can be regarded as definitive; unless someone is now working on a bibliography somewhere in Europe, it would seem to be too late for anyone to catch up with the torrent of publications that appears every month. It is a handy little book which I use frequently, and would not be without it.

— Hugh Davies

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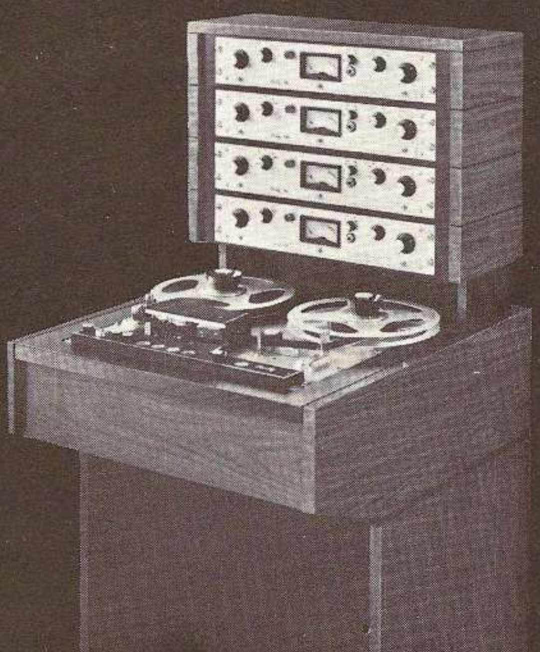

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