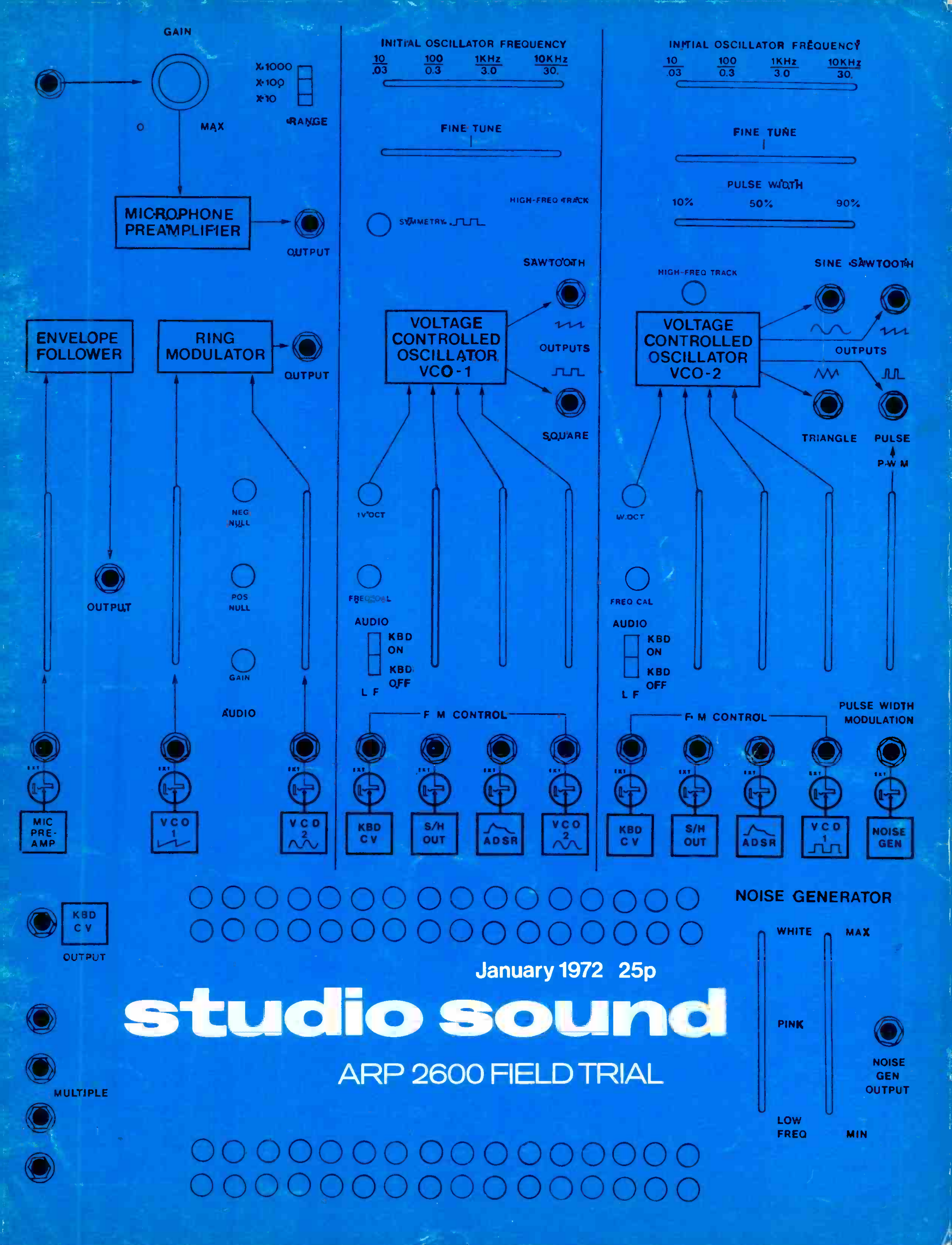

January 1972 25p

studio sound

ARP 2600 FIELD TRIAL

Consultant designed for Audio International

Like many other recently opened studios, Audio International have installed Neve to serve as an important part of the facilities this organisation offers. The console shown here was designed by Neve to provide 24 input channels, 16 output groups plus stereo output, 4 reverberation groups, 4 foldback groups, 4 monitor loudspeaker circuits and many other features included as standard in Neve equipment.

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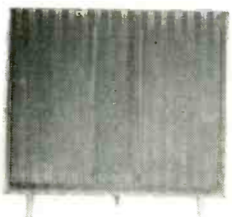
Rupert Neve Of Canada Ltd.
P.O. Box 182, Etobicoke, Ontario, Canada. Telephone: (416) 677 6611

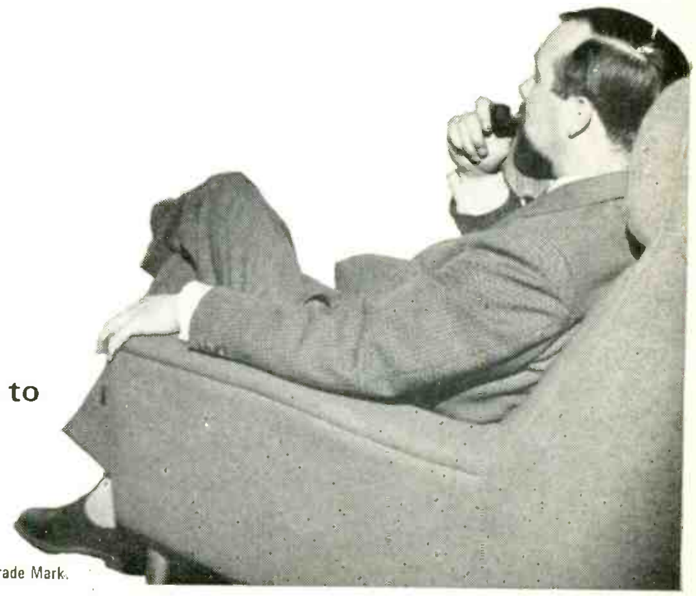
wireless

It has been suggested that a perfect amplifier would be equivalent to a piece of wire with gain.

A piece of wire ? First of all it would hum, so we'd have to screen it. This would increase the input capacity so we'd have to make the screening large or the conductor small. Then we would have output resistance and, if of appreciable length, we'd have inductance and termination problems as well. All in all a 303 power amplifier would be much easier.

The funny thing is; even if we had our perfect piece of wire with gain and compared it with a 303, the two would sound *exactly* the same no matter how carefully we listened.





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INCORPORATING TAPE RECORDER

JANUARY 1972 VOLUME 14 NUMBER 1

EDITOR DAVID KIRK **CONSULTING EDITOR** JOHN CRABBE

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ADVERTISEMENT MANAGER TONY NEWMAN

Editorial and Advertising Offices: LINK HOUSE, DINGWALL AVENUE, CROYDON CR9 2TA. Telephone: 01-686 2599

COMMERCIAL RADIO took a step towards reality on November 11 when the Minister of Posts and Telecommunications moved the second reading of the Sound Broadcasting Bill. The Bill proposes broadening the ITA into an Independent Broadcasting Authority responsible both for commercial television and local sound broadcasting. A maximum of 60 stations might be introduced; this figure could only be significantly increased by closing BBC local stations.

The first stations were being tentatively considered for London, Birmingham, Manchester and Glasgow. Transmission may commence in 1973.

Though carried by 289 votes to 257 (32 Government majority), the Bill received considerable criticism from both sides of the House. Mr Critchley (Con) feared that commercial radio would be a massive vulgarity, and disapproved of the curious status given to local newspapers. This referred to the clause that, while no newspaper had a prescriptive right to run a station, it would have the right to take up a share of the equity provided its circulation represented a substantial proportion of the local population. If the IBA considered the circulation too small, a newspaper might still represent to the authority that it was likely to suffer financially from the introduction of commercial radio. No distinction would necessarily be made between privately owned newspapers and the many connected to national newspaper chains.

Mr Mayhew (Lab) said the Bill entrusted to the IBA powers which the ITA had shown no qualification for exercising properly. From first to last it had handled its responsibilities with a lamentable weakness and with a lack of influence and power in relation to the programme companies. Was the ITA, in the light of its record with Thames Television and London Weekend, qualified to judge in the public interest which programme company was or was not capable of running these stations? His opposition to the Bill was fundamental. He was opposed to the whole conception of broadcast advertising. It had not proved itself. Commercials, especially those which interrupted programmes, were not liked by listeners. There was an extraordinary independent television broadcast recently of *Hamlet*. In one memorable sequence the Danish king, at prayers, said 'The words fly up, my thoughts remain below'. This was followed by a bottle of Danish lager being poured into a glass. By 1978, commercial broadcasting would be seen for what it was —a phoney, a form of environmental pollution.

Mr Gorst (Con), supporter of a commercial radio association, considered 60 stations to be inadequate. He regarded this as regional rather than local broadcasting and he too objected to the special rights that would be given to newspapers.

Mr Mackenzie (Lab) pointed out that, of the 400 companies registered in commercial radio, 30 were tied to a single commercial Organisation. This concern, he added, had contributed £25,000 to the Conservative cause at the last election. They had made an investment and perhaps now were waiting to get their dividend.

Strangely, Labour refused the Minister permission to reply to the debate.

Sound broadcasting was discussed on the same day by the General Synod of the Church of England. The Bishop of Oxford hoped careful study would be given to the best ecumenical use of local radio stations. The Archdeacon of Chester denied reports that the Church of England were considering setting up their own commercial radio station.

The effect of commercial radio on the sound recording industry is likely to be twofold. Advantageously both programme and advertisement preparation will create work for the smaller studios hardest hit by depressions in the record industry. Disadvantageously, if commercial radio runs true to form, the transistorised public will be subjected to still more pop. Whether the stale outpourings of Radio One *without* ads prove more attractive than a hopefully more imaginative Radio £ *with* remains to be ascertained. Either way, commercial radio seems likely to reduce public incentive actually to buy this kind of music.

FEATURE ARTICLES

REGULAR COLUMNS

EQUIPMENT REVIEWS

CORRESPONDENCE AND ARTICLES

All STUDIO SOUND *correspondence should be sent to the address printed on this page. Technical queries should be concise and must include a stamped addressed envelope. Matters relating to more than one department should occupy separate sheets of paper or delay will occur in replying.*

Articles or suggestions for features on all aspects of communications engineering and music will be received sympathetically.
Manuscripts should be typed or clearly handwritten and submitted with rough drawings when appropriate. We are happy to advise potential authors on matters of style. Payment is negotiated on acceptance.

SUBSCRIPTION RATES

Annual UK subscription rate for STUDIO SOUND *is £3 (overseas £3·80, $8 or equivalent.)*
Our associate publication Hi-Fi News *costs £3·12 (overseas £3·66, $8·64 or equivalent.) Six month home subscriptions are £1·50* (STUDIO SOUND) *and £1·56* (Hi-Fi News).

STUDIO SOUND *is published on the 14th of the preceding month unless that date falls on a Sunday, when it appears on the Saturday.*

PAST ISSUES

A small number of certain past issues may still be purchased from Link House, price 31p each including postage.

Photostat copies of any STUDIO SOUND article are available at 25p including postage.

BINDERS

Loose-leaf binders for annual volumes of STUDIO SOUND *are available from Modern Bookbinders, Chadwick Street, Blackburn, Lancashire. Please quote the volume number or date when ordering.*

News

AES lecture

JOHN KUEHN of Bruel & Kjaer Laboratories Ltd, probably the most well known and respected manufacturers of comprehensive audio measurement equipment, gave an informative lecture on recent developments in this field to the British Section of the Audio Engineering Society on October 12 at Imperial College. After outlining improvements made in equipment over the last 25 years (e.g. measuring microphone stability is now 0.3 dB per 100 years, whereas transistorisation has only just achieved the reliability actually experienced with thermionic valves) and various techniques evolved in order to speed up measurements, his lecture mainly centred around the recently developed B & K 'Real Time' analyser. This comprises a group of third octave filters, amplifiers and rms detectors, their outputs being electronically scanned at a high rate and displayed on a rectangular CRT, together with reference levels. The instrument (about £5,000) features a basic 50 dB coverage, with alternatives of a 10 dB or linear vertical display, and decay time constants of 200 ms, 20s or 'infinite', the latter being such as to 'freeze' any transient for leisurely analysis—for example, handclap characteristics may be studied without initial recording.

In addition to its basic application, the instrument could be used for rapid determination of reverberation time and for impulse analysis in combination with a reference spectrum and digital computer. Another application was the immediate observation of speed irregularities in tape recorders using pink noise recording.

During the discussion period many other special aspects of audio measurements were covered as well as the usual controversial topic of the precise meaning of such terms as 'average', 'rms', 'peak' and 'peak-rms', particularly with regard to complex musical waveforms. Although in general use, it was thought that the expression peak-rms would be better quoted as maximum-rms. Also raised were the difficulties of measuring the safe exposure to high level sounds of various types, such as industrial noises and the modern phenomena of 'beat/pop' music and its reproduction via loudspeakers.

AKG demonstrate spring reverberation unit

A STEREO REVERBERATION unit employing a spring system was demonstrated to the trade recently at Command Studios. The *BX20* offers a decay time from 2 to 4.5s with independent control of each channel and better than 60 dB channel separation (according to DIN 45405). A remarkable degree of insulation against external vibration is provided by a single-point pendulum mounting system. This is claimed to be capable of avoiding feedback even in the immediate vicinity of monitor loudspeakers (up to 100 dB spl). Price of the *BX20*, including remote control unit, is £975. Further details: AKG Equipment Ltd, Eardley House, 182-184 Campden Hill Road, London W8 7AS.

APRS 72

THE DATES OF their fifth annual exhibition of professional recording equipment have been announced by the Association of Professional Recording Studios. APRS 72 will be held at the Connaught Rooms, Great Queen Street, Kingsway, London WC2.

Ampex OB vehicle for Algerian Television

AN OUTSIDE BROADCAST vehicle suitable for use in desert regions has been supplied by Ampex to Radio Television Algerienne. Designed for video tape recording, the vehicle contains a *VR-2000B*, colour sync and test signal generation and colour monitoring. Space has been left for a further *VR-2000B*. A double air-conditioning system maintains a 22°C working temperature in an ambient environment up to 45°C. The custom-built aluminium body forms part of a 100 mm thick thermal insulation. Designed by Ampex and built at their Nivelles (Belgium) factory, the vehicle also includes a refrigerator, water cooler and extensive storage areas.

Sansui four channel

FOLLOWING ON the heels, if that is the right word, of CBS (whose SQ system demonstration was reported in the November issue), Sansui have introduced their own four channel disc. The event took place on September 23 at the Royal Garden Hotel, London. Those in attendance included several representatives of the CBS company and some interest was aroused among the remainder of the audience as to what their comments and questions would be when the demonstration was over.

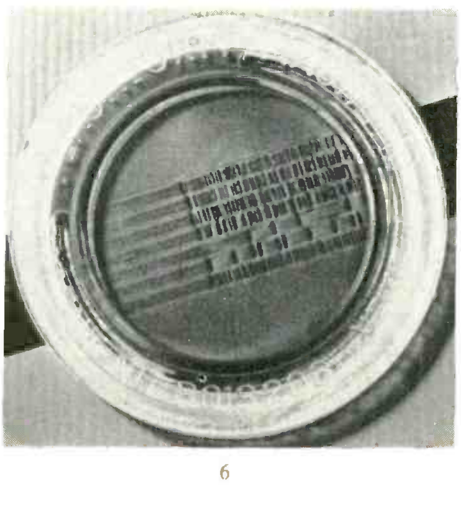
In the Sansui system, the two front signals are obtained in the normal fashion, and to them are added the two rear signals, shifted through 90°. The left rear signal is shifted through plus 90° and added to the left front signal, and the right rear signal is shifted through minus 90° and added to the right front signal. There is a blend resistor connected between the two rear channels before the phase shift occurs and one between the two front signals before the summing resistors. The two channels thus obtained form the two front signals if the record is being played on a two channel system, or they can be de-matrixed to produce, it is claimed, the original four channels.

Here it should be said that the listening conditions at the Royal Garden Hotel were much better than those in which the CBS demonstration was heard. Therefore it is no discredit to CBS to say that the Sansui demonstration seemed superior. The sound images in four, two, and single channel were far less confused and appeared to be a great deal more stable.

After the demonstration, members of the audience were given a four channel disc to test in their own surroundings. While stereo compatibility was reasonable, mono compatibility was not.

New Company to market Crown

IAN MARSHALL, founder and managing director of Carston Electronics Ltd, has resigned from the Carston Board and formed Macinnes Laboratories Ltd. The new company have been granted exclusive marketing rights for Crown International of Indiana, USA. Macinnes will honour all warranties on Crown equipment supplied by Carston and plan to appoint retail outlets for Crown amplifiers.



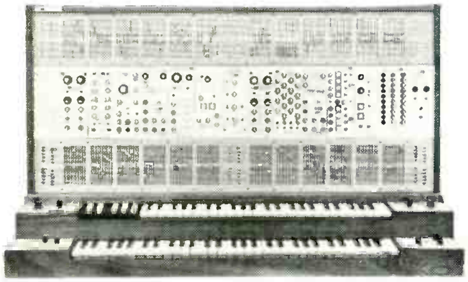
Magnetic viewer

A NEW VERSION of the 3M magnetic tape viewer is now being marketed from 3M House, Wigmore Street, London W1A 1ET, price £17.50. The unit measures 45 mm across and is here illustrated over a length of 12.5 mm computer tape. It comprises a circular plastic moulding containing iron oxide particles in liquid suspension.

Microphone survey

THE ADDRESS of F. W. O. Bauch, Ltd, Neumann microphone agents, was incorrectly stated in last month's microphone survey. This should have read: 49 Theobald Street, Boreham Wood, Herts. *(continued over)*

Synthesize to harmonize



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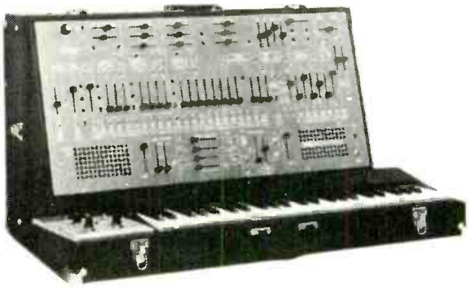

The ARP 2600 synthesizer is also available for hire

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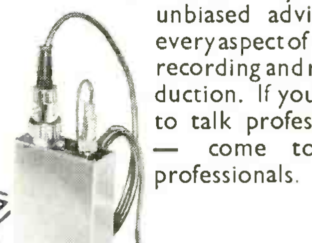

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Microphone Cable Stocks

FUTURE FILM Developments (38 Hereford Road, London W2 5AJ. Tel. 01-229 8054) are now stocking microphone cable with twisted twin conductors (14/0076) in red and black core colours covered with braided screen and a PVC sheath. The sheath is available in any of eight colours. The standard length of 100m costs £9.50.

Reel to Cassette Duplicator

AVCOM SYSTEMS Ltd have announced the production of a new reel-to-cassette duplicating system. The duplicator, manufactured by Telex of Minneapolis, will produce, with six slaves, 84 *C-30* cassettes per hour to NAB standard. The Model *235CS-1*, as it is called, has available three track configurations: ½ track single and dual channel, ¼ track dual channel and ¼ track four channel. A typical six-slave system will cost £1,295. The UK distributors are Avcom Systems Ltd, Newton Works, Stanlake Mews, Stanlake Villas, London W12 7HA.

Studio Class Plug-in Modules

APOLLO ELECTRONICS announce a new range of eight plug-in modules for use in sound recording installations. They are the *MA80* microphone amplifier, *PE16* presence equaliser, *CL36* compressor-limiter, *LA26* mixer-line output amplifier, *PA10* monitor amplifier, *TB90* talkback amplifier with built in dynamic microphone, *SG56* signal generator, and *MP62* magnetic pickup amplifier. All are mounted on a 190 x 45 mm front panel and utilise 16 way DIL plugs with gold-plated contacts at the rear. The microphone amplifier is a good example of what is offered. It is described as a general purpose input amplifier capable of raising the input level from -74 dBm to the standard 6 dBm line level. Gain is continuously variable from 0 dB to 80 dB by means of a switch operating in 10 dB steps in conjunction with a 'Fine' control. A switchable filter is provided for use with microphones, cutting out below 40, 80, and 120 Hz and having a 'flat' (20 Hz) position as well. Maximum input and output level is +19 dBm, input impedance (standard) is 600Ω unbalanced, but this can be altered between 50Ω and 50 kΩ on request, and for balanced inputs a variety of plug in transformers are available as extras.

All the units, apart from the monitor amplifier, require 24V dc power supplies. The monitor requires 32V ac.

PRECIS

Owing to minor technical difficulties, unhappily obvious to some overseas readers, the *Precis* column has been omitted from this issue. It will continue from next month.

Letters

Dolby B

Dear Sir, Shortly after reading John Shuttleworth's review in the September issue of STUDIO SOUND, I received my own Kellar *KDB1* noise-reduction unit and, after making a number of tests and measurements, I have come up with several points which may be of interest.

Input overload when in the replay mode has been eliminated, presumably by connecting the replay presets across the inputs. Also, unless I have been lucky in getting a better than average unit, the matching between channels has been improved, as the response measured in the A record/B replay configuration is easily within the claimed ±1 dB from 20 Hz to 15 kHz.

Distortion, measured under the same conditions, reaches 0.6 per cent at around 400 Hz, and seems curiously unaffected by changes in level. With the Dolby switch out the distortion drops to less than 0.3 per cent, still well above the claimed figure of 0.1 per cent.

The Dolby level tape supplied, incorrectly labelled 400 Hz (19 cm/s)—actually it is 400 Hz (9.5 cm/s)—is slightly under-recorded, measuring 5.6 dB below 320 pWb/mm, instead of the expected 4.8 dB difference between DIN and NAB levels.

Particularly when used with high-output tapes, the overload capacity of 10 dB above NAB level is inadequate, the unit clips at just over 4 dB above DIN level when set up with the tape supplied. I would suggest choosing a suitable 'Dolby' level for the brand of tape used, to give a margin of at least 6 dB above the peak recording level appropriate to that tape, bearing in mind that the generous reduction in noise allows the use of a rather lower peak recording level giving lower distortion, plus an increased safety margin to cope with unexpected peaks on live recordings. For example, I use Scotch *203*, working to a peak level of 320 pWb/mm, and I have chosen a Dolby level of 2 dB below this, giving 8 dB headroom. It is very helpful to mark the recorder's meters at the chosen level; this saves a lot of time setting up the record calibration.

In order to avoid errors in replay level, I strongly recommend recording a few seconds of the calibration tone at the beginning of all processed tapes, allowing accurate adjustment of the replay level, even where tapes are not all recorded to the same Dolby level.

Incidentally, the effect of an error in replay level is a step in the hf response at intermediate levels, –20 dB to –30 dB or so. For example, a replay level 2 dB low gives rise to a 1.5 dB loss above about 1 kHz. Also note that variations in the HF response of the recorder will be exaggerated when using the Dolby system, so that special care is needed to get as level a response as possible from the recorder, and to maintain this response by sticking to the same brand of tape as used for setting up the recorder.

Finally, unlike your reviewer, I feel that the *KDB1* is of great value at 19 cm/s where no limiters or compressors are in use, on music with a wide dynamic range, particularly when making copy masters, when hiss tends to build up somewhat.

Yours faithfully, D. M. Wright, 36 St Andrews Road, Henley-on-Thames, Oxon.

Keith Monks Review

Dear Sir, May I congratulate STUDIO SOUND and Mr John Shuttleworth for the excellent review of our microphone floor stands in the December issue.

I have read with interest how Mr Shuttleworth has become involved in defending himself after he has written a review. A manufacturer who sends his equipment for an independent review must expect criticism and, if the readers see it is not a whitewash, they will take far more notice in future. Carry on Mr Shuttleworth with factual criticism of equipment but go easy next time I send something!

May I make some comments on the various models, not in disagreement with Mr Shuttleworth, but thanking him for the facts presented. As a result I am arranging for all future models to incorporate most of his suggestions.

MS/M microphone floor stand: the screw-in legs, as a result of the comments, now have a guide for the threads. The extension tube now has a stopper to prevent the tube falling out from the bottom of the stand.

BA/M boom arm: this model has been removed from our range and is replaced by the *BA/M2*. It is the same length with the two threads and interchangeable counterweight but has the same locking device as the *BA/L*.

MS/PA toggle floor stand: the legs like the *MS/M* which screw in have now a lead-in thread.

It is my intention to increase the range when the demand occurs.

Yours faithfully, T. K. Monks, Director, Keith Monks (Audio) Ltd, 5 Fleet Road, Fleet, Nr Aldershot, Hampshire.

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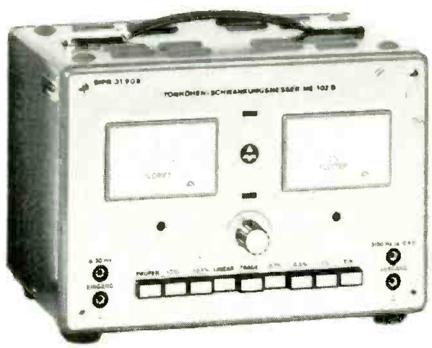

Illustrated is the ME 102B, one of the three types of Wow and Flutter Meters distributed by us exclusively in the U.K. It is widely used by all the leading Broadcasting. TV and Recording Studios, manufacturers of tapedeck-tape recorders, turntables, record-changers—in fact by anyone concerned with the accurate measurement of drift and wow and flutter. Fuller details on application.

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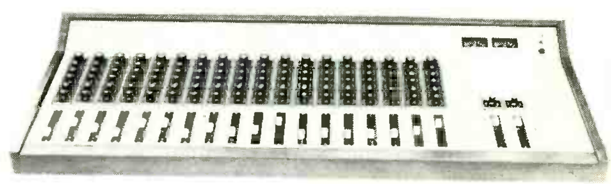
Seasonal Greetings from Alice



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The Forty-First AES Convention

P. A. LOMAS
REPORTS FROM NEW YORK

THE October convention took place as last year in the somewhat seedy New Yorker hotel, New York, on October 4 through 8. As usual, the organising officials—John Eargle (Convention Chairman), Jacqueline Harvey (Exhibits) and Dorothy Spronck (Administration)—ensured a smooth enjoyable week. The papers were imaginatively chosen, drawing large interested audiences. The exhibition, while showing no new ideas, provided the usual fun of the fair. The East Coast convention is always better attended than the West, and there were many overseas visitors to swell the ranks. From England, I saw Percy Wilson (who needs no introduction) and John Moseley (Command Studios); and from Holland Mr J. L. Ooms (Philips). Other notable visitors included many from Japan. One of the most important functions of any exhibition and conference is to allow you to meet colleagues, friends, and new faces in your occupation—of the most fruitful talks occur after hours.

Some 80 papers were read, covering a wide variety of subjects. It is impossible to list them all, so here are some of the highlights. The magnetic recording and reproducing sessions on Tuesday afternoon were devoted partly to cassette technology with one paper on the Sony dual-capstan machine (Masahiko Morizono and Kenkichi Umeda), two on setting optimum duplicating levels (James Wood, GRT, and Tom Montgomery, Olive). and one on chromium dioxide tape (J. Dickens, DuPont). Tuesday evening's session on digital techniques, jointly sponsored by the IEEE, proved a fascinating introduction to the new technology to which we will all have to acclimatize. After an introductory paper by Barry Blesser (MIT) to set the scene, we listened to papers by Tom Stockham on the design of a/d and d/a converters which included demonstrations of some of the problems which can occur, and on the use of such techniques to restore old 78 rpm discs.

One session was devoted entirely to medical electronics, showing how the two branches of science can help each other. Seven papers were read here, and in the evening there was a 'workshop' session about stethoscopes.

The highlight of Wednesday was a day-long workshop on studio tape recorders, starting with discussions on the how and why of recording and followed in the afternoon by practical sessions on the major equipment manufacturer's products. These covered design philosophy, specifications and alignment. The evening session took the form of a question-and-answer discussion primarily on maintenance.

Four channel reproduction is still the centre of interest, not to say controversy. Ben Bauer (CBS), fresh from his world tour, demonstrated and talked about SQ on Thursday morning, and Duane Cooper (University of Illinois), Peter Schieber (Audiodata Co) and R. Itch (Sansui) all gave their versions of the ideal matrix scheme in the afternoon. The same session included a paper on the JVC system using discrete carriers, linked with the Dorren Quadracast four channel fm scheme. David Robinson (Dolby Labs) talked about and demonstrated the B noise system applied to fm broadcasts.

Electronics took over on the last day. In the amplifier section during the morning, Bob Moog described various programmable attenuators. Barry Blesser talked about his new modular compressor for EMT, and Jim Wood showed how to make a simple stereo programme phase checker. The afternoon was devoted to electronic music; both synthesisers and organs were covered. This was capped in the evening by an electronic music concert, which had every seat taken. Noisy but fascinating.

While these discussions were going on in the conference rooms, the manufacturers outside were getting down to the hard work of displaying, talking, selling and entertaining. Vast quantities of paper were distributed (one stand admitted to giving out nearly 900 sets of literature), and usually ended up in the Martin Audio bag. Altogether 66 companies took part, either in rooms or stands in the four connecting halls. There was a healthy increase in the number of European displays.

Rupert Neve, at their first NY show, exhibited a console connected to an Ampex *MM1000*, 16 Dolby units, and earphones for all. Each track of the 50 mm tape was identified with a picture of the microphone placement used in the recording session, so that everybody could try their hand at being a remix engineer. Derek Tilsley and Geoffrey Watts presided. The theme on the Dolby stand across the way was noise reduction for all—from studio to home, via A and B. Photomurals showed how this was done, all the more interesting in view of the arrival of two competing systems from Burwen Labs and DBX. Neither of these was demonstrated well, particularly the DBX, so judgement will have to be postponed for studio tests, but each seemed to suffer from the expected classical defects of companders. Other European manufacturers used their US affiliate companies to display their products but often sent men from home to attend. Philips (Philips Broadcast Equipment Corporation) had a wide range of audio gear, including the new mixing desk and eight track tape recorder introduced at Montreux. The recorder is surely a marketing error—who buys eight track these days?

Ferrograph were on the Elpa stand, and Penny & Giles on the Harvey Radio stand; AKG (talking about the *BX20E* reverberation unit), Sennheiser, Agfa, BASF and Nagra (first US showing of the stereo machine) were all represented.

The main surprises from US manufacturers came from the tape recorder men. Ampex introduced their *MM1100* for comments, with production about seven months away. This is a scaled down machine comparable in size with the existing 3M machine; meters and electronics (modules from the *MM1000/AG440* system) are mounted in front and below the deck plate. With electronic back tension, simple logic and a counter as original equipment, it will sell around $20,000. The *MM1000* at $25,000 will now contain the servo capstan as standard. Following the success of the video synchroniser, the Audiotec is a new unit enabling optical film projectors to be connected. The significance of these two techniques has not yet fully dawned on the industry; I think they promise to revolutionise both television and film audio.

The 3M surprise was another new machine, using the existing transport with the addition of a dc motor (thus allowing for their sync unit). All electronics are on a single card below for each channel; also included as a built in feature are Dolby A noise reduction modules. Again this machine was unveiled early for comments (which I hear were enthusiastic) and it will not be in production for another nine months. Meanwhile 3M sales are assured by a thumping 25 per cent reduction in the price of the normal 16 track machine—which must have produced howls from yesterday's customers.

Scully continued to show their simplified 16 track machine, *Model 100*, which is apparently selling very well. Crown introduced another blockbuster amplifier in the shape of a dual channel 600W unit, type *M600*. Duplication equipment was lacking this year, with only Electrosound showing a high speed mass duplicator. Gauss appear to have dropped out following their amalgamation with MCA. Extrovert Howard Holtzer demonstrated his new cutter system and read a paper on its design. Allison Research had to leave a tree behind after union complaints; they did however show a new $50 multiplier building block which could form the basis of a compressor limiter system, with well defined input output control characteristics; Kepex and Gain Brain

(continued on page 13)

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continued

were there too. Unfortunately they also had to leave the orange drink machine behind but this was replaced by an enterprising coffee salesman a few booths away.

Mixers continue to expand in size and complexity. Olive Electrodynamics of Montreal showed a new desk of excellent construction. This company also pioneered the automated remix system where the fader settings made during a remix session are digitally recorded on an unused track; on final replay the situation is exactly repeated, together with any updating information which may have been entered. The technique is in such demand that desks by Automated Processes will shortly have this feature.

Delay lines are the first digital products to become available and, following the introduction of the Gotham *Delta-T101* last March, new units are available from Melchor, Eventide Clock Works and Knowles Electronics. All of these showed the ease with which delay could be controlled, as well as the peculiar noise characteristics (quantizing noise) to which they are prone. The problem is only financial, not fundamental! Gotham Audio, as well as showing the Neumann range, introduced the Studer *A-80-16* into the USA and have already sold three.

Upstairs on the seventh floor were the demonstration rooms. Burwen and DBX had their noise reduction systems; Sansui, Columbia and JVC demonstrated four-channel sound systems—JVC used a laser to produce an oscilloscope type display showing separation and uniqueness of each signal. Vega demonstrated the volume available from their loudspeakers; ARP were using electronic synthesisers and related equipment; Melchor displayed delay lines and mixer modules; and finally Acoustic Research played music to show off their new *LST* studio monitor loudspeaker.

No description of the AES Convention would be complete without a mention of that major social event, the Banquet. The food was fairly good, though not excellent, but we were fortunate in being well entertained. The outgoing president, George Bartlett (NAB) introduced Dr Woodward (RCA) as the new president, following with the other new officers. Ben Bauer then presented the awards, which were international. The Gold Medal (ex Potts Award) was awarded to Leo Beranek for 'contributions to the design of speech communications, electroacoustic instrumentation, loudspeakers, and acoustical spaces for broadcasting, conventions, and musical performances. The Silver Medal (ex Berliner Award) was given to Dr Ray Dolby for 'the invention, development, and introduction of practical noise reduction systems for professional and consumer use'. For this work he was also given the unusual and distinctive honour of being elected at the same time to a Fellow Award. Rorback Madsen (Bang & Olufsen), Erik Porterfield (CBS) and Peter Tappan (Bolt, Beranek and Newman) were also recipients of Fellow Awards. Donald Powers (Roanwell Corp) was given a citation for his work in establishing and coordinating AES section activities in the USA and abroad.

We hope that Ben Bauer started a tradition of bringing to the platform the wives of the awards winners—not as a surrender to Woman's Lib but to acknowledge the work that they have put in to help.

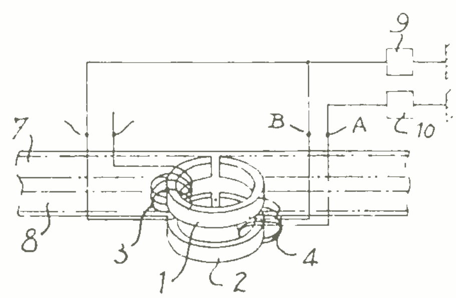
After the awards, we listened to a speech by the composer / conductor Morton Gould who tried to get across a serious message amid his many stories and asides. The next day was the final day and by evening most of the stands were out of the hotel. The 41st Convention was over.

Postscript. After my report on the 40th Convention, I promised to obtain the name of the author of a paper on brain control of synthesisers for a reader at the University of Surrey, Guildford. This I have done, but have unfortunately lost trace of the reader. If he will contact Studio Sound, I can pass on the information to him.

Patents Review

STARR SA of Belgium have patented a method of eliminating crosstalk between adjacent magnetic tape replay heads (BP 1,246,651). A compensating voltage equal and opposite to that produced by the stray flux is induced in the replay segments. This is obtained by connecting one side of both replay coils to earth via a common resistor. The other side of the coil producing the crosstalk is taken to earth via a load resistor adjusted to suit the magnitude of the compensation required. The remaining terminal, that on the head being replayed, is taken to the replay preamplifier. The circuit is shown in **fig. 1**. The arrangement is reciprocal in that another load resistor connected from the output terminal to earth will have the same effect if the output is taken from the non-earth side of the first load impedance (from A).

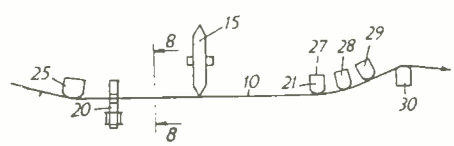
FIG. 1



British Patent 1,246,419 is concerned with the problem of monitoring video tape recordings and has been prepared for the BBC by R. R. Atkinson. The absence of simultaneous video replay facilities often necessitates the use of a second recorder in parallel with the master machine, an inconvenient and expensive procedure. An obvious solution would be a second video head wheel farther down the tape though this would be costly and impractical.

The BBC propose a simple modification to existing vtrs, capable of indicating a fall in tape modulation resulting from clogging on one or more video heads. Two fixed heads would be added to the recorder, positioned to scan the cue track before and after the headwheel (**fig. 2**). A 'monitor record' head (20) applies a signal which is in due course modulated by successive sweeps from the headwheel (15). A 'monitor pickup' head detects these modulations and converts them into an oscillogram, the timebase being synchronised with the headwheel motor (16). The height of the four displayed waveforms then corresponds to the relative output level from the four headwheel segments. Alternatively, the pickup signal may be fed to an alarm circuit.

FIG. 2



AKG's BP 1,246,253 is titled 'A plastics diaphragm for an electro-acoustic transducer'. While superior to paper diaphragms in terms of strength and sensitivity to climactic agents, plastics suffer from low internal damping. To overcome this, AKG have developed a light plastics diaphragm coated 'on at least one surface' with a fibre fleece. They prefer a fleece of natural origin, either from raw cotton or raw animal wool. This can be applied to the diaphragm in various ways, the simplest being to give the fleece a thin layer of adhesive and solidify it under heat and pressure.

Ira Leonard Eisner, citizen of Stamford,

(*continued on page 15*)

continued

FIG. 3

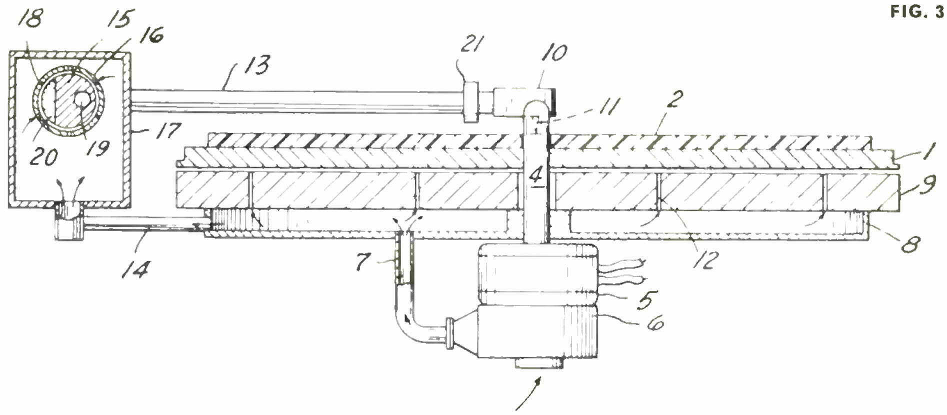
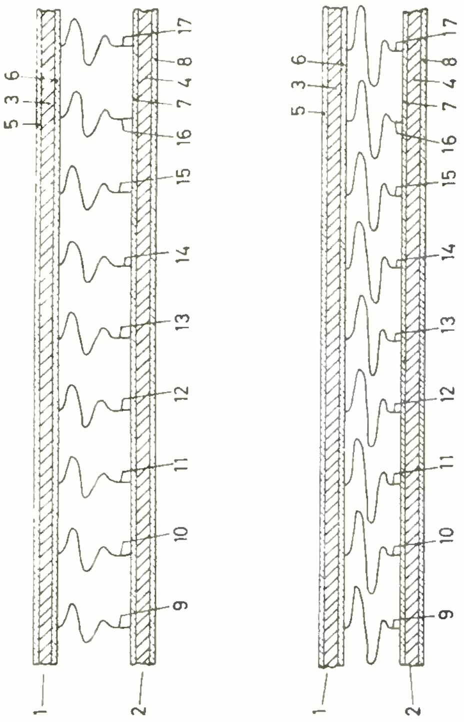


FIG. 4 (a) (b)



Connecticut, describes a 'Radial phonographic pickup arm and turntable combination using gas bearings'. The turntable may be driven in conventional manner but rides on a gas bearing powered by a compressed air source. A counterbalanced rod carries the reproducing cartridge, and slides freely on compressed air. Gas-loss is avoided since the offset rod carrying the stylus is longer than the housing through which the gas enters. **Fig. 3** shows the system and the manner in which a single compressed air source can lubricate both the turntable and pickup arm. The cartridge (10) tracks on an exact radius of the disc (BP 1,248,133).

Fig. 4 is reproduced from BP 1,250,397 dealing with 'Improvements in or relating to sound damping material and the manufacture thereof.' D. Stempel A.G. begin by noting the limitations of conventional sound damping materials—consisting of sheets or plates connected to each other by spaced intermediate webs. Attempts to improve the sound damping of such material by filling the spaces between the webs with, for example, sand or glass wool, introduce cost and weight problems and in many cases produce no substantial improvement. Drawing a shows a cross-sectional view of a typical damping panel using the Stempel proposal. Sheets 1 and 2 are of a composite plasterboard, cardboard (5 and 6) lining the inner plaster (3). The two inner surfaces are glued to a cellular structure formed from cardboard webs. The webs are compressed into folds—to such an extent in version **b** that the folds interlock. The plasterboard sheets are each 12.5 mm thick, connected by a web structure 80 mm thick in its uncompressed state.

THE FOLLOWING list of Complete Specifications Accepted is quoted from the October issues of the Official Journal (Patents). Copies of specifications may be purchased at 25p each from The Patent Office, Orpington, Kent BR5 3RD.

October 6

1,253,453
RCA Corporation
Display screens particularly for use in dark trace cathode ray tubes

1,253,458
General Motors Ltd
Electronic tachometer

1,253,460
Matsushita Electric Industrial Co Ltd
Telephone leaveword device

1,253,462
Sony Corporation
Electron gun

1,253,465
Varian Associates
Microwave electron tube apparatus embodying slow wave circuits

1,253,470
Kombinat Robotron VEB
Electronic control for electromagnetic actuating devices

1,253,485
Kyorin Seiyaku K.K.
Process and apparatus for the coating of particles or powders

1,253,498
International Standard Electric Corporation
Electronic supervision circuit for telecommunications systems

1,253,550
Matsushita Electric Industrial Co Ltd
Electronic language teaching system

1,253,551
Thomson CSF
Pulse-modulated doppler-type electromagnetic detection system

1,253,577
Boucher & Co Ltd
Tray or duct members for supporting service cables and the like

1,253,599
Telefunken Patentverwertungs
Pot-core coil for communication engineering with a plurality of symmetrical windings, in particular a loading coil

1,253,605
Poly-optics Inc
Method for making optical fibres

1,253,634
International Standard Electric Corporation
Tape recorders

1,253,638
Philips Electronic & Associated Industries Ltd
Circuit arrangement for a pulse-controlled connection of a telecommunication signal source to a telecommunication signal load

1,253,641
Philips Electronic & Associated Industries Ltd
Multiple-contact connector socket

1,253,642
British Relay Ltd
Systems for distributing television programmes by cable

1,253,652
National Research Development Corporation
Magnetic Lenses

1,253,653
Words on Wheels Ltd
Language laboratories

1,253,654
Plessey & Co Ltd
Data responsive systems

1,253,670
Westinghouse Electric Corporation
Pulse width modulated amplifier

1,253,674
General Dynamics Corporation
Processing of digital or digitized analog information for high density data transmission or recording

1,253,698
International Rectifier Corporation
Direct-current power supplies

1,253,719
Marconi Co Ltd
Multiplex signal transmission systems with pulse code modulation

1,253,725
Standard Telephones & Cables Ltd
Lead wire locating device

1,253,768
Merlin Gerin
Linear induction motor producing travelling magnetic fields of opposite directions

1,253,777
Considlio Nazionale Delle Ricerche
Reversible cell having RbAg4I5 as electrolyte and a silver anode.

1,253,793
Tokai Rika Denki Deisakusho
Miniature electric synchronous motor

1,253,797
Robert Bosch
Eddy current brake

1,253,820
General Electric Co
Fabrication of field effect transistors

1,253,823
Westinghouse Brake English Electric Semiconductors Ltd
Multi-terminal semiconductor devices

1,253,829
Bradley Ltd
Amplitude modulators

1,253,882
Telefonaktiebolaget L M Ericsson
Synchronisation e.g. of a pcm receiver and a transmitter

1,253,929
Collins Radio Co
Frequency synthesiser

1,253,939
Siemens AG
Transistor amplifiers

1,253,978
Micro Consultants Ltd
Analogue signal processing system

(continued over)

1,254,014
Kockums Mekaniska Verkstads AB
Diaphragm valve sound transmitters operating on gaseous pressure medium
1,254,020
Western Electric Co Inc
Waveform generation apparatus
1,254,034
Carasso, A
Sealing device for a terminal for a multi-conductor cable cooled by a circulating fluid
1,254,037
Euphonics Corporation
Ultrasonic transducer employing suspended piezo electric plate
1,254,043
Bogen W
Multi-track erasing head
1,254,086
Licentia Patent Verwaltungs
Monolithic piezoelectric resonator or filter arrangements
1,254,115
Signalling Electronics (PTY) Ltd
Potential level detecting apparatus provided with a surge arresting circuit
1,254,161
International Standard Electric Corporation
Time bandwidth reduction system for facsimile transmission
1,254,163
Nippon Electric Co Ltd
Solid state visual display devices
1,254,206
Commissariat A L'Energie Atomique
Electro-optical phase displacement cell
1,254,236
Square D Co
Stationary electrical contact assembly with permanent magnet blowouts
1,254,295
Fernseh GmbH
Recording apparatus
1,254,328
Holotron Corporation
Ultrasonic beam combiner in holography

October 13

1,254,366
Meidensha K. K.
Inverter circuit
1,254,371
Warwick Electronics Inc
Electrical musical instrument
1,254,384
Standard Telephones & Cables Ltd
Printed circuit boards
1,254,386
International Standard Electric Corporation
Printed circuit board connector
1,254,388
Nippon Electric Ltd
Manganese-zinc ferrite materials
1,254,499
Texaco Development Corporation
Method and apparatus for analysing system-generated noise signals
1,254,503
Blaupunkt Werke GmbH
Transistorised wide band amplification stages
1,254,508
RCA Corporation
Edge connector
1,254,511
Matsushita Electric Industrial Co
Ferromagnetic materials
1,254,564
Sony Corporation
Recording and reproducing system for colour video signals
1,254,588
Sony Corporation
Endless tape cartridge
1,254,608
Standard Telephones & Cables Ltd
Multiunit loudspeaker
1,254,709
Meazzi Srl Caldironi F. and Olivieri A.
Drum set with electronic amplification means
1,254,753
Politechnika Warszawska
Device for stereovision X-raying
1,254,834
Landis & Gyr AG
Electric circuit arrangements for multiplying two values
1,254,845
Plessey Co Ltd
Pressure-responsive signal-generating devices
1,254,875
Marconi Co Ltd
Methods of and apparatus for producing an optically readable pattern corresponding to a magnetically recorded pattern
1,254,900
North American Rockwell Corporation
Ratioless memory circuit using conditionally switched capacitor
1,254,916
Vsesojuzny Nauchnoissledovatelsky Institut Kriogennogo Mashionostroenia
Demodulator for detecting the envelope of a single-polarity pulsating voltage
1,254,921/2
Mattel Inc
Multiple sequence sound reproducer
1,254,973
GTE Laboratories Inc
Television synchronising system
1,255,040
Danfoss A/S
Speed and voltage controls for ac motors
1,255,059
Sony Corporation
Colour image pickup device
1,255,109
ITT Industries Inc
Electrical filter assembly
1,255,131
Landis & GYR AG
Electromagnetically-operated changeover switching devices

October 20

1,255,188
Obukkov, V A and Glazkov, V P
Rotor of a synchronous non-salient-pole machine
1,255,196
International Standard Electric Corporation
Digital phase meter.
1,255,210
Littwin A. K.
Magnetising and demagnetising apparatus and method
1,255,224
Sanders Associates Inc
Recording CRT light gun and method
1,255,239
North Electric Co
Ferroresonant voltage regulator devices
1,255,246
Burndy Corporation
Flat shielded cables
1,255,261
Soc D'Etudes Recherches et constructions electroniques
Analogue-digital converters
1,255,264
Eriez MFG Co.
Magnetic rolls
1,255,287
AKG Akustische U. Kino-Gerate GmbH
Headset with a microphone adjustably mounted on an earpiece
1,255,292
Marconi Co Ltd
Piezoelectric transducers
1,255,313
Baldwin Co D. H.
Compact piano construction
1,255,319
Amp Inc
Apparatus for and method of connecting electrical terminals to wires
1,255,373/4
Siemens AG
Methods of manufacturing components employing a high-energy beam of electromagnetic radiation
1,255,381
International Business Machines Corporation
Mounting for a read/write head
1,255,382
Westinghouse Electric Corporation
Power peak limiting control for direct current drives
1,255,449
Compagnie Generale D' automatisme
Character-reading apparatus incorporating electronic scanning circuitry
1,255,528
Northrop Corporation
Pseudo voltage controlled oscillator
1,255,542
Bendix Corporation
Pulse generating oscillator circuit
1,255,579
Ampex Corporation
Control circuit for a bidirectional recorder
1,255,593
Motorola Inc
Modulation processing system for a phase or frequency modulated transmitter
1,255,727
RCA Corporation
Tape lifter
1,255,815
Regus AG
Electrical inverters
1,255,834
Standard Telephones & Cables Ltd
Speech recognition apparatus
1,255,862
ESB Inc
Intercell connectors for electric storage batteries
1,255,883
Philips Electronic Associated Industries Ltd
Ultrasonic wave frequency-selection devices

October 27

1,256,009
Lanier Electronic Laboratory Inc
Tape device for tape recording and reproducing machines
1,256,137
Nippon Electic Co Ltd
Multiplexing apparatus
1,256,141
Ricoh KK
Magnetic recorders
1,256,145
Hell, Dr Ing Rudolf
Method for producing a rastered recording of a video signal obtained by photoelectrically scanning a continuous tone picture
1,256,146
Philips Electronic and Associated Industries Ltd
Cassette holder
1,256,147
Mallory and Co Inc
Solderable stainless steel
1,256,176
De Jur-Amsco Corporation
Intermittent film transport means for a motion picture projector
1,256,188
Philips Electronic and Associated Industries Ltd
Generator for producing ultrasonic oscillations
1,256,205
Ampex Corporation
Making of lithium ferrites
1,256,350
Pedrick, A. P.
Television using colours produced by light ray scan of prismatic surfaces on screens of glass or other suitable materials.
1,256,363
Rockwool AB
Sound Insulating composite floor structure
1,256,381
Ditta Incis Dei Frantelli Seregni
Tape recorder track changing mechanisms
1,256,399
Sony Corporation
Convergence means for a colour cathode ray picture tube
1,256,405
International Business Machines Corporation
Adaptive delay line equaliser
1,256,408
Magnetic Analysis Corporation
Quadrature pulse generator
1,256,499
Diamond H. Controls Ltd
Alternating current supplies
1,256,526
RCA Corporation
Multilayer circuit board techniques
1,256,527
Remix Radiotechnikai Vallalt
Method of and arrangement for manufacturing single-wire or multi-wire windings
1,256,541
Matsushita Electric Industrial Co Ltd
Electron gun for a cathode ray tube
1,256,565
Kelsey-Hayes Co
Electrical rotational speed sensor
1,256,577
Thomas & Betts Corporation
Electrical plug connector
1,256,602
Danfoss A/S
Control signal generator for striking the controlled rectifiers of a three-phase inverter
1,256,640
Standard Telephones and Cables Ltd
Transmission line
1,256,645/6/7
ESB Incorporated
Electric batteries

Designing a Studio Mixer

Part Six by Peter Levesley *

IF we refer for a moment to fig 1 of the first article, July 1971, we can take our bearings again. Up to now, we have reviewed the whole system from output back to input and then discussed in detail the function of the various parts, arriving at the end of the Equaliser Section last month. It would be advisable to read again the paragraphs in Part One on page 349 headed Distribution Wiring. There is not really a lot more that can be said in a theoretical sense about this, the principal interest centring now on the practical realisation of the theoretical ideas. It will be easier to see the practical points raised if we go forward a little way and talk about mixing and mixing amplifiers right away.

The Inputs from the various signal sources, microphones or lines, have by this time been amplified and equalised to a standard condition and we are now ready to mix them together. A Mixer is required to combine a number of input signals so that the output is the algebraic sum of the inputs. The word 'algebraic' means that the summation takes into account the phase, polarity and amplitude of the inputs when performing the additions. There are methods of addition which can ignore one or other of these factors.

There are four main considerations which have to be taken into account when designing a mixer and these may be listed as follows:

1 Interaction.
2 Isolation.
3 Law Distortion.
4 Signal to Noise Ratio.

We shall go through them in turn and **fig. 1** will illustrate the various points as we take them in turn. **Fig. 1a** shows a simple circuit which will perform the mixing function for us. Some cheap passive mixers designed for domestic tape recorders work on this principle and, given certain limitations, they perform adequately. Why not use such a system in our Mixer? The rub comes when we examine the limitations and that is what this discussion is all about.

1 Interaction

Interaction is the effect whereby operating one fader causes level changes on the channels not specifically controlled by that fader. In **fig. 1a** fader one can cause level changes in the output signal due to an input via input two. How does this come about? Let us imagine that a oscillator is connected to input one and input two is open circuit. The oscillator is delivering an input voltage of 1V rms and VR1 is set for maximum output. The oscillator output impedance is low enough for us to say that we have a constant voltage drive to the input terminal, whatever the setting of the fader. We can calculate the voltage that will be delivered to the output under two different conditions—

* *Walsall Timing Developments*

Fader 2 at top

$$V_{out} = \frac{V_{in} \times Req_1}{R_1 + Req_1} \quad \text{where } Req_1 = \frac{R_2(R_3+VR_1)}{R_2+R_3+VR_1}$$

$$= \frac{1 \times 6.66}{16.66}$$

$$= 0.4 \text{ volts}$$

Fader 2 at bottom

$$V_{out} = \frac{V_{in} \times Req_2}{R_1 + Req_2} \quad \text{where } Req_2 = \frac{R_2 \times R_3}{R_2+R_3}$$

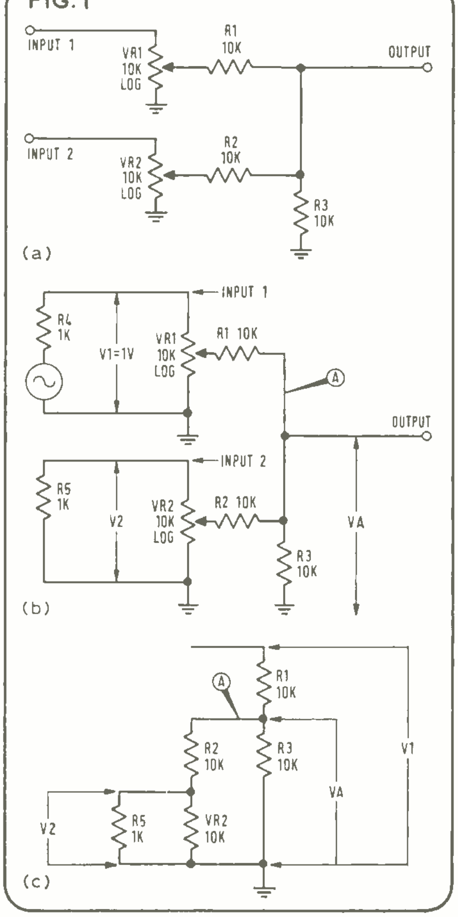
$$= \frac{1 \times 5}{15}$$

$$= 0.334 \text{ volts}$$

The difference in dB between these two conditions is

$$20 \log_{10} \frac{0.4}{0.336} = 1.5 \text{ dB}$$

FIG. 1



with fader two at the top and bottom of its travel. (See above calculations.)

With a system of only two channels, we might be able to overlook an interaction of 1.5 dB, but very few mixers are restricted to this number. If we had eight similar channels using the same component values as in our example, the 'worst case' interaction (that is the interaction of seven channels on the eighth) would rise to 4.3 dB which is certainly not acceptable.

Examination of the formulae above will show that with this circuit, the interaction would rise to 6 dB with a large number of channels and the reason for this is the progressive unimportance of resistor R_3 as the number of channels increases. It can be shown that the equivalent resistance of all the mixing resistors (R_1, R_2, etc) in parallel will be much lower than the resistance of R_3. One way to overcome this difficulty would be to make the value of R_3 very low to start with, which would postpone the point at which the number of channels had this effect. A disadvantage of this technique is that the insertion loss of the circuit would be very large, necessitating an amplifier to recover the loss.

2 Isolation

When two signals are presented to the inputs of a circuit such as **fig. 1a**, it can be shown that a certain proportion of input one will feed back through R_2 and VR_2 from the mixing point and thus be present at input two. If we are only concerned with two inputs to one mixer this does not matter, but it might be the case that the signal feeding input two is fed to some other equipment. The portion of input

(continued over)

continued

one signal will go along with it and may give rise to undesirable results. We say that in this case there is 'crosstalk' between input one and input two, because there is a similar signal feed from input two across to input one. Where the crosstalk is very low we can say that the degree of isolation is good, and we can calculate the theoretical isolation and express it in decibels. To do this we inject a known signal at one input and measure the proportion of this signal that feeds through to the other input. The ratio between the two readings can be expressed in decibels and a figure of better than –70 dB can be considered satisfactory. At this level, the signal is comparable with the circuit noise.

How does the circuit shown in **fig. 1a** measure up in this respect? **1b** shows the circuit redrawn using an input one source with a finite output resistance. Input two is loaded with a resistor of the same value which would be equivalent to having a second, similar, generator connected, but with the output control turned down. Let us suppose that both faders are turned fully up for the purpose of calculation. This makes things easier and I am all for an easy life. Let V1 = 1V rms. The first step is to calculate the voltage across R_3, the mixing point. The resistance from point A to earth is calculated from the resistor values as shown in **1c.** This can he worked out as 5.22 K. The voltage at A due to input one is thus

$$V\hat{A} = \frac{1 \times 5.22}{10 + 5.22} = 342 \text{ mV}$$

Knowing this, we can work out the voltage at input two (V_2) due to $V\hat{A}$.

$$V_2 = \frac{342 \times 910}{10{,}910} \text{ millivolts}$$

$$= 28.5 \text{ millivolts.}$$

This can be expressed as a ratio in decibels with reference to input one (V1)

$$20 \log_{10} \frac{V2}{V1} = 20 \log_{10} \frac{28.5}{1000} = -31\text{dB}$$

Not a very encouraging result, I think we would all agree. One way we could improve matters would be to reduce the output impedance of the generators—indeed if we could make it zero ohms, the isolation would be perfect. In practice it is not possible to reduce the generator impedance to this extent and so some crosstalk would always be present. A better way would be once again to reduce the value of R_3. The lower we can make the voltage at the mixing point the better, because the lower this is the less voltage there is to be fed back to the opposite input.

It can be shown in fact that to obtain the degree of isolation suggested we would have to reduce the value of R_3 to about 30 ohms in **fig. 1b.** This gives us two reasons for considering the value of R_3 carefully and more will be said in a minute.

3 Law Distortion

The controls that we use as faders and gain controls in audio systems are logarithmic controls. We use this expression very freely but what does it mean? We have already demonstrated back in the early part of this series that the human ear responds to ratios in sound level. This is also true in matters of pitch incidentally. A change in sound level is judged not as it stands but by reference to the previous level heard.

This means that for each change in volume to be heard as the same, as the general level increases, each change must be made larger. On a volume control, we try to make each angular movement of the spindle produce the same relative increase in volume. In other words we construct it to produce so many 'decibels per degree'. This is called the 'law' of the control. With a slide fader, these often have a scale printed on them which is so many decibels per unit of movement. Because these controls are logarithmic in action—decibels are logarithmic quantities — they are called logarithmic controls or more usually log controls.

Having gone to all this trouble to grade the track in the potentiometer so carefully and make it fit the printed scale so well, it would be a great pity if we were to ruin the whole thing by so loading the control that the law was distorted. We can perhaps see how this can happen by making a table from measurements made on a typical control and seeing how the results are affected by loading the control with a resistor of the same value. **Fig 2** shows how the circuit is arranged and the test is carried out by measuring the voltage at the slider of the potentiometer by means of voltmeter V. A constant 10V is applied to the top of the potentiometer and the meter readings are taken in ten per cent steps of rotation reading. If we had a potentiometer with a mechanical and electrical rotation of 300°, we would measure the output voltage every 30°. A first set of readings are to be made with switch S_1 open and a second set with it closed, and the following table is typical of what would happen. The potentiometer chosen for the job is one of the ten per cent LOG Type. This means that the voltage output at 50 per cent mechanical rotation is ten per cent of the full voltage applied and this is the same as the vast majority of volume controls. The value of the control is 10 kΩ, as shown in **fig. 2.**

The table is self explanatory and it shows that there is some departure from the ideal curve when the control is loaded. The error is shown in column four, indicating a worst deviation of 1.9 dB at 80 per cent. This would be more than could be tolerated in a professional application and bearing in mind that there must always be some distortion of the law, the aim must be to minimise the effect. A suggested worse case deviation would be about 0.5 dB and this implies a loading resistor of some five times the value of the total track resistance of the volume control or fader. We do not want to make the value of this resistor too high in value or else we shall lose too much level in the mixing.

4 Signal/Noise Ratio

We are now in a position to consider the actual voltage level at which it is best to mix and, from this, determine the value of the resistors. We have seen that the value of the mixing resistor (R_3 in **fig. 1a**) is of great importance and the conclusion has been arrived at the lower we can make its value, the better. On the other hand, the lower the value, the greater the voltage loss in the mixing network, the greater the amplifier gain will have to be to recover the signal level after mixing. This implies noise is going to be introduced which will worsen the signal to noise ratio. As usual, a compromise must be reached between the several factors that we have considered: Interaction, Isolation, Law Distortion and Gain/Noise.

There are no prizes for deducing that I am going to use the Virtual Earth Amplifier as the means of generating a low value of resistance to do the duty of R_3. This, as we have previously seen, can be made more or less any value that we like and we can use the gain and noise analysis that we made before to determine the best values for the various components.

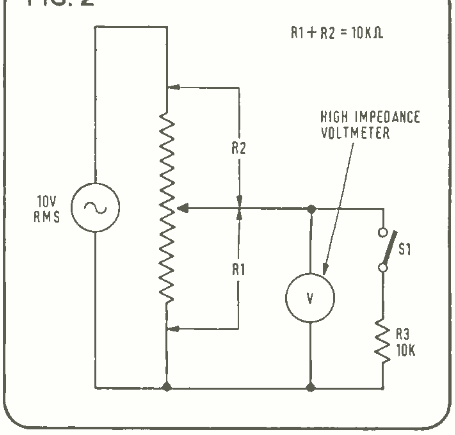
We know from the previous work that we can expect an equivalent input noise level *at the virtual earth point* of about –126 dB, or 0.4 microvolts. Clearly if we want a signal to noise ratio from the amplifier of around –80 dB we must ensure that the actual signal voltage reaching the mixing point must be 80 dB more than 0.4 microvolts—namely 4 millivolts.

The next thing to be considered is the maximum output that the mixing amplifier can

Vin = 10V

1	2		3		4
% Rotation	V out Switch open	dB Rel	V out Switch closed	dB Rel	dB ERROR
100	10	0	10	0	0
90	6·3	–4	5·1	–5·8	1·8
80	3·98	–8	3·2	–9·9	1·9
70	2·51	–12	2·11	–13·5	1·5
60	1·58	–16	1·39	–17·1	1·1
50	1·00	–20	0·92	–20·7	0·7
40	0·63	–24	0·59	–24·5	0·5
30	0·40	–28	0·39	–28·3	0·3
20	0·25	–32	0·25	–32·2	0·2
10	0·16	–36	0·16	–36	0
0	0	00	0	00	0

FIG. 2



deliver and the relationship between this and the normal average working level. We know from previous calculations that the maximum output level obtainable with a 30 volt supply rail (which is what we use) is about eight volts rms, or some +20 dB. It is generally considered necessary to allow a margin of 20 dB between the normal generating level and the absolute maximum level. This margin of 20 dB is called the Headroom, for obvious reasons. To allow 20 dB headroom in this case we must establish the normal operating level as 0 dB, or about 800 mV. The operational amplifier thus has an input voltage of 4 mV and an output voltage of 800 mV, establishing its gain as 200 times, or 46 dB. We know that we want a virtual earth resistance of somewhere about 1000 ohms for optimum noise performance from the amplifier because this resistance is the source impedance seen by the amplifier. We can thus establish the value of the feedback resistor as 150 kΩ because

$$\frac{150000}{200} = 750 \text{ ohms, which is about right.}$$

Finally we can select the value of R_1 to give adequate isolation between inputs and about 10 dB overall gain from the mixer stage. We know that the gain of a virtual Earth amplifier is given by

$$\text{Gain} = \frac{R_2}{R_1}$$

$$\text{Thus } R_1 = \frac{R_2}{3{\cdot}16} \text{ for 10 dB gain.}$$
$$= 47 \text{ k}\Omega.$$

We can now calculate the isolation between inputs using the same method as in section two above. Assuming that the generator source resistance is about 1 kΩ as in **fig 1b** we can see that the isolation between inputs is at least 70 dB, which we already suggested as quite adequate. In practice we can make the output impedance of the amplifiers which feed the faders much lower than 1 kΩ which considerably increases the isolation—at least to 80 dB.

In section three the minimum value of the mixing resistor which could be used with a 10 kΩ logarithmic fader was suggested as 47 kΩ and we have calculated this as being the suitable value for the input resistor R_1. This gives two good reasons for using these values and they are therefore the ones selected for use in the system. It might be asked why a 10 kΩ value is chosen for use as a fader. The reason is that with this value several similar potentiometers can be used in parallel without affecting the voltage level on the line which feeds them too much. It is perhaps significant that 10 kΩ is used as a 'bridging' impedance when parallel feeds are to be taken off 600Ω lines. We can calculate the loss in level on a 600Ω line caused by placing a 10 kΩ load across it. Let us suppose that the unloaded 600Ω line is operating at a voltage level of 1V. When the 10 kΩ load is connected, this forms a potential divider and reduces the voltage level. The loaded voltage is given by

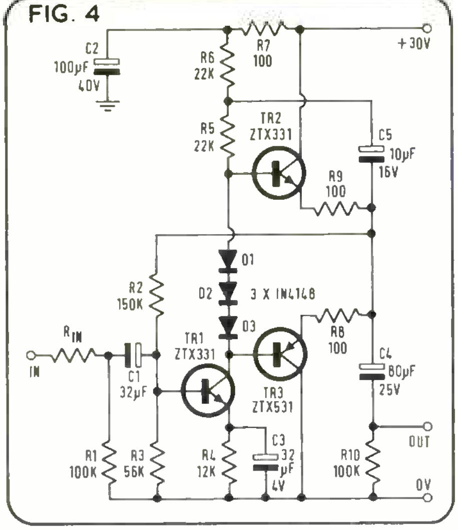
$$V_L = \frac{1 \times 10{,}000}{10{,}600}$$
$$= 944 \text{ millivolts}$$

This represents a loss of 0.5 dB which would not be perceptible to the ear.

The final step in our working is to calculate the interaction between channels in the same way as we did in section one. This will tell us the maximum number of input channels that we can use in parallel with the mixer amplifier as described. Let us allow a maximum variation in one channel of 0.5 dB when all other channels are varied over their full range.

As we have already seen the reason for the variation is the changing effective parallel resistance of the unused channels as their controls are altered from maximum to minimum output position. The worst case is when the top end of the fader is not fed from a low impedance source but is left floating, because the full variation (i.e. 10 kΩ) is experienced as the position of the control is altered. It can be shown that if we impose a limit of 0.5 dB in the worst case as quoted for N channels, then N = 25. In other words, we can use up to 25 inputs to the mixer circuit as quoted before the interaction exceeds 0.5 dB. In a practical case of course the number of channels could be much higher because the variation in resistance of a fader fed from a low impedance source is much less, only being a quarter of the nominal value.

FIG. 4



Final mixer amplifier

The circuit for the final mixer amplifier is shown in **fig. 4** and it can be seen that this is very similar to the operational amplifier shown as **fig. 15** in November's article. The feedback resistor has been altered to 150 kΩ and the resistor from TR 1 base to earth has been altered to correct the dc conditions.

Two identical amplifiers are mounted on one card known as a General Purpose Amplifier (GPA). This title is given because the actual circuit of several types of amplifier in use throughout the system is very similar, the principal difference being component values. We have therefore produced a single card which can, by altering component values be made to work as a Mixer Amplifier, Line Amplifier or Headphone Driver. For the Mixer Amplifier application, we need several input resistors and we have provided five positions for Rin. If it is required to provide more inputs than this, one of the Rin positions can be short-circuited with a wire link and the extra resistors mounted on a tag strip conveniently sited to suit the layout. **Fig. 5** is the printed circuit layout and **fig. 6** is the schematic of the contents of the card, the figures in squares being the edge connector pin numbers.

FIG. 3

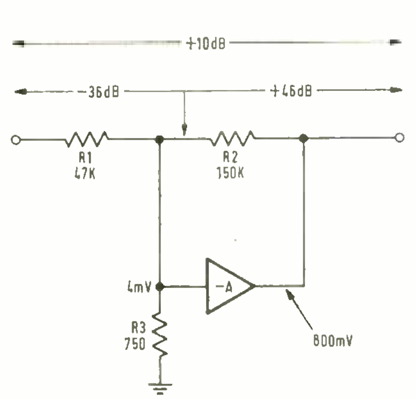


FIG. 5

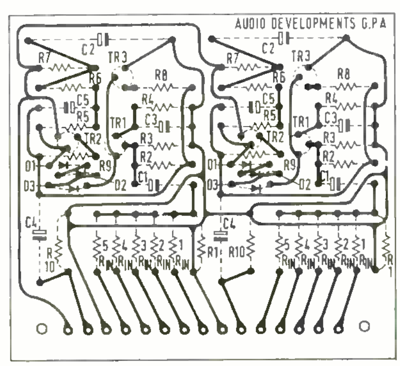
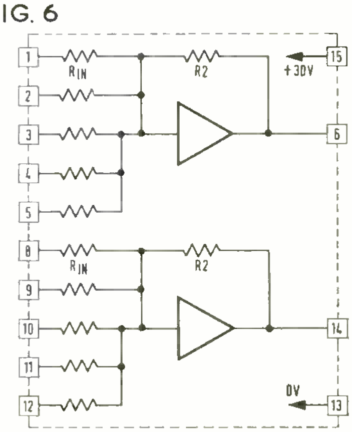


FIG. 6



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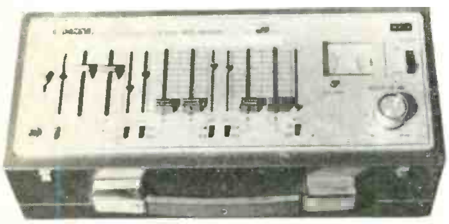
Internavex 1971

BY JOHN DWYER

VTR equipment on the REW stand.

Sony portable mixer feeding six inputs into one or two outputs.



THIS, the second Internavex, was held around the beginning of September at Olympia. The event was organised by the National Committee for Audio-Visual Aids in Education. As the title suggests, the exhibition was more likely to prove of interest to those in the teaching profession, but it provided a number of opportunities to see recent developments in helical-scan video recording.

The Sony stand held an impressive array of vtr equipment. Although small-screen monitors may have helped matters, the colour video pictures were some of the best seen. There were seven colour monitors above the live scene so that some sort of comparison was possible. Also on show here was a compact sound mixer selling for £45.

The Decca stand had a nice line in potted plants and LP sleeves. Further investigation showed a set of colour monitors, none of which were switched on. Decca were concentrating their efforts on their range of 'educational' records.

The Ampex stand was busy. Notable here was the *AC-125* television production centre, a compact means of controlling three cctv cameras. It consists of three sections: a video control unit which has a fader, special effects generator and a waveform sampling facility; three video monitors; and a four-input audio mixer with vu meter.

Also on show was a single tube colour camera made by FIL. The pictures seen on it were as good as those seen anywhere else, though the camera is still being improved upon. The tube works by filtering the colours through a number of 20 lines/mm filter gratings inclined mutually at 45°. The video output signal is thus separated into broadband luminance and narrow band red and blue signals, and registration problems are minimal. Thus, it is claimed, setting up is very easy, the only adjustments being to black, red and blue levels. The camera can be obtained for around £1,500. One of its big advantages is the high degree of compatibility with monochrome signals.

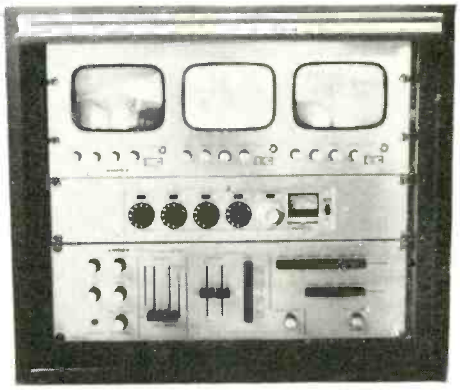
Ilford were exhibiting their Zonal tape. Zonal are now a division of Racal and will be covered in a forthcoming factory visit.

Fraser Peacock had a stand near the door. They had on display a 'low cost, cassette-to-cassette duplicator'. An ordinary cassette was played through a small portable, after which the cassette was removed, copied, and the copy played on the same small portable. I was asked if I could detect any difference between copy and 'master'. Needless to say, I couldn't.

REW were the only retailers with a stand of much interest to readers of this magazine, and an extensive array of video equipment was in evidence. REW have been a substantial supplier to educational establishments for several months now. They recently opened a basement department at their Charing Cross Road branch and are now trying to supply recording studios.

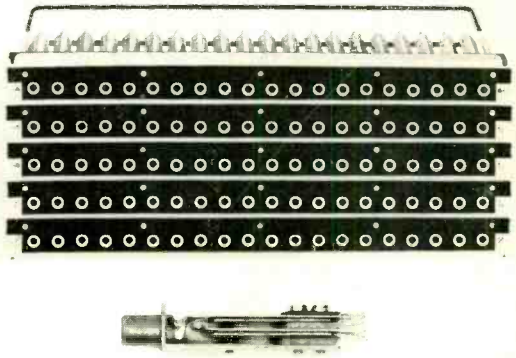
Philips have extended their cassette concept into video and on August 18 launched their VCR system. Their exhibit at Internavex suffered from the use of a wide screen display, though they do not lack courage.

Shibaden showed a range of black and white cctv and monitoring equipment. Their new camera, the *HV-40S*, is a 16 mm separate mesh vidicon which weighs in at 2.5 kg. The unit features built-in exposure control. A new vtr, the *SV-700ED*, is fitted with an electronic edit facility. Shibaden claim that editing is noise-free; picture breakup was indeed undetectable. It is possible to record intermittently or to insert other programmes electrically with equally good results. Still frame viewing is also featured. Audio dubbing is also possible although this was not demonstrated. Recording time is 70 minutes on a Shibaden *R-706* video tape.



Ampex AC-125 television production centre.

EVR player and film reel. The monochrome film carries luminance and coded chrominance information.



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Studio Diary

BY KEITH WICKS

ASSOCIATED Newspapers, responsible for the *Daily Mail* and *Evening News*, as well as a string of provincial newspapers, are expected to figure prominently in the commercial radio scene. Their company, the Philip Birch Consortium, has been booking the **Roger Squire Studio** for a number of presentation programmes, one of which was played to 500 of the key people in this fast expanding business. This programme included interviews conducted in the street and studio material presented by disc jockeys Bob Snyder, Roger Scott and Guy Hamilton. In the days of the pirates Bob Snyder was with Radio 270. After that he went to Radio Antilles in the Pacific. Roger Scott and Guy Hamilton also have radio experience, Guy being an established BBC DJ who has compered many Radio One Club programmes. We are obviously going to hear a lot more about Philip Birch, ex-skipper of the Radio London pirate ship, and the Consortium of which he is managing director.

United Artists Records have been using the Roger Squire Studio to make tapes for their representatives. These recordings will be issued in cassette form so that the reps can play them in their cars, thus familiarising themselves with the company's products. A master tape will be made every month and copied on to 100 cassettes.

Yet another demonstration tape made at Roger Squire's Studio has passed a BBC audition. Stewart Francis, a disc jockey for about four years, is the latest of Roger's customers to successfully adapt himself to radio techniques. In a period of six months only three would-be disc jockeys passed the BBC test and all of them did it with the aid of demonstration tapes made at this studio. However, anyone thinking that they can acquire instant fame and fortune by sending in a Squire-recorded tape should bear in mind that passing the audition is only the first step. It means that the applicant's name is put on a list of approved disc jockeys, so when a new show is being planned he has a chance of being chosen.

Reports from the States indicate that the programme which was broadcast to coincide with the reopening of the old London Bridge at Lake Havasu went down very well. This programme was taped by Tony Mercer, a regular visitor to the studio, and transmitted 'live from London' to the people of Lake Havasu City by their local radio station. To add atmosphere to the occasion the broadcast was relayed over several public address systems.

With so much work it is little wonder that Roger Squire is not worried by rumours that more disc jockey studios are soon to be launched. As he said: 'The world's smallest studio is still chugging along'.

At **Intersound,** Al Saxon recorded a self-produced single for Phoenix Records, and Thames Management have been in with the Harry Roach Constellation. Simmsoframi of Paris, Avenue Recordings and Pickwick have all been recording cover versions of various songs for issue on budget albums.

Marquee's studio manager, Phil Dunne, faced with the problem of recording a choir which was too large for the studio, ended up hiring the Pye mobile unit and a girls' school, Queens College in Harley Street. After an interesting session, the chivalrous engineers presented the principal of the college with a bouquet for putting up with the large recording van and the multitude of cables used. The material was written by music teacher David Bedford and will be issued on John Peel's Dandelion label when kazoos, brass and organ have been added.

Dandelion are also working on a new Medicine Head album, a follow-up to one entitled *Heavy On The Drum.* Manfred Mann, who has his own jingle company, has been in to produce a number of tracks for commercials. The *Private Eye* crowd, now celebrating their magazine's tenth anniversary, are recording an lp to mark the occasion.

The latest improvement to Marquee's technical facilities is the installation of a new monitoring panel which has increased the facilities available on the desk.

Ken Cameron reports that **Anvil Studios** at Denham have now completed all the music recording for the film and the album of Norman Jewison's production of *Fiddler On The Roof.* This work, which has now been released, occupied the studio for 15 months and was engineered entirely by Eric Tomlinson using the 24/8 Neve desk, RCA 35 mm recorders and four and eight track Studers.

Producer Gordon Smith has been working at the **Tooting Music Centre** with Natchez Trace, a country group. From now on, Gordon will be a regular visitor to the studio as he recently agreed to make four albums there each month for issue on the Philips label. Irvin Chandler recorded demos for April Music and Barry Kirsh did some demos which have now become prospective masters.

The Allen and Heath desk used at the studio is compact and can be removed from the desk to be taken on mobile jobs. Thus one day they were using it in the studio to record reggae by Manley Benton, the next it was installed in Southfields Methodist Church.

At Hampstead's **Pan Sound Studios** John Bluthal, star of *Never Mind The Quality, Feel The Width*, made a single called *The World Of Manny Cohen.* The producer was Ivor Raymonde and this item will be released on the President label. Others at the studio this month have included Simon Plugg and Grimes, Money Jungle and Brian Matthew.

At **Mayfair Studios** Tick Tock Music recorded a number of compositions by Geoff Stephens. Julie Stevens of *Girls About Town* fame recorded a master for Trend Records, the producer being Les Stewart. Pickety Witch recorded masters for release overseas, and the American Chambers brothers have been in with producer Ian Green laying down album tracks.

Mayfair is another studio able to undertake mobile work. They recently covered a Chrysler industrial show for Grout Advertising at the Talk of the Town. Ampex and Revox stereo machines were used together with a small mixer kept for mobile work.

Apple have announced that they should have a quadraphonically equipped reduction room in operation sometime in January. I hope to visit this new half million pound studio very soon as there are some interesting features, such as an ultra-low noise ventilation system, widely variable room acoustics, and an echo chamber which can provide reverberation times up to four seconds. A special feature of the control room is the panoramic window, so big that apparently it had to be installed first, the rest of the building being constructed around it. Marquee Studios recently replaced their glass as it had become badly scratched after a year in use. Does this mean that the Apple building will have to be demolished next year?

At the **Jackson Studios** the Chelsea team had a ball recording a single, aided by one cheer-leader and 20 fans. Ron Black, England's foremost Frank Sinatra impersonator, who spent five years studying that singer's technique, has been recording album tracks in the same style. The second recording for Sangam, England's first Punjabi label, has been completed, the first having topped the charts in Bradford, Birmingham and Southall. Other work at the studio has included the first album for the new Rema organ label.

Wally Watkivs, a director of **Garrett Studios** in Tel Aviv, recently visited London. He told me about his studio and the way the record business operates over there. Wally is also a director of Garrett Electronic Industries, manufacturers of amplifiers and other audio equipment. After five years in operation it was decided that the company should build their own studio. This took a year to complete and it has now been open for nine months. Much of the equipment, including the control desk, was built by GEI, recorders are by Ampex and Revox, compressors by Audio & Design, and microphones by Sennheiser and AKG. For echo Grampian and Fairchild spring units are used, the present lack of EMT plates being explained by the very high import duty in Israel. At the moment it is 160 to 180 per cent.

A very interesting fact about the recording industry in Israel is that records are not released until they are hits. What happens is that artists record a few numbers in the studio

(*continued on page 28*)

SYNTHETIC STERE
REVERBERATION

LAST month a method was described of obtaining a full stereophonic spread of reverberation in two or more (say N) channels from a device using only N delay lines. The 'orthogonal matrix feedback' reverb units described gave a good distribution of echoes across the stereo (or quadraphonic) image, and also gave a high density of echoes, which increased and became more random with time. Unfortunately, despite these good qualities, the reverberation produced by such units can be shown to suffer from a ragged frequency response, causing a rather coloured quality. Most of the following will concern itself with how this coloration can be eliminated, yielding reverb units which are 'better than the real thing' insofar as they have a flat frequency response.

The orthogonal matrix feedback reverberation unit is constructed as in **fig. 1a,** where each line represents N distinct signal paths, where the matrix circuit is 'orthogonal' (i.e. such that whatever the input signals are, the total energy of the N output signals equals that of the N input signals to the matrix), and where the 'plus' block has its, say, i'th output equal to the sum of the i'th signals in each of the two N-channel inputs to the block. The convention of using a single line to represent N signal paths is a great simplification, as a comparison of **fig. 1a** with last month's **fig. 4** will illustrate. The variable gain g (which should be between −1 and +1) is applied to all N signal paths, and varies the reverberation time of the unit. The delays of the N delay lines used in **fig. 1a** should be mutually incommensurable, i.e. not simply related to one another.

A linear circuit with N inputs and N outputs is said to be *unitary* if it preserves the energy of signals passing through it, i.e. if for all possible input signals, the total energy of the N output signals equals the total energy of the N input signals. It is clearly possible to replace the orthogonal matrix in **fig. 1a** by any unitary circuit. However, each echo thus produced will only have a frequency-independent stereo location if the components of each input of the unitary circuit at each output all have a flat frequency response and differ from one another in phase by a phase angle that is independent of frequency. Such a 'smearless' unitary network may be realised by means of a number of 90° phase difference circuits (see ref. 1) followed by a matrix circuit.

FIG. 1 (a) ORTHOGONAL MATRIX FEEDBACK REVERBERATION UNIT

(b) SIMPLE MONOPHONIC REVERBERATION UNIT

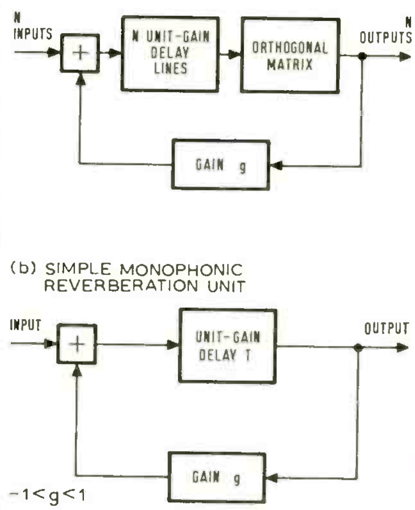
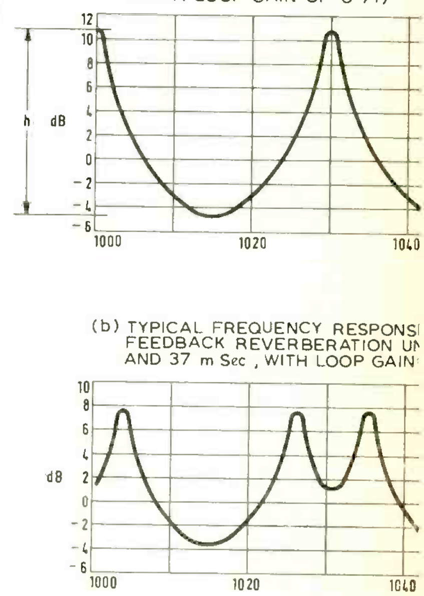


FIG. 2 (a) TYPICAL FREQUENCY RESPONS UNIT AS IN FIG 1b (THE EXAMI AND A LOOP GAIN OF 0·71)

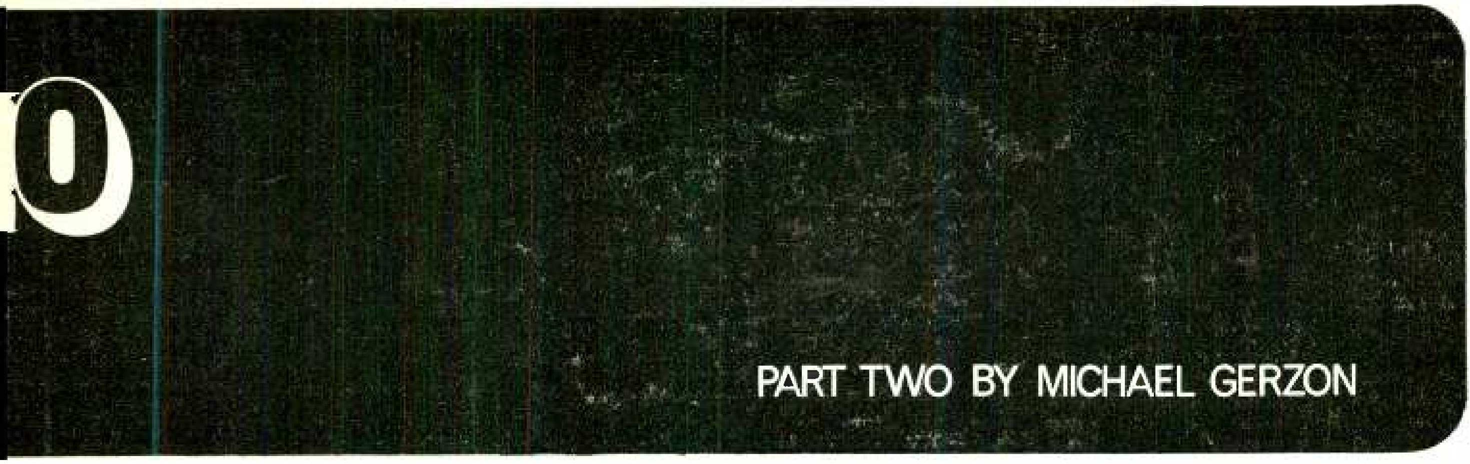
(b) TYPICAL FREQUENCY RESPONSI FEEDBACK REVERBERATION UN AND 37 m Sec, WITH LOOP GAIN



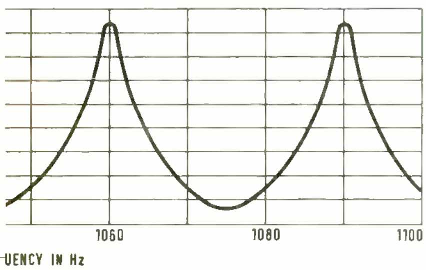
Unitary circuits are of importance because a collection of N unity gain delay lines is a unitary circuit, as is an N-channel orthogonal matrix. However, another important aspect of unitary networks is that, as they preserve the energy of all signals, they may be considered as having a 'flat total frequency response', even though the frequency response of the signal emerging from any one of the N outputs may not be flat. Unitary circuits are the N-channel analogue of a unity gain, all pass circuit. Thus in order to avoid a coloured sound it is desirable that an N-channel reverberation device should be a unitary circuit.

Before looking at the frequency response of **fig. 1a** it is first convenient to examine the simplest possible case, i.e. the single-line monophonic reverberation unit of **fig. 1b.** This type of reverberation device is known to have a 'comb filter' frequency response (see ref. 2) such as that illustrated in **fig. 2a.** If T is the delay of the delay line in seconds, then the frequencies at which the gain of **fig. 1b** is maximum are spaced 1/T Hz apart from one another. If the loop gain is g then the ratio of maximum amplitude gain to minimum amplitude gain is $(1+g)/(1-g)$ and is shown in dB as h in **fig. 2a**; thus if $g=0.7$ (a typical practical value), then $h=15.1$ dB, and if $g=0.9$ $h=25.6$ dB. It is clear that the frequency response of **fig. 2a** is highly unsatisfactory—the height h of the comb is rather large, its teeth are narrow, and the frequency response varies in far too regular a manner to be a good imitation of room reverberation. This results in a very coloured sound.

Similar faults occur with the orthogonal matrix feedback unit of **fig. 1a.** The presence



F A SIMPLE MONOPHONIC REVERBERATION
SHOWN HAS A DELAY OF 33mSec



: 2-CHANNEL ORTHOGONAL MATRIX
THE EXAMPLE SHOWN HAS DELAYS OF 29
1 AND A θ=45° ORTHOGONAL MATRIX)

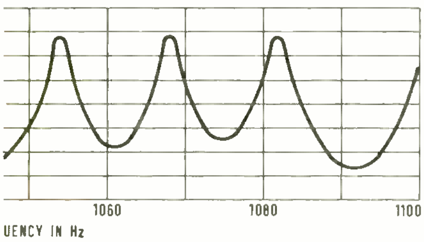


FIG. 3 MONOPHONIC REVERBERATION DEVICE WITH FLAT FREQUENCY RESPONSE (DUE TO SCHROEDER AND LOGAN)

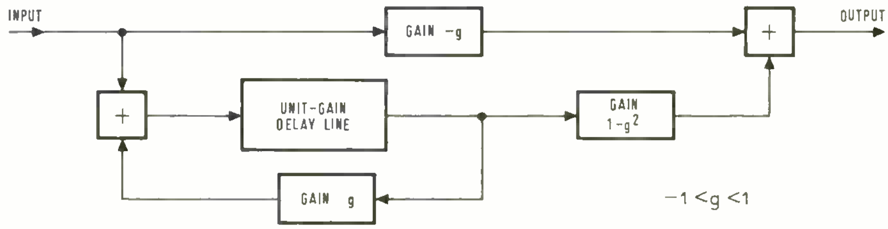
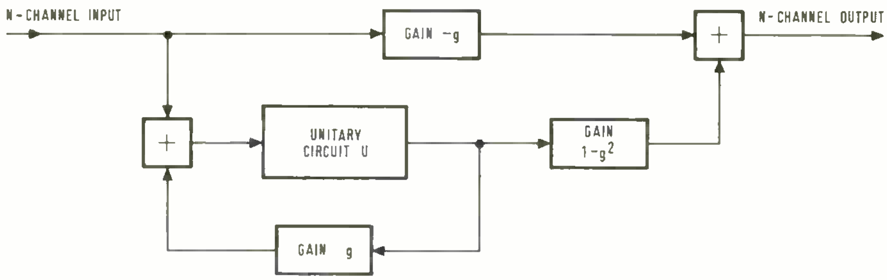


FIG. 4 (a) ADDING A DIRECT PATH AND A FEEDBACK PATH TO AN N-CHANNEL UNITARY CIRCUIT TO OBTAIN A NEW UNITARY CIRCUIT. GAIN g IS SUCH THAT $-1<g<1$



(b) N-CHANNEL UNITARY NETWORK OBTAINED BY CASCADING UNITARY CIRCUITS

of N different incommensurable delays helps to make the frequency response* more irregular, which does help to reduce coloration a little. However, the frequency response will still be too regular. For example, a two channel unit with delays T_1 and T_2 will have a frequency response which is a function of two periodic variations whose periods are $2/(T_1+T_2)$ and $2/(T_1-T_2)$. A typical example of such a frequency response is shown in **fig. 2b.**

In reference 2, M. R. Schroeder and B. F. Logan describe a modification of the monophonic unit of **fig. 1b** that has a flat frequency response. This 'colourless' version of the monophonic unit is shown in **fig. 3**, and is obtained from the feedback reverb unit of **fig. 1b** with loop gain g by adding to $(1-g^2)$ times the output of the feedback loop minus g times the direct sound from the input. As long as the gains of the direct and the fed-back sounds are precisely as in **fig. 3,** then it can be shown (see ref. 2) that the frequency response of the resultant output is flat, even though the phase response is not.

Schroeder and Logan's technique thus adds a direct path and a feedback path to a unity gain flat frequency response network (i.e. a delay line) in order to get a new unity gain flat frequency response device (i.e. the monophonic reverb unit of **fig. 3**). This technique can be

(continued over)

*The 'frequency response' of an N-channel network with complex matrix frequency response $M\omega$ is defined to be the square root of trace $[M_{2\pi f}(M_{2\pi f})\dagger]$, where f is the frequency, and $M\dagger$ the Hermitian adjoint of M.

applied to any N-channel unitary circuit, as in **fig. 4a**. In **fig. 4a**, a feedback path with loop gain g is applied to the unitary circuit U, and $(1-g^2)$ times the output of this feedback loop is added to minus g times the input signal. Using matrix algebra arguments, it is possible to show that the resultant circuit of **fig. 4a** is also a unitary circuit. The N-channel signal passing through the network of **fig. 4a** will thus be heard as having a 'flat frequency response', although the output signal may be very different from that at the input. The circuit of **fig. 4a** will be called the *feedback modification* with loop gain g of the unitary circuit U.

Another way of putting together unitary circuits to obtain a new unitary circuit is to cascade them as in **fig. 4b**, i.e. to place one unitary circuit after another. The cascaded circuit is clearly also unitary, as its total energy output equals its total energy input. By repeated application of feedback modifications and of cascading, a wide variety of new unitary networks can be created out of just a few basic unitary circuits. An example of such an N-channel unitary network built up from four basic unitary networks U, V, W and X is shown in **fig. 5**, in which the contents of each of the five broken-line boxes also form a unitary network.

All this is of great use in designing 'colourless' stereophonic reverberation devices. A collection of N unit-gain delay lines is an N-channel unitary circuit, as is an orthogonal matrix. Thus if the unitary circuit U in **fig. 4a** is taken to be a collection of N unit-gain delay lines followed by an orthogonal matrix, then the whole of **fig. 4a** becomes an orthogonal matrix feedback reverberation device with an added direct path between input and output. Because this circuit is unitary, the direct sound plus reverberation emerging from it has a 'flat frequency response' and so lacks undesirable coloration. Furthermore as described last month, if the orthogonal matrix strongly cross-couples the delay lines, then echoes appear uniformly across the N-channel stereo image.

While the monophonic reverberation unit of **fig. 3** and the above-described 'colourless' stereo unit give a flat overall frequency response, they are rather inflexible, as the loop gain g of the feedback loop determines both the reverberation time and the ratio of direct to reverberant sound. Thus one cannot alter one without altering the other. In the monophonic case, Schroeder and Logan (ref. 2) have suggested that a number of monophonic units should be cascaded, each unit incorporating a delay of different length. This procedure maintains a flat frequency response, reduces the proportion of direct sound at the output, and helps to randomise the reverberation and increase the echo density. Unfortunately, it also tends to make the reverberation build up rather slowly and unnaturally in a 'Gaussian' fashion, and the need to prevent this fault means that not more than five simple units can be cascaded. Also, as soon as any direct sound is added to the resulting 'colourless' reverberation, the frequency response again becomes coloured and 'unflat'.

However, providing a 'feedback modification' to a number of cascaded reverberation units provides a means of allowing the ratio of direct to reverberant sound to be varied while still maintaining a flat frequency response. As an example, consider the N-channel network of **fig. 5**, in which each of the unitary circuits U and W consist of N unit-gain incommensurable delay lines, and the networks V and X are orthogonal matrices. Effectively, this circuit consists of a feedback modification (with loop gain h) of a cascaded pair of colourless orthogonal matrix feedback reverb units (with loop gains f and g respectively). Direct sound emerges from the circuit of **fig. 5** with a gain $(fg-h)/(1-fgh)$. Thus for a given value of f and g the ratio of direct to reverberant sound can be varied by varying h. If $h=fg$, then no direct sound emerges and the output of **fig. 5** is just reverberation. In the typical case $f=g=0.71$, the variation of h from 0.5 to -0.5 will vary the proportion of reverberant sound in the output from 100 per cent to 36 per cent without changing the reverberation time greatly.

Not only does an N-channel reverb unit based on **fig. 5** allow the proportion of reverberation to be varied while maintaining a flat frequency response, but the actual reverberation time also can be continuously varied. This is done by increasing f and decreasing g (or vice-versa) while keeping their product fg constant. Thus, if $fg=0.5$, g may be varied between, say, 0.625 and 0.8 while f varies between 0.8 and 0.625. If the delay lines in the unitary circuit W of **fig. 5** have an average delay of about 100 ms and if those in U average about 20 ms, then the overall reverberation time of **fig. 5** would vary from something over 1.5s to just over 3s as g varies from 0.625 to 0.8. This type of colourless reverberation unit allows an even greater flexibility if the orthogonal matrix V is made continuously variable. By varying this, the degree of cross-coupling between the short delay lines U can be adjusted, so that the rate at which the early echoes spread out from their initial positions can be controlled to simulate differing room acoustics.

The simplest stereo version of **fig. 5** would be a two channel unit incorporating four incommensurable delay lines. In general, it is unlikely that a reverb unit incorporating less than four delay lines will give a sufficiently high density of echoes. A high density of echoes is easiest to achieve if the loop gains f and g in **fig. 5** are close either to one or to minus one, but with analog delay lines it becomes difficult to maintain the feedback stability if the loop gain has an absolute value very much above 0.7 for the reason described last month. Indeed, the biggest practical problem in designing reverb units of the type shown in **fig. 5** is making all the gains accurate enough, so that small errors do not accumulate to cause instability or inaccurate reverberation times.

Real concert hall reverberation has a longer reverberation time at very low frequencies than at mid-frequencies. In reference 3, L. Beranek suggests that the reverberation times of rooms should vary with frequency for speech and music as shown in **fig. 6**. For this reason, it is necessary to replace the constant loop gain g round the longest delay lines in a synthetic reverb unit by a 'step filter' with a gain g at mid frequencies, but with a gain g^1 of slightly larger absolute value at low frequencies. Because the reverberation time depends critically on the loop gain, the difference between these values is likely to be small (e.g. $g=0.7$, $g^1=0.8$).

Unfortunately, the substitution of a step filter for a constant gain prevents circuits such as **fig. 4a** and **fig. 5** from being unitary any more, although if care is taken to use filters with the minimum possible amount of phase

FIG. 5 UNITARY NETWORK USING 4 BASIC UNITARY CIRCUITS AND 3 FEEDBACK PATHS. EACH OF THE NUMBERED BOXES 1-5 ENCLOSED BY BROKEN LINES IS A UNITARY NETWORK $-1<f<1$, $-1<g<1$, $-1<h<1$.

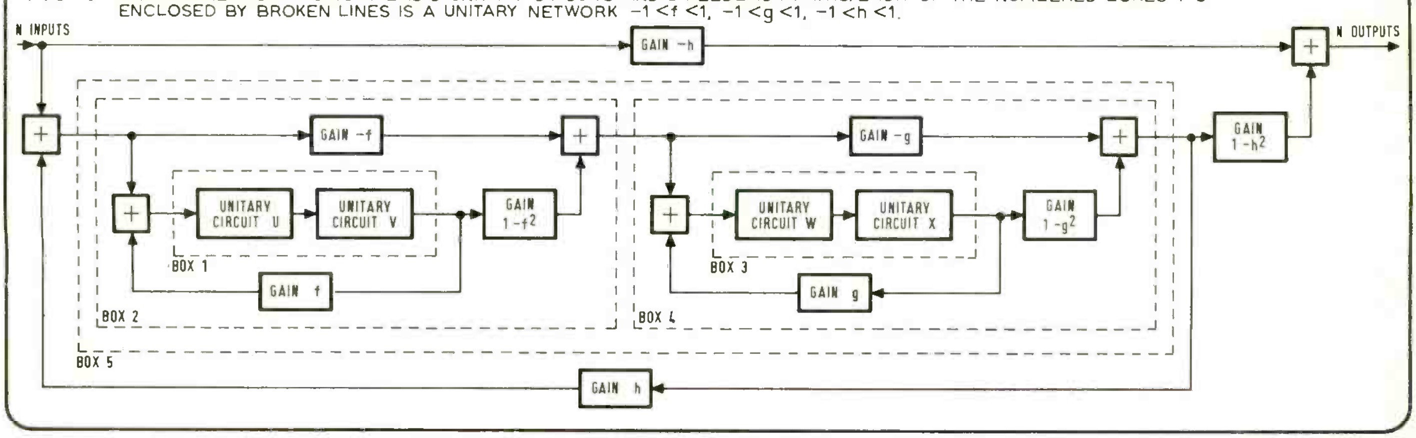


FIG. 6 REVERBERATION TIMES AT DIFFERENT FREQUENCIES SUGGESTED BY BERANEK FOR SPEECH AND MUSIC. REVERBERATION TIME EXPRESSED AS A MULTIPLE OF THE VALUE AT 800Hz

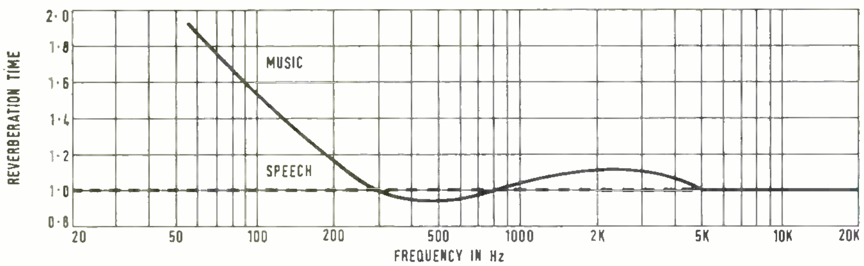
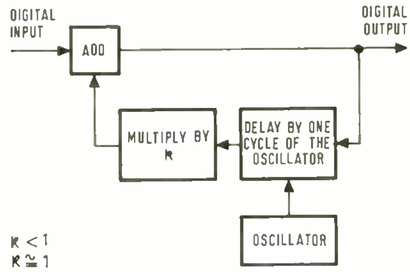


FIG. 8 SCHEMATIC OF A DIGITAL LOW-PASS FILTER



shift, the resulting coloration should not be grossly objectionable. The step filters will also cause individual echoes to have an amplitude and a stereo position that is frequency dependent, but this should not be pronounced on early echoes, and will in any case only affect low frequencies.

It is in fact possible to incorporate step filters in a modified form of **fig. 4a** that is unitary. If the 'gain g' and 'gain −g' circuits of **fig. 4a** are replaced by circuits with the complex frequency responses g(ω) and −g(ω) respectively, and if phase compensation is incorporated into the 'gain ($1-g^2$)' circuit so that it then has a complex frequency response $-g(\omega)_2 - g(\omega)/g(\omega)^*$, then the circuit of **fig. 4a** remains unitary. The phase compensation applied to the 'gain ($1-g_2$)' circuit is physically possible only for a restricted range of possible complex frequency responses g(ω). Among these physically possible cases is that of the step filter that is a modified RC all-pass filter, which has the complex frequency response $g(\omega) = g\frac{g^1 - j\omega RC}{g + j\omega RC}$, where g^1 is the low frequency gain, −g the high frequency gain, and RC is the time constant of the step filter.

If one or both of the gains f and g in **fig. 5** are replaced by step filters as described above, so that the boxes two and four remain unitary, then it is not in general possible to choose a complex frequency response h(ω) for the circuits outside box five so that the ratio of direct to reverberant energy remains independent of frequency. In this case, it is probably best to use step filters with the minimum possible phase shift for, say, g and h, and to put up with the small coloration caused by the resultant departure from perfect unitary behaviour.

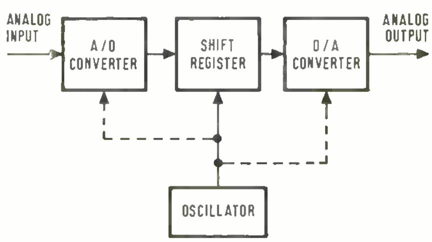
In all the above reverb units, it is of course possible to replace the orthogonal matrices by 'unitary matrices' (i.e. by smearless unitary circuits as discussed earlier) and/or to place the matrices before the delay lines rather than after them. Thus the designer of stereo reverb units has a wide range of options open to him to cope with various requirements and applications.

The recent development of all-electronic audio delay lines is worth further examination in the light of the above. Two types of lines have received wide attention: the 'bucket brigade' and the digital types. At the present stage of development, small signal degradations introduced in each stage of the line render the bucket brigade delay line unsuitable for delaying high quality audio more than a few milliseconds. A good introduction to the principles of digital delay lines is to be found in reference 4, and the following is only intended to sketch the possibilities of incorporating reverb units within the digital circuitry of such lines.

The conventional form of audio signal, in which an instantaneous sound pressure is represented by a voltage or current proportional to it, is known as the 'analogue' form of the audio signal. It is also possible to represent the audio in 'digital' form, in which the sound pressure at each moment is represented electrically by a sequence of, say, 10 voltages, each voltage in the sequence having a value of either 0 units or 1 unit. The number of voltages in the sequence used to represent a value of the audio signal is called the *word length* of the digital representation of the signal and the larger the word length the more accurate and precise this representation can be. The ultimate effect of these inaccuracies on the final reproduced audio signal is known as *quantization noise;* clearly this noise becomes smaller as the word length becomes longer. As a digital signal has only two possible voltage values it is possible to recover a digital signal without any degradation or distortion even when it has been passed through a circuit with a less than perfect noise, distortion, or frequency response.

In a digital delay line (see **fig. 7**), an input analog signal is first passed into an A/D converter (i.e. analog-to-digital converter). The digital signal is then passed into a circuit known as a *shift register* that stores a large number of digital signal values and which is designed to transfer all stored signal values to the next in a series of storage points in the circuit whenever it is 'instructed' to do so by a pulse emitted by an external oscillator. The digital signal will eventually emerge from the far end of the shift register with a delay that is determined by the number of storage points within the shift register and by the frequency of the oscillator. Finally the digital signal is passed into a D/A converter (i.e. digital-to-analog converter) to give a final delayed analog output. (As indicated in **fig. 7**, the oscillator is also in fact used to synchronise the operation of the A/D and D/A converters.)

FIG. 7 SIMPLIFIED BLOCK DIAGRAM OF DIGITAL DELAY LINE



Now while a digital signal is virtually immune to all forms of distortion, the A/D and D/A conversion processes can introduce distortion, noise and a non-flat frequency response. Furthermore, high-quality A/D converters tend to be very expensive. For this reason, it would save money if a synthetic reverb unit were implemented using as few A/D converters as possible. Thus it is desirable to realise the whole reverb unit apart from the A/D converters at the input and the D/A converters at the output with circuits acting on digital signals rather than on analog signals. Fortunately, it is possible to perform processes such as multiplication by a constant or addition of digital signals by standard computer-type logic circuitry just as easily as in the usual analog signal case. Moreover, because of the immunity of digital signals to minor distortions of all types, and because of the accuracy of digital multiplication, it is possible to make the loop gains of feedback loops round delay lines and orthogonal matrices very close to +1 or −1 without any tendency towards instability or inaccurate reverberation times. Although such circuitry is not yet standard, it is also possible to implement digital versions of filter circuitry; **fig. 8** shows schematically how a filter with performance very similar to that of an analog RC low-pass filter may be implemented by way of example. Thus the whole of a reverberation unit can be realised digitally with greater stability than in the analog case, and using no more expensive A/D converter circuits than would be necessary if digital delay lines were used merely to delay the start of the reverberation from an analog reverb unit.

There is one important precaution that needs to be taken when analog circuits are replaced by digital ones. Whenever digital signals are multiplied, the output has a longer word length than the input. If the word length is shortened to equal that of the input, additional quantization noise is added to the signal, and the result can easily be a very poor signal-to-noise ratio. For this reason, it is highly desirable that the internal digital circuitry of a digital reverb unit should handle word lengths rather longer than that provided at the outputs of the initial A/D converters. *(continued over)*

SYNTHETIC STEREO REVERBERATION

continued

It is especially important that the shift registers should handle a long word length as the feedback round them recirculates any quantization noise, causing it to build up. In a similar way, feedback round any type of delay line causes any noise introduced by the delay line to be increased—if the loop gain is 0.7 the delay line noise is increased by 2.9 dB, and if the loop gain is 0.9 then the noise of the delay line is increased by 7.2 dB.

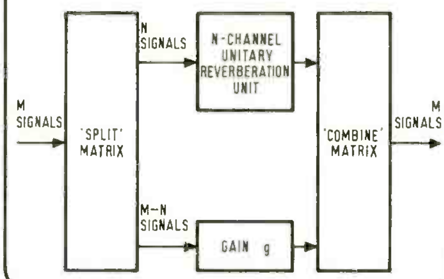
Whatever method is used to implement unitary reverb units, some practical operational problems remain. The recording engineer is accustomed to regarding synthetic reverb as something that is just added to the direct sound. Thus in mixing desks the reverb units are put in circuit between the echo send and echo return points.

However, as we have seen, the uncoloured quality associated with unitary reverb units can only be maintained if the quality of the reverberation is adjusted to match both the ratio of direct to reverb energy and the final reproduced position of the sound. Thus to provide a completely colourless reverb the signals fed to each unitary reverb unit must be pre-mixed to the position and level that is desired in the final two (or four) channel mixdown; moreover, no signal must be fed to more than one unitary reverb unit.

While such procedures are the only way to obtain colourless reverberation, their inconvenience and the required modifications to mixing desks and operational practices probably mean that in practice colourless reverberation will be added to sounds as in standard studio practice. The very process of addition will re-introduce coloration, but this could be rendered relatively harmless if enough incommensurable delays are used sufficiently to randomise the reverberation. However, in cases such as the manufacture of pseudo-stereo or pseudo-quadraphony where it is desired just to add a colourless blanket of reverb to a pre-mixed recording, it is advisable to use a unitary reverb unit providing the desired ratio of direct to reverb energy (see ref. 5).

It is worth noting that a unitary reverb unit with a small number (say N) of channels can be used to provide colourless stereophonic reverberation for a larger number (say M) of channels of sound. The basic procedure is shown in **fig. 9**, where the 'split' matrix is an orthogonal or unitary matrix with an M channel input, an N channel output, and an (M–N) channel output. The 'combine' matrix is a converse circuit with an N channel and an (M–N) channel input and an M channel output such that were the 'combine' matrix to be placed straight after the 'split' matrix, then together they would have no effect on the M-channel signal passing through them. The insertion of an N-channel unitary reverb unit as shown in **fig. 9** results in a colourless reverberation; if the gain g of the (M–N) channel path is adjusted to match the gain of the direct sound passing through the reverb unit, then the direct sounds will still come from their original positions. For the best results, the N channel signal emerging from the split matrix should be the encoded signal of a workable N channel matrix system of M channel sound; e.g. for M=4, the N channel signal might be that of, say, the Sansui or CBS 'SQ' two channel matrix system. As another example, if it is desired to use a three channel unitary reverb unit to provide colourless four channel reverb, the one channel output of the split matrix might be the 'focus' signal of ref. 6, and the three channel output might be the signals L, R and P of table 6 of ref. 6.

FIG. 9 COLOURLESS M-CHANNEL REVERBERATION UNIT BASED ON AN N-CHANNEL UNIT (N<M)



It has been the aim of the two parts of this article to survey techniques of using delay lines in synthetic stereo reverb units, and it has not been possible to go into many proposals in any depth. It will be apparent to the reader that a full understanding of such reverb units is inherently highly mathematical, but the circuits derived have the virtues of relative simplicity and good behaviour. Furthermore, they offer advantages such as a good stereo spread of reverberation and a colourless quality that are not otherwise obtainable.

As one recent commercial 'stereo' reverb unit is in fact two mono reverb units, it is worth mentioning that a good stereo spread of reverberation is a highly desirable property that is responsible for the sense of depth and space associated with good stereo. The sceptic can convince himself of this by adjusting the stereo width of any good crossed figure-of-eight coincident microphone recording made with reasonably distant microphones. I hope to present results about the importance of stereo reverb spread in these pages at some future time, and references 7 and 8 provide useful information on this.

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STUDIO DIARY

continued

and have demo discs made. These are sent to the disc jockeys at the radio stations and if the listeners show sufficient interest in any of the records by asking to hear them again then they are released. Record sales are very low over there, an LP that sells 4,000 copies being considered to have done very well, and this is the reason for the cautious approach to releasing records.

Because record sales are so low I was surprised to hear that Garrett are planning to open a 16 track studio in the near future. At the moment they have four track recording facilities, although their 32 channel control desk is designed for 16 track working. Clients are continually asking for 16 track facilities in spite of the fact that they seem to be managing extremely well with the existing set up. The studio has achieved a great deal, their first pop recording getting to the top of the hit parade and seven of the current top 10 being recordings made at Garrett. They have also had more records than anyone else at the number one position. The studio is the most expensive in Israel, the charges being approximately double those of their rivals (both of them). They are, nevertheless, very cheap by London standards, the sterling equivalents being £15 per hour for recording and £10 for dubbing, mixing and editing.

With the high cost of equipment, high duty and low returns it would seem that in Israel you need to have seven records in the top ten to survive.

In the September issue, I reported that **Sound Exchange Studios** of New York had a digital tape timer with the capability of searching for pre-designated locations on the tape. Designed by Steve Katz and Richard Factor, a number of these units were made by the associated company, Even Tide Clock Works, of which Steve is the chief engineer. The latest news is that Ampex have bought the device and will be marketing it soon.

Impressions

BY JOHN SHUTTLEWORTH

AUDIO FARE AT THE FAIR

THIS year's Audio Fair, like last year's, was held at the Olympia exhibition hall towards the end of October. Regrettably, a number of well known firms were not exhibiting this year, but there were certainly plenty of others showing things of interest.

Revox were displaying their Dolby B recorder which was playing a ¼ track 9.5 cm/s Dolby tape into Sennheiser headphones. The signal-to-noise ratio was excellent but the signal itself was lacking in hf response and did not sound clear to me.

Ferrograph were also displaying a Dolby B recorder playing Dolby tapes at various speeds through Sennheiser headphones. While I found the s/n ratio again excellent, I did not find the 19 cm/s tape as satisfying as I would expect. Only having heard the Sennheiser phones briefly before, I wondered if these were the cause—but a visit to the Sennheiser stand on the second floor soon dispelled doubts on this score. Enquiry at their desk elicited the information that they were using non-Dolby tapes on a Revox at 19 cm/s.

A visit to the Kellar stand, where the *KDB1* and *2* Dolby B noise reducing systems were being shown, reinforced my experience that at slow tape speeds these units do an excellent job.

The other noise reduction system demonstrated was the Philips dynamic noise limiter. This works on replay only and is claimed to give a significant reduction in hiss level from any programme source, be it tape, disc or tuner. Cost is estimated at about £4 extra when fitted to a Philips cassette recorder and about £14 as a complete add on unit for any system.

The demonstration of the system on cassettes was impressive and, since it can be used to improve the s/n ratio of existing recordings, it seems to be well worth investigation.

Philips were also demonstrating their video cassette recorder. This has its own tuner and can record one programme while another is being watched. It records in colour to a very acceptable standard, will accommodate a colour camera (not yet available from Philips) and will replay prerecorded cassette programmes.

Operation is as simple as a domestic cassette audio recorder and at under £300 this unit should create a lot of interest. On the Philips stand downstairs was an enormous recorder with spools nearly a metre in diameter. These are not being made generally available in spite of the interest shown by visitors.

The most impressive presentation was by Armstrong who decorated the end of their air conditioned room to resemble a modern living room, and had fully automated demonstrations worked by a Revox, I believe with holes punched in the guard band of the tape to actuate a photo cell. The demonstration ran smoothly and the material was varied and well chosen. The psychedelic lighting during the 'pop' session was most effective, and obviously a good deal of thought and trouble had been taken.

Unfortunately the sound was not as good as it might have been. Sitting in the front row, I began to suspect the speakers were out of phase. I mentioned this to the gentleman from Armstrong on the way out; he became most indignant, claiming that the sound was all right and if I didn't like it there must be something wrong with me. I know he is not alone in the latter opinion, but I still would have liked the chance to switch the Revox to mono to check my impressions. If this was not the cause, then there must have been something amiss elsewhere.

The most musical and satisfying demonstration I visited was that given by Quad. This company always go to great lengths to find suitable signal sources, and this time they were using a nine year old disc suitably filtered, and 38 cm/s tape played via a Studer, with tone controls flat. From both disc and tape the sound was clean and pleasant and it was one of the few demonstrations that I would like to hear again.

The new look *ELS* with the black grille was far more elegant than I had imagined. The *FM3* tuner is now in production and should be available soon.

After leaving the Quad demonstration I was attracted to the door of the Hi Fi Theatre by a loud volume of sound coming from there. When I went in, the noise proved so unpleasant that I had to leave. Going to the main entrance to the theatre, I read that the session in progress was a lecture on multitracking so I must have arrived at the instant when we were being shown how easily things could go wrong.

AKG were showing their range of headsets, outstanding among these for value being the *K60*—pleasant to listen to and light to wear.

Other headsets I noticed were the Koss range which, though giving excellent sound from the more expensive version, were generally too heavy for me and tended to fall off if one looked downwards.

Goodman's were showing the new 'double *Maxim*' and unfortunately announce the demise of the old *Maxim* at the same time. With the exception of the Celestion *Ditton 10*, I know of no commercially available small speakers suitable for use in mobile control rooms that come anywhere near the old *Maxim* for sound quality. I hope to be able to examine the 'double sound' more closely soon.

Tannoy were giving their usual demonstration, switching disc through various units in turn. The *York* gave an excellent account of itself. It was a good move on Tannoy's part to have sectioned units on display, as well as glass sided cabinets enabling the visitor to see the very high standard of workmanship.

I found the Goldring demonstration a little disappointing as I know the *800E* to be a very 'musical' cartridge and the Quad *303* + *33* to be an impeccable amplifier. To me the sound was a little too strident though generally clean and otherwise pleasant. Either the discs in use or the speaker system must have been rather bright and my finger itched to push in the 7 kHz filter on the Quad, a suggestion which horrified the Goldring engineer present at the time.

Uher were showing their 'Hi Fi' stereo cassette recorder which is designed for the bottom end of the industrial market. If some of the sounds it produced at Olympia are any indication, they have a winner here. Though it costs £185, its ease and convenience of use should make it ideal for interview work.

Heco were demonstrating their range of speakers and made a point of the fact that they all sounded alike, which they certainly did, a change from some manufacturers who display speaker systems all sounding different, but all claimed to be right.

Sansui were demonstrating their four channel synthesisers which, although difficult to assess properly owing to the large number of people in the room, gave impressive results on sound effects. Jets landing and taking off sounded most realistic. On music it was not so successful in the adverse conditions of the demonstrations and one had the impression that 'Japan's finest symphony orchestra' also used extra percussion at the back of the hall. The sound, was however, impressive enough to justify further investigation under better conditions.

I find DIN plugs ridiculous to use and expensive to buy but I suppose we are stuck with them now. Quality Audio Supplies were showing a large selection of leads and plugs which seemed to be of reasonably good quality at a lower price than most others available. It is good to see a British manufacturer who can compete with our Japanese friends.

BY ANGUS MCKENZIE

REVAMPING VALVE EQUIPMENT

I WAS surprised to learn that currently very little is taught about valve circuitry in university and college courses in audio engineering. For this reason there appears to be considerable vagueness on the part of younger engineers about the workings of valves in audio equipment. It should be made clear therefore that much excellent equipment has been designed using valves, equipment which, far from being only good for the scrap heap, may be considerably improved by minor modifications using, for example, better types of valve.

A customer recently brought in a stereo portable valve mixer made by a reputable supplier of mixers for public address and semi-professional use. Surprisingly, the company could not supply a circuit diagram for this equipment although it had been bought fairly recently, and my colleagues and I had to puzzle out much of the circuit to find out why the performance was so poor and how it could best be improved. The first valve, an *EF86* pentode, had only to amplify by a small amount since the customer had specified that the mixer was for use with capacitor mics. The manufacturer had obtained a reduction of gain by taking off the cathode decoupling capacitor to increase current feedback, but this caused a deterioration in hum level by the cathode being at a higher impedance from ground. The anode load resistance had not been reduced in value and thus directly fed a 500 kΩ channel gain pot with the slider connected to a 500 kΩ feed resistor to a mixing bar, which then fed yet another 500 kΩ stereo master gain control, the latter slider feeding through a series resistor to a triode with a little anode to grid feedback. Not only was the noise level exceptionally bad, but the frequency response of the equipment varied depending upon the positions of the channel and master gain controls. The output stage also contained a Baxandall type tone control circuit, the audio output from the mixer being taken from the output of this stage. No one told the customer when he bought the mixer about the need for this stage to look into a high impedance. For some time he had been using fairly long leads to his tape recorder, thus introducing more high frequency loss.

The overall distortion of the mixer was approximately one per cent under reasonable operating conditions. The addition of a simple cathode follower after the original output stage, preceded by a new master gain control of 250 kΩ, not only allowed the mixing amplifier and tone control stages to be worked at a higher, less noisy level but also gave an output impedance of only a few hundred ohms. All this needed the addition of relatively few components. The original master gain control was disconnected and the high impedance mixing resistors taken straight to the grid of the mixing valve, giving virtual earth mixing. In this way some 250 mm of screened wire to and from the master gain control was also eliminated, giving a response within fairly close limits from 30 Hz to 20 kHz. The smoothing was also improved by the addition of an extra decoupling capacitor, helping to improve the noise level overall by approximately 10 dB under the conditions required by the client. The final performance was quite reasonable, and the distortion was improved to one tenth of the original value. This sort of modification to equipment which some users are on the point of throwing out can so easily be carried out in a fairly short space of time, and it is time well spent.

There is a glut of secondhand, early models of professional stereo tape recorders on the market. Models originally costing over £1,000 are now changing hands for two or three hundred pounds, and occasionally even less. Quite a number are in excellent condition mechanically but are in a bad state electronically, as well as having well-worn heads which do not have direct replacements at a reasonable cost. A year ago I was quoted £60 for a replacement head for a German recorder, the explanation being that these heads had to be specially made in small quantities for replacements. Most machines made about 10 years ago had heads which required a step-up transformer to work into the first valve, although some were of rather higher impedance and worked direct. The latter were invariably unbalanced and tended to suffer from hum pickup. The early Revox models are a typical example of this.

Most replay heads available today are made to match into transistorised replay amplifiers which require a head inductance of between 65 and 85 mH to match into them for best noise performance. If an old type replay head is replaced by a more modern one an attempt should be made to select one having a similar inductance. Otherwise the original valve circuit will have to be completely replaced by a transistorised one.

It will usually be found that because of its better construction and usually finer replay gap, a modern replay head will have better high frequency performance. In certain cases turning down the replay equalisation may only shift the replay time constant and not remove the high frequency boost which was originally designed to give a flat playback from the older head. In fact it is far easier to design a replay amplifier giving a flat output response from heads available today than it was a decade ago. Some very unusual types of replay amplifier time constant correction were used with valve equipment. One frequently found a very high ratio input step-up transformer working directly into a valve stage with heavy anode to grid feedback. The feedback would also incorporate a time constant circuit, to give the correct equalisation curve, as well as additional high frequency equalisation for head loss corrections. Such a circuit provided a 6 dB per octave bass boost because the replay head's inductance was made effectively greater by the step-up transformer, and the input grid acted as a virtual earth. Under these circumstances the equivalent circuit of the replay head can therefore be regarded as a low impedance voltage source driving a very high inductance to the virtual earth point, the inductance causing a 6 dB per octave roll off from the bass end upwards. The response of the entire system was highly dependent on the replay head used. With new heads drastic changes in component values may have to be made round the first valve. It is not easy to calculate these, since the input transformers used may have secondary impedances as high as 1 MΩ at high frequencies, and leakage capacitances and inductances between the primary and second windings of the input transformer may have unpredictable effects on a modern replacement head.

A number of companies are now making transistorised replay amplifiers built on printed circuit boards and requiring from 18 to 30V supply. These will usually be found to have an unbalanced input unsuitable for some older machines having a balanced and sometimes very long output lead from the head to the original transformer. A one to one, mumetal-screened input transformer should be used under these circumstances. It should be designed to work into approximately 10 kΩ maximum, which is the impedance reached at around 20 kHz with a modern 70 mH replay head. Such a step-up transformer will often reduce hum level pick up in the replay head wiring dramatically.

The dc supply to the transistorised replay amplifier can be easily taken from the machine's HT supply, a large resistor of 47 kΩ or so feeding a zener diode to earth, and a dc feed

(continued on page 39)

ARP 2600/3604 ELECTRONIC MUSIC SYNTHESISER

THE ARP *2600/3604* belongs to the category of electronic musical instruments known as voltage controlled synthesisers. Conventional electronic keyboard instruments, politely called 'organs', comprise 12 oscillators pre-tuned from C up to B-flat, additional octaves being obtained by frequency division. The result is polyphonic but lacks much in the way of lasting tonal interest—I emphasize the word *lasting* since even a sinewave can have a temporary appeal. Synthesisers, on the other hand, use comparable circuits (oscillators, filters, transient generators, reverberators) in an essentially linear rather than parallel fashion to obtain a far wider range of tone colours. This advantage is off-set by one disadvantage: the resultant instrument is, from the keyboard's point of view, monophonic. In practice this means that if you play C and D simultaneously, you only get C. There are several ways round this problem, which I'll return to later.

Manufactured in the US by Tonus, the *2600* is the smaller of two synthesisers in the ARP range. It was conceived as a live performance instrument in that there is little need to 'plug-up' before a performance; the more common module connections have been prewired and may be brought into effect simply by opening the relevant fader.

The synthesiser face is divided into 11 panels (detailed in **figs. 1** to **11**), each representing one section of the instrument. Sections may be coupled into a wide variety of chains, depending on the effect you are after.

Fig. 1 shows the extreme left section. The seven black blobs represent the miniature jack sockets used to couple modules not already joined through faders. If one wished to process an externally created signal (piano?), this could be miced direct into microphone preamplifier. Gain is controlled by a rotary fader and a three-position range switch. The amplified signal could then be extracted at the output socket and plugged into another module. If that module just happened to be the envelope follower, then this connection already exists. You simply raise the vertical mic preamp slider to the desired level.

You might alternatively wish to use speech to modulate a sawtooth tone. Since the sawtooth is prewired to one input of the ring modulator, a patch cord joining the mic preamp output to the other modulator input achieves this effect. Inserting a jack overrides the prewired sinewave from VCO-2 (Voltage Controlled Oscillator Two) so all that remains is to hear the result. The ring modulator output may be patched via the mixer into the amplifiers feeding the monitor loudspeakers.

Fig. 2 shows the first of the three tone-source oscillators incorporated in the *2600*. Two horizontal sliders, one coarse, one fine, determine the initial oscillator frequency. In a live performance, this might be adjusted so

(continued over)

FIG. 1

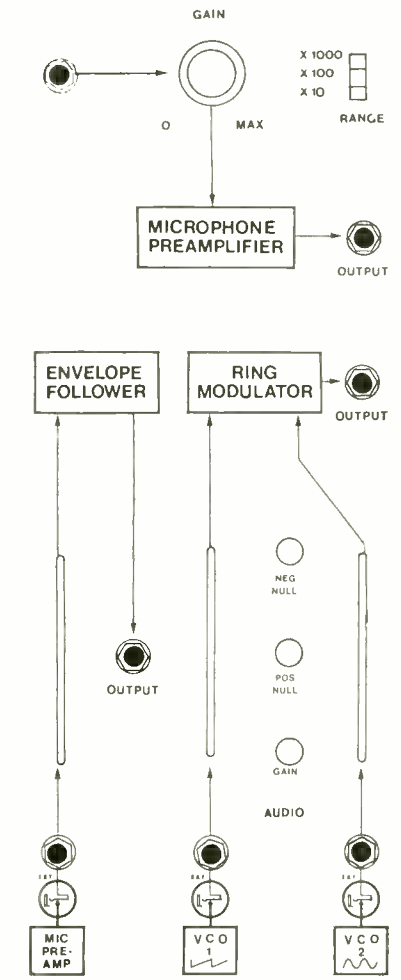
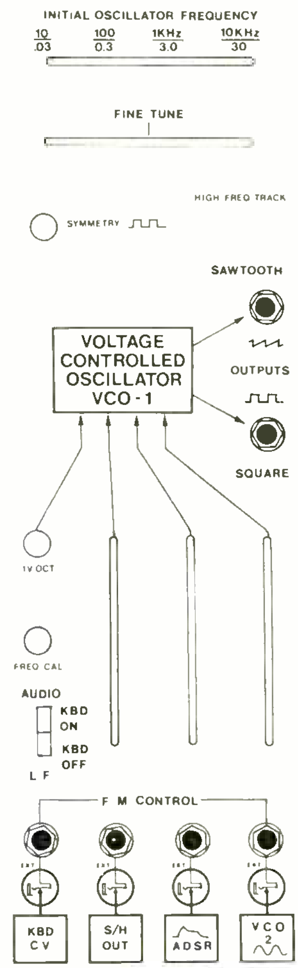


FIG. 2



MANUFACTURER'S SPECIFICATION

Compact electronic music synthesiser including the following units:

Three voltage controlled oscillators covering .03 Hz to 20 kHz in two ranges. Five waveforms including variable-width pulse, triangle, sine, square and sawtooth.

One voltage controlled low-pass filter. Variable resonance, dc coupled, doubling as low distortion sine oscillator.

One voltage controlled amplifier with exponential and linear control response characteristics.

One ac or dc coupled ring modulator.

Two envelope generators.

One envelope follower.

One random noise generator. Output continuously variable from flat to —6 dB/octave.

One bidirectional electronic switch.

One sample and hold with internal clock.

One microphone preamplifier with variable gain in 20, 40 and 60 dB ranges.

One general purpose mixer with panpot.

Two voltage processors with inverters.

One voltage processor with variable lag. Doubles as low-pass filter.

One reverberation unit. Twin uncorrelated stereo outputs.

Two internal monitor amplifiers and speakers with stereo 8Ω headphone jack.

One four-octave keyboard with variable tuning, variable portamento, variable tone interval and precision memory circuit.

Price: £1,360 (This equipment is also available on hire from F. W. O. Bauch at £25 per day basic rate.)

Manufacturer: Tonus Inc, 45 Kenneth Street, Newton Highlands, Massachusetts 02161, USA.

Distributor: F. W. O. Bauch Ltd, 49 Theobald Street, Boreham Wood, Herts.

that middle C on the *3604* keyboard corresponded to an accompanying acoustic instrument. Used conventionally, the keyboard would then raise or lower the tone frequency by the normal equal-temperament ratio (1V per octave, 1/12V per semitone). Alternatively, the preset tone interval may be switched out and microtone ratios substituted.

Oscillators Two and Three function in the same way, producing the waveforms illustrated beneath each output socket. All three modules have fm control inputs, prewired as labelled. The bottom-right socket on VCO-1 is coupled to the sinewave output of VCO-2. If VCO-2 is switched to its lf range, and the VCO-2 fader raised, the resultant slow sinewave swings the VCO-1 frequency across a wide or narrow range, the degree depending on the control voltage. Left of this socket, still on VCO-1, is the ADSR signal. This is prewired from the attack / sustain / decay / release generator, the section converting constant-level tones into, for example, simulated bell tones. Opening the ADSR fader on VCO-1 produces a pitch modulation each time the keyboard is pressed.

'S/h out' (we're still on **fig. 2** if you're lost) introduces a device I have not hitherto found on a portable synthesiser. This is fed by a 'sample and hold' module producing purely random voltages, in turn derived from white noise. The resultant music, and it unquestionably is music, is as uninhibited as ink blottings on a stave: never repeating, sporadically inspiring. I am told it's addictive.

Fig. 3 illustrates the VCO-2 panel. This is a more versatile oscillator than VCO-1, with four output waveforms. The mark/space ratio of one shape may be modulated by a signal inserted at the bottom right socket, in this case prewired to the noise generator. A horizontal slider beneath the tune control sets the initial pulse width. Any or all outputs may be patched into other sections without audibly reducing the pitch.

Fig. 4 shows the third oscillator, VCO-3, at first glance identical to VCO-1. The two significant variations are slider control of the pulse width (governed in VCO-1 by a preset), and a prewired fm signal from the noise generator. This differs from VCO-1's prewired s/h generator in producing a continuous random change in tone frequency, rather than discrete random steps. Otherwise the fm prewiring to VCO-3 is identical to VCO-1.

We have now covered three tone sources and two 'treatments'—the ring modulator and the envelope follower. **Fig. 5** shows the heart of the *2600*, from the live performer's point of view: the voltage controlled filter. This is prewired to accept and mix signals from the ring modulator, VCO-1 (square), VCO-2 (pulse), VCO-3 (sawtooth) and noise. These are labelled 'audio' and pass through the filter network. The three 'control' inputs govern the filter characteristics in a manner that makes studio desk equalisers look very tame. Once the initial filter and resonance frequencies have been set, opening the VCO-2 slider results in the VCO-2 sinewave swinging the filter frequency. The swing speed is dependent on the sinewave rate which may be anything from 0.3 Hz to 10 kHz.

The ADSR input produces one of the most interesting basic effects available on a synthesiser, altering the tone colour of a note during its attack/decay cycle. The ADSR label shows the type of cycle commenced each time the ADSR section is triggered (for example by pressing the keyboard). The leading and trailing pulse shapes may be adjusted over a usefully wide range, as may the sustain voltage and final release time. Since the filter frequency is dependent on a control voltage (whether fixed by the two horizontal faders or applied from an external source), it follows that the ADSR signal can be made to modulate the filter frequency during the life of each note. Since

FIG. 3

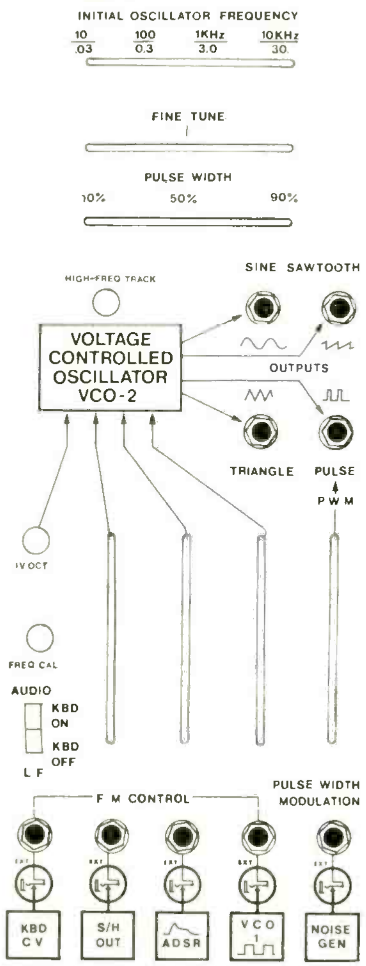


FIG. 4

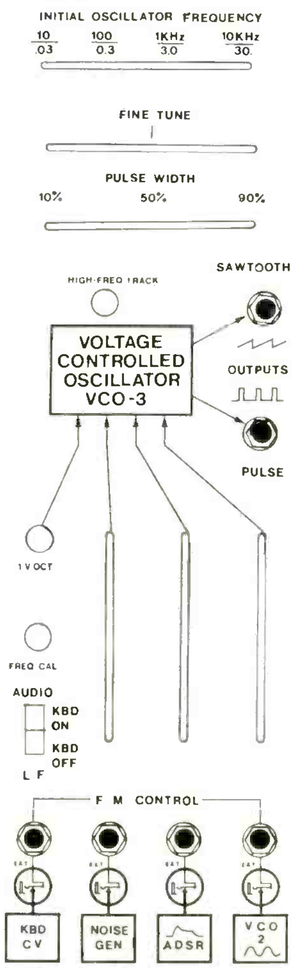
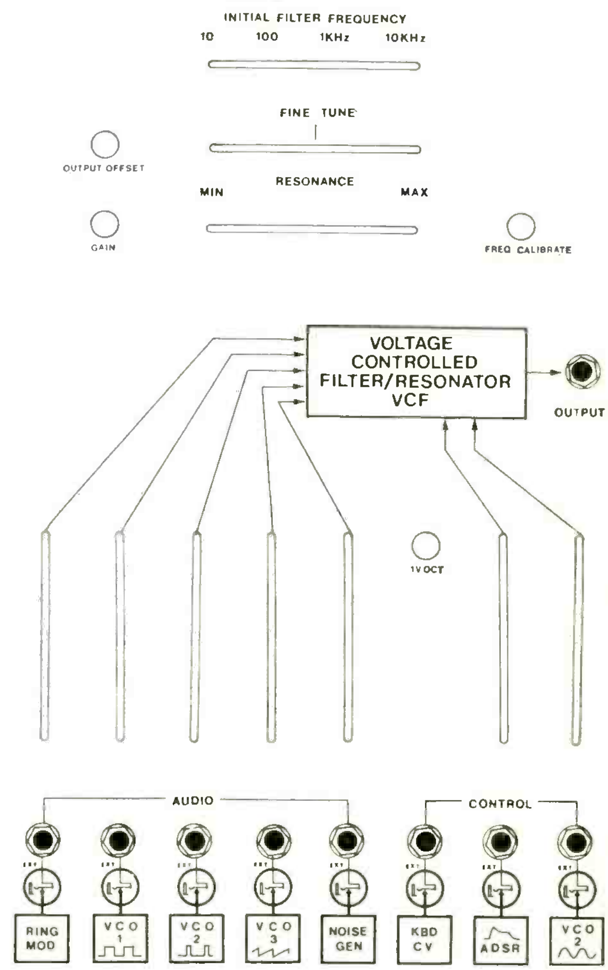


FIG. 5



each note receives the same treatment cycle, the effect is musically sensible and yet more extreme than any acoustic instrument could usefully achieve.

The filter output may, like any other output, be routed to any audio or control input without causing any damage. If you wish to hear the output, you simply raise the prewired fader to the mixer (**fig. 8**) and turn up the internal loudspeaker level. In this condition, the keyboard would control the pitch of the three vcos unless overridden by alternatives patched into the KBD CV (keyboard control voltage) sockets on each oscillator. The filter cutoff frequency is raised and lowered by the same basic semitone, again unless over-ridden.

The simplest form of dynamic control available on a synthesiser is the on/off provided on most divider organs. You select a key, press it, and out comes your tone. The attack is effectively instant, as is the 'decay' when the key is released. To obtain this and more complex wave envelopes, the filter output, oscillator output or what-have-you is routed to the voltage controlled amplifier. The two audio inputs (bottom left, **fig. 6**) are prewired to the voltage controlled filter output and ring modulator output. Again. any alternative output could be patched into these sockets, breaking the prewired route.

FIG. 7

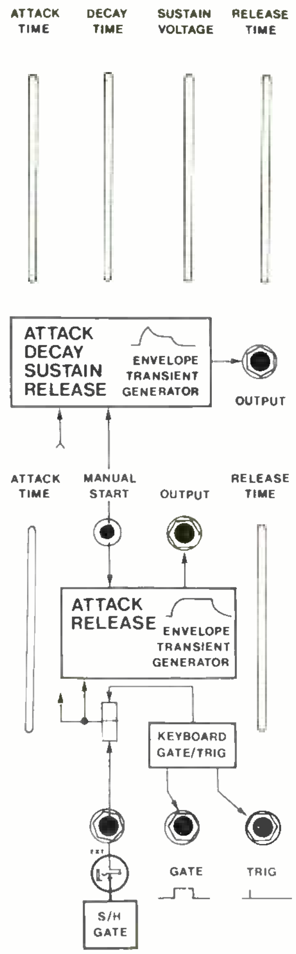


FIG. 8

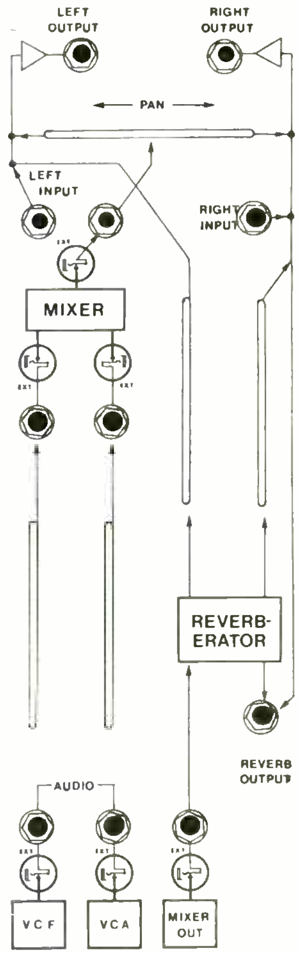


FIG. 6

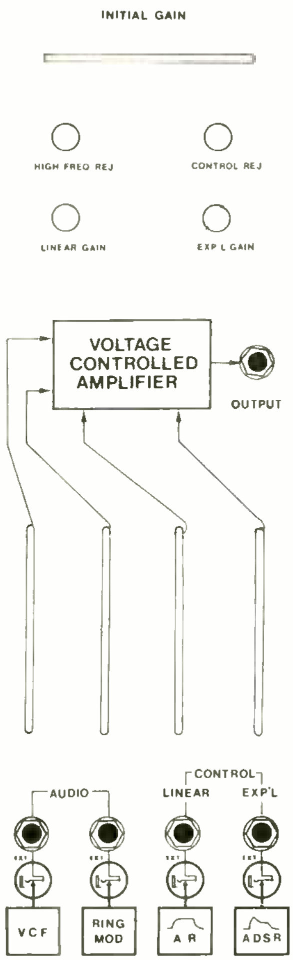
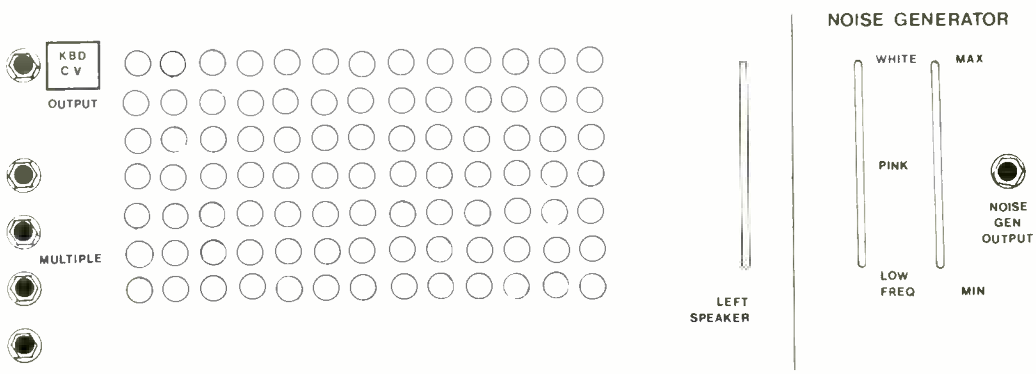


FIG. 9



The two prewired control signals (bottom right) come from a pair of envelope transient generators in an adjacent section. The lower pair of sliders in **fig. 7** respectively govern the leading and trailing edge of a transient voltage. Since the gain of the vca is governed by the control voltage, a tone entering it will be modulated in loudness according to the rise and fall of the envelope voltage.

Four sliders at the top of **fig. 7** produce a more complex envelope which rises to a peak (according to the attack time setting), then descends more or less rapidly (decay time) to a ramp. The ramp level is set by the sustain voltage slider, and its length by the 'release time' control. The two envelopes may be mixed in varying proportions by adjusting the AR and ADSR sliders in **fig. 6**. The initial vca gain is set by the horizontal slider.

Fig. 8 shows what would commonly be the final section in an ARP chain. The two audio inputs at the bottom left are respectively prewired to the voltage controlled filter and voltage

(continued on page 37)

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continued

controlled amplifier. The two mixer channels may be patched to separate left and right outputs or reduced through the prewired routeing to a single channel controlled by the horizontal pan slider. The mixer output is also prewired to a pair of reverberation springs, their outputs being fed out of phase to the final output stage. Vertical sliders govern the reverberation level and, once more, the prewired input may be over-ridden and/or the spring output taken to an alternative section.

Fig. 9 shows the left loudspeaker grille (the right can be seen in the photo, as can the relative positions at each section). Internal monitor level is governed by the speaker fader adjacent to each grille. Left of the drawing are a keyboard control voltage output (rising and falling according to the keys pressed) and four 'multiple' sockets. If you wished to patch several outputs into, say, one side of the ring modulator, you could plug up to three signals into the parallel coupled multiples, taking the output from any remaining socket in this group. If you ran out of multiples, you would have to solder up your own multiway patch cords.

The faders on the right of **fig. 9** control the output level of a noise generator. Just left of this fader is another which filters the 'white' hiss into a bass-heavy 'pink'.

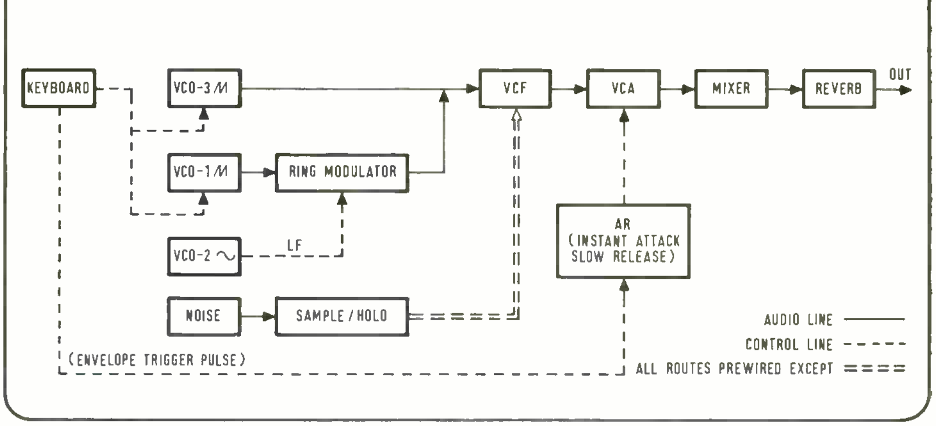
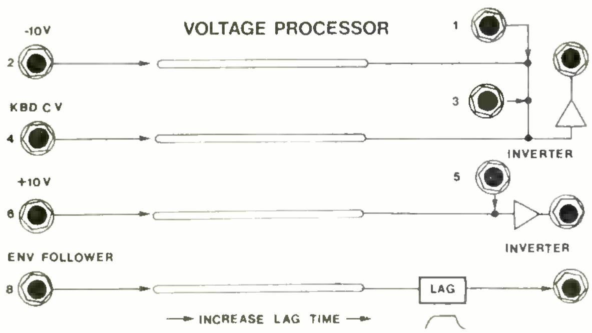


FIG. 12 LOCKED HARMONY WITH RANDOM FILTER FREQUENCY

If you possess at least a smattering of musical ability, you may have tried playing a one-finger melody on a keyboard instrument using a left finger to descend from the starting note by the same number of semitones as the right rises ('contrary motion'). The voltage inverter (**fig. 10**) makes experiments of this kind very simple. One of the six inverter inputs (number four) is prewired to the keyboard control voltage. If this voltage is inverted (by opening the horizontal slider) and patched into an oscillator, the resultant tone can be adjusted to fall in pitch as you go up the keyboard, rising as you go down. It is the work of a few seconds to set to play a synthesiser—there are no compulsory years of key bashing—but a versatile imagination is essential.

Fig. 12 shows a network of audio and control patches typical of those possible on the *2600*. The resultant sound can be changed beyond recognition within the network by varying relative oscillator frequencies, initial filter frequency and attack/release envelope shapes. To reproduce a network exactly, you would have to note every relevant patch and slider position exactly. ARP simplify this forbidding task by supplying pads of panel facsimilies from which **figs. 1** to **11** are reproduced. In this

FIG. 10



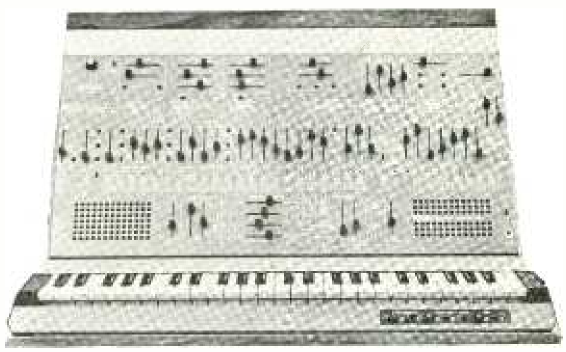
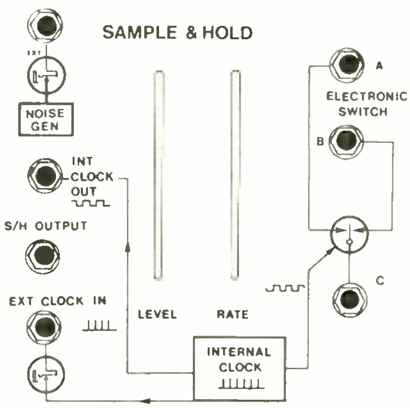


FIG. 11



two oscillators to rise and fall symmetrically.

The sample and hold section, mentioned earlier, samples the noise generator output at intervals predetermined by the 'rate' slider. It produces an endless series of ramp voltages, each sustaining until the next sample. Its applications are obvious though probably too avante garde for this decade's 'Top ten'.

The **fig. 11** panel also carries an electronic switch, producing an output which alternates between signals patched into sockets A and B. Alternatively, one signal fed to C is switched between A and B.

And that's it. The various labelled circles represent covered presets intended for routine tuning though in fact considerably extending the instrument's flexibility. Like any other musical instrument, the sounds produced by a synthesiser depend very largely on the performer's skill. Little manual dexterity is required case, VCO-1 and VCO-3 have been spaced four semitones, producing what musicians are pleased to call a 'third' whenever one keyboard note is pressed. The VCO-1 waveform is made slightly more complex by being amplitude modulated in the ring modulator. VCO-2 provides a slow modulating sinewave. The tones thus generated are applied to the vc filter, vc amplifier, mixer, reverb springs, and then out to the tape machine or monitor amplifier. Nothing extraordinary. Note, however, the random voltage ramps being applied by the sample and hold generator to the vc filter. A rapid sample speed produces a fast modulation at the filter frequency. Though the filter cutoff point changes at a regular rate, its range varies randomly. The effect was entirely new to me, and also pleasant.

Since the keyboard is in circuit, the **fig. 12**

(*continued on page 39*)

ARP 2600/3604 FIELD TRIAL

continued

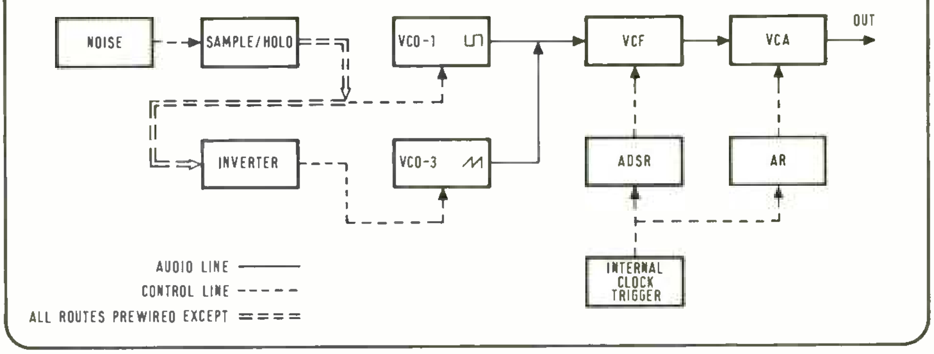
network is capable of playing any monophonic melody (unless you credit the locked thirds as being polyphonic). **Fig. 13** shows another recipe, this one requiring no human performer. Here the random s/h signal modulates the VCO-1 squarewave frequency. The same random signal, inverted, also controls VCO-3. Tonus pretune the inverter so that, with the slider fully open, the output is an exact polarity reversal of the input. VCO-1 and 3 are thus locked in symmetrical polyphony. The ADSR envelope varies the filter frequency during the life of each (random pitch, uniform duration) note. Each filter envelope (ADSR) and each dynamic envelope (AR) are triggered by the same 'clock' oscillator controlling the sample and hold rate.

These are just two of many thousands of networks obtainable with the ARP. Unquestionably, many syntheses are uninteresting, others downright unpleasant unless heard in a suitable context. But given patience and imagination, plus a multitrack facility, the composer is in total control of his audio environment.

The purpose of a field trial is to discover the bugs. I found a few. Firstly, the spring reverberation unit contributes a hum. This was not high enough to upset single syntheses but caused trouble when I attempted multitracking. Bauch rightly point out that a studio would use an external reverberation unit.

Secondly, the lack of numerical control calibrations and the rather sporadic control layout made notation rather difficult, with or without the facsimile pads.

FIG. 13 RANDOM MELODY WITH INVERTED HARMONY



Third, the keyboard to synthesiser umbilicals are forced through severe angles which tend to pull the plugs from their sockets.

Fourth, the absence of a power indicator might conceivably lead to accidents, particularly as the mains switch is a very small and easily overlooked toggle.

My fifth and last criticism, equally if not more applicable to another American maker of synthesisers, concerns the patching arrangement. The *2600* would be far more versatile and easier to use if it incorporated the matrix board patching system pioneered by a certain firm in Putney and used on the larger ARP *2500*. Unless you possess a forest of multiway patch cords, you cannot equal the network permutations obtainable on a pin matrix. Even with such a forest, the consequential tangle of cords falling over the panel face would be difficult to work with.

Although the pin matrix is superior to patch cord routeing, the ARP prewiring system must offer considerable attraction to performers of popular keyboard music. For simple networks, opening prewired faders is faster even than pin plugging and the chance of 'missing a hole' smaller.

The *2600/3604* is attractive in appearance and fairly easy to carry. Metal or wooden cabinets are available and both are sturdy. The metal is visually the more attractive.

I can best sum up my reaction to the *2600* by saying I should like to get my hands on the *2500*.

David Kirk

Manufacturer's comment: All later models and facsimiles carry numerical control calibrations. They also incorporate a power indicator. The umbilicals have been replaced by one long connection cable.

RECORDING STUDIO TECHNIQUES

continued

to the replay amplifier is taken from across this (the feed being positive). Frequently only an external switch throwing different values of resistor in the feedback circuit of the transistorised replay amplifier will be necessary, although it may be desirable to retain the machine's variable peaking equalisation circuits, particularly for obtaining a flat response at lower speeds.

Such modifications as those outlined above have been carried out by the writer to a Telefunken *M5* recorder with an improvement of approximately 6 dB in the signal-to-noise ratio of the replay amplifier in addition to a significant improvement in frequency response.

Many older stereo tape recorders have record amplifiers with an output far in excess of any required today since tapes produced at the time the machines were made were considerably less sensitive and had much poorer high frequency response than those available today. Many users have found the hum level of the record amplifiers excessive when used with modern tape, and this is due to the final amplifier requiring less drive to give a particular tape flux level. Any hum present in the output stage therefore becomes more noticeable on the tape and it is necessary to decrease the gain in the record amplifier's output stage by increasing the feedback. At the same time care should be taken to preserve the high output impedance required by most head feed circuits, otherwise the value of the current head feed resistor should be increased. The Telefunken *M5* drove the head from a voltage step down, current step-up transformer, and constant current was achieved by feedback across a low value resistor in series with the earth return to the secondary. Increasing the value of this resistor considerably increases the feedback and reduces the hum level, as well as improving linearity of the output stage. To avoid instability treble boost capacitances in the cathode circuitry should be removed and the bias traps in the head unit should be very carefully adjusted to minimise the possibility of bias frequency being fed back to the output driver stage. Minor equalisation may also be necessary in the feedback circuit to flatten the bass response and hence convert the entire output stage to a constant current drive. The variable equaliser found in the early stages of many machines can then be modified to give a variable, high frequency 6 dB per octave lift, which is all that should be necessary with modern record heads and tapes for use at 19 and 38 cm/s.

Modifications such as the above can give an electronic performance almost as good as on modern machines, but the condition of the tape path should be very carefully examined. It may well be necessary to replace almost all the tape guides and flywheels if they are worn and liable to cause tape damage. In general many older machines were built like battleships and if suitably modified will give many more years of service. Comparatively recently the BBC embarked on a programme of rebuilding many of their EMI *BTR2* recorders, and these are currently enjoying a new lease of life.

However, it is essential that the importers of foreign equipment either carry a more comprehensive selection of spares or provide a very much better importing service than has been evident of late. With this in mind it cannot be stressed too strongly that a good selection of spares should be bought with any modern tape recorder since it is only fair to assume that some difficulty might be experienced in a few years time. It would be wise for any prospective purchaser to ensure that adequate spares are available at short notice and that they will continue to be so at least five or, better, 10 years after the model has been discontinued.

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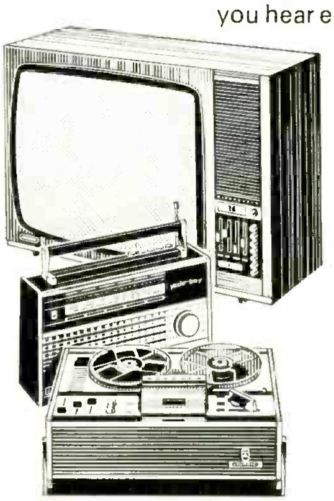

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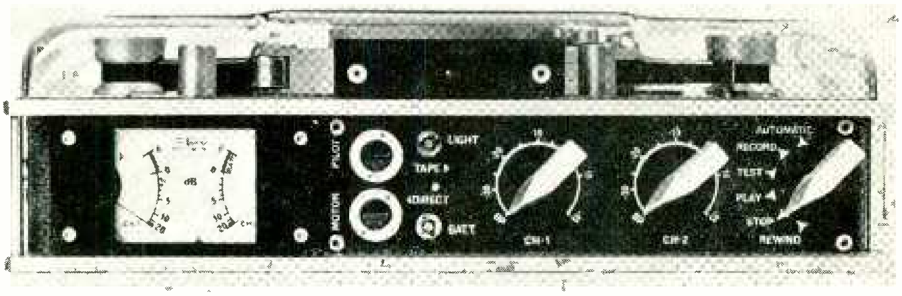
Equipment Reviews

STELLAVOX SP7 BATTERY STEREO TAPE RECORDER

MANUFACTURER'S SPECIFICATION

Speed stability at 25°C:	less than 0.1%
Tape slippage:	less than 0.1%
Wow and flutter:	less than ± 0.12%
Built-in power supply:	Six batteries of standard size AA for 2-6 hours
External power supply:	12 to 20V DC about 0.12A
Frequency response of the amplifiers:	20 Hz to 20 kHz ± 1 dB
Frequency response, overall:	30 Hz to 15 kHz ± 2 dB
Total harmonic distortion at 1,000 Hz:	less than 2%
Erasure at 1,000 cps 500 pWb/mm:	greater than 70 dB
Signal to noise, weighted (ASA 'A' filter) (at 500 pWb/mm):	greater than 60 dB stereo, 65 dB full track
Crosstalk overall:	greater than 40 dB
Loudspeaker diameter, with power amplifier:	88 mm, 1W
Inputs—Mics 1 and 2	0.2 to 75 mV
automatic	symmetrical 1 to 40 mV
mixer 1 and 2	1.55 V/ 820 kΩ
diode 1 and 2	440 mV adj. with pot
pilot	1V to 1.5V; Z greater than 10 kΩ
clapper	positive pulse
Outputs—Phone 1 and 11 (output)	1.55V (max 2.8V) asym
Phone 1 and 2	1.55V/5 to 2000 Ω
diode 1 and 2	440 mV/470 Ω
pilot (with SXQ)	1V to 1.5V
Weight:	3.1 kg, 3.5 kg with batteries and tape
Dimensions, overall:	80 x 215 x 300mm
Max. reel diameter:	130mm (max. 300mm with extenders)

Price: £525 (stereo ½ track, 38 cm/s corrected)
Distributor: Beaulieu Cinema Ltd, 234 Baker Street, London NW1 5RT.



THE review model arrived in a suitcase complete with two AKG *D224* microphones and leads, an AKG *M2* stereo microphone mount, a pair of Sennheiser stereo headphones, two reels of Scotch *203* tape, NAB spool adapters, batteries and mains power unit/battery charger. In fact, with the exception of a microphone stand, it represents a complete recording studio in a suitcase.

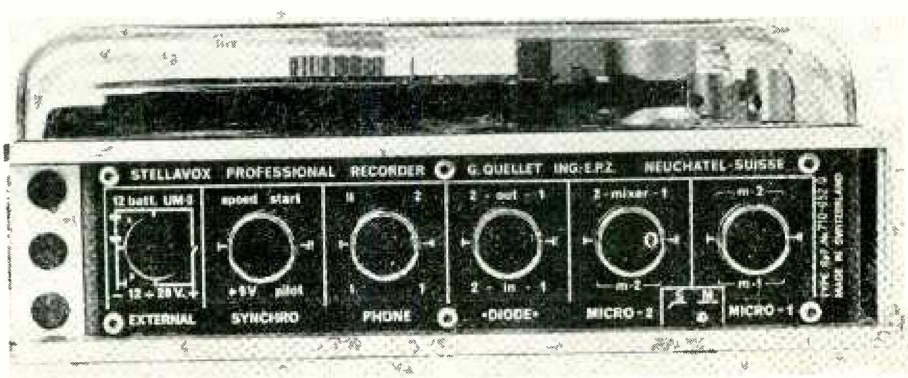
The recorder is in a strong but light metal case and is decorated in 'brushed aluminium' and matt black giving a pleasing workmanlike appearance, and has a clear plastic lid of adequate strength. The bottom of the recorder and the back of the case which form the lid of the battery compartment are covered in grey 'leather'.

On the left-hand end of the recorder are six five-pin DIN sockets: reading from back to front they are external power supply; synchronise (not operative on the review model); phone/balanced line out (not on review model. Balanced line out is an optional extra); diode i.e. line in and line out; Microphone 2/mixer; Microphone 1. The connections to the various pins on each socket are clearly marked on the recorder case, a method other manufacturers might consider using.

On the front of the recorder are, reading from left to right, the 'modulometers' or ppms for the left and right channels respectively, two visual indicators—the upper for use with pilot tone systems and the lower an indication of motor speed—three small switches, a small push button which switches on a light to the modulometer when pressed in and switches it off when released, below this a miniature toggle switch labelled tape-direct for A-B monitoring and below this another push button labelled BATT. When this is depressed the RH modulometer reads battery voltage. Next are two potentiometer controls marked in dB which control the inputs to channels one and two, and lastly the main function switch with six positions: rewind; stop; play; test; record; and automatic. On the right end of the recorder is the speed change knob for selecting speeds from 9.5 to 76 cm/s and a control for fine adjustment to speed together with a spare panel for fitting extra controls if required. Changing the speed of the recorder does not change the equalisation as this is fitted inside the interchangeable head blocks, and the machine can be converted to its various versions by changing these.

On the left of the deck is a roller tensioner with a 60 Hz strobe for checking the various speeds, and near this a switch for dynamic or condenser microphones. When in the condenser position marked II power is supplied at the microphone socket for suitable condenser microphones such as the Neumann *FET 70* series. The left guide roller has a series of dots on it used for editing. When the recorder is in the play mode the pressure roller can be pulled clear of the capstan and locked in this position by lifting the small knob on the pressure roller arm. The tape can then be moved by hand while monitoring on phones or LS until the correct place is found. The LH guide roller is then rotated until a dot just appears from under the metal. The tape is then rewound slowly by hand until the next dot just appears. The point on the tape that was on the replay head gap is now beneath a dot marked on the head assembly. It can now be cut with scissors, or marked with chinagraph pencil. This is not as simple as the guide on some machines but is greatly preferable to poking around at the head gap, and works very well.

(*continued on page 43*)



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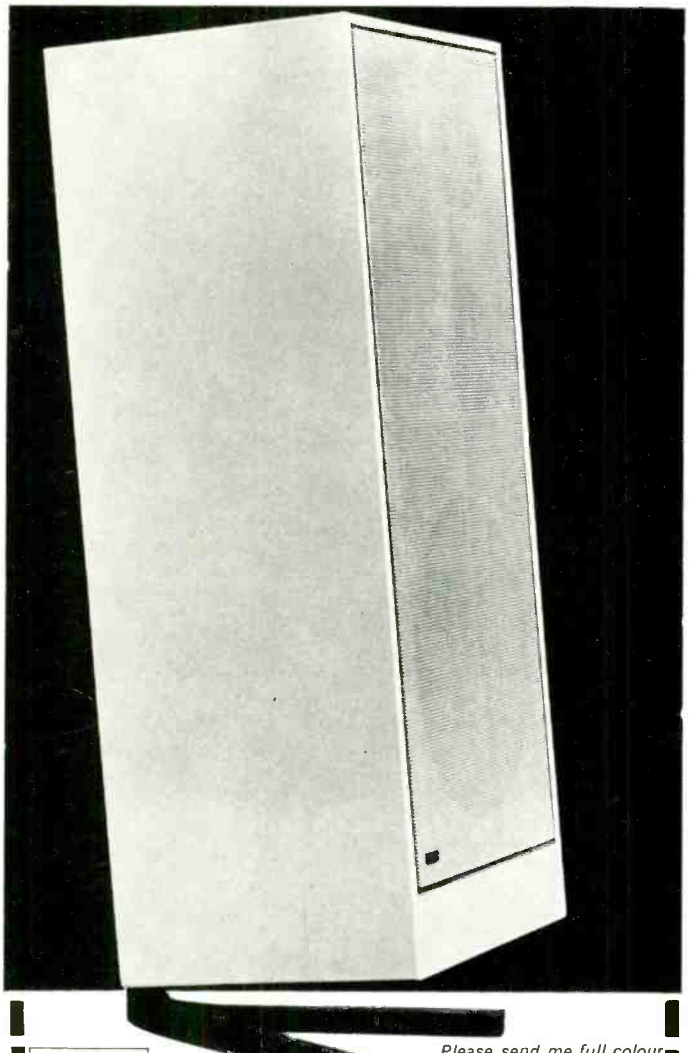

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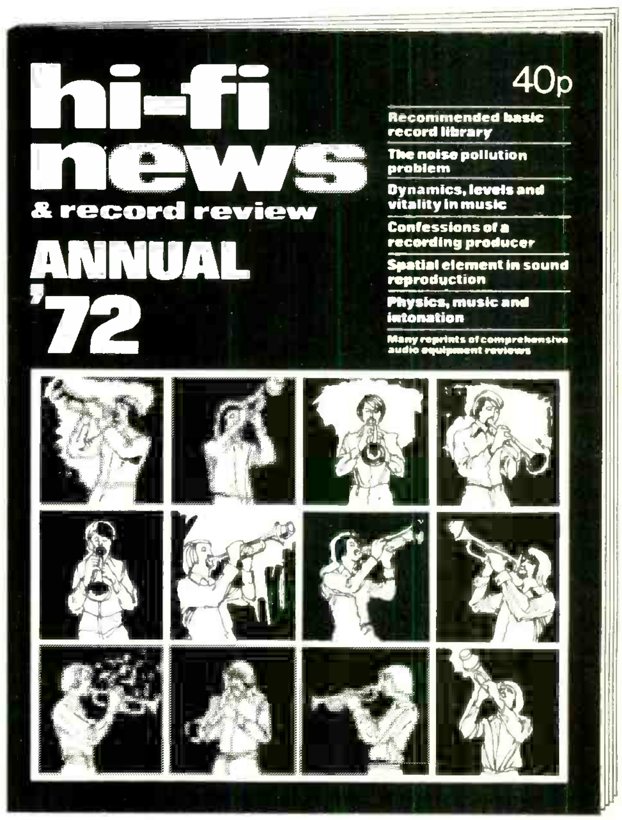

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continued

To the right of the pressure roller is the speaker potentiometer control for adjusting the volume of the monitor amplifier feeding the small speaker in the deck. The on/off switch is built into the control. After this is the RH tensioner roller which carries a 50 Hz strobe for speed checking.

First impressions on opening the case were very favourable, it was obvious that considerable thought and care had gone into the preparation of the 'Studio in a Suitcase' and even the screwdriver necessary for changing the head assemblies was included.

The recorder and all its accessories are beautifully made and gave a feeling of confidence rarely encountered in electronic equipment, and it was no surprise to find in use that everything worked perfectly each time.

The rewind really is fast and not the usual 10 cm/s found on most portables, though as no brakes are applied when the machine is switched to 'stop' tape should be allowed to run right off or the RH spool slowed by hand before doing so. Stopping from rewind in the middle of a 300 mm spool without taking this precaution does nasty things to a tape.

When running at 38 cm/s the recorder throws a tape loop just before the take up spool but the RH tensioner smooths out the jerk when this takes up, and under normal conditions this has no effect on the recording or playback.

When switching from 'stop' to 'test' for getting levels before recording the switch passes through the 'play' position and the recorder very occasionally starts just enough to throw its loop. If this is not taken up by hand before switching to 'record' a further loop is thrown and this double size loop did snatch on one occasion, spoiling the start of recording when the machine was switched to record at the last moment.

The recorder was first taken out on a session when a recording of the Shostakovich Festival Overture was made.

The *D224s* were used in back to back cardioid mode and the recording was very successful. At the same session a recording was made with a Philips *Pro 20* and *C24* microphone, and a small section of the Stellavox and *D224* recording was spliced into this. To date no one who has heard this recording has been able to tell where the insert is, even when asked beforehand to listen for it.

Listening to the complete *D224*-Stellavox recording one is inclined to think how excellent the microphone must be, and in fact most listeners have remarked on this—a real compliment to the quality of the recording made by the Stellavox.

At the start of this recording session a short section was recorded using the automatic gain control, and though the general level on the tape was lower than that subsequently used for the rest of the recordings the recorder produced a clean signal with no sign of 'breathing' or other undesirable effects and the method of recording would obviously be of great use in situations where it was not possible to get the levels right beforehand. In the 'Automatic' recording mode the two input level controls remain in circuit as threshold controls. It is possible to set the level on 'Record' then switch to 'Automatic'. This sets the threshold and will give virtually identical results to manual level adjustments.

It was obvious from the very high quality of recording made with the two *D224* microphones that the Stellavox was a very fine recorder, and it was no surprise to find that its replay-only response from a 38 cm/s IEC test tape was within ½ dB throughout. In fact the variation was so small that it could well have been due to the tape rather than the recorder. A 1 kHz tone was recorded at 320 pW/mm and the replay level measured with a wide range VVM. The tape was then erased on the Stellavox and the output of the erased section on replay was measured. The wide range unweighted s/n ratio measured in this way was 54 dB.

The 1 kHz tone recorded at 320 pW/mm was then replayed and the fundamental filtered out. The residual 'distortion' was measured as 0.1 per cent. This was repeated at 60 Hz giving a distortion of 0.06 per cent and at 10 kHz with a distortion of 0.2 per cent. These figures are excellent by any standards.

Measurements were made of rms wow only and then combined wow and flutter both with 130 mm spools and then with 300 mm spools in the adapters, measurements being taken at the beginning, middle and end of each spool. The worst results obtained were

130 mm spool	wow	0.03%
	w & f	0.07%
270 mm spool	wow	0.03%
	w & f	0.09%

Use of batteries instead of mains power made no difference to these results. Crosstalk was measured by recording a 1 kHz tone at 320 pW/mm on a clean tape on one channel only and then measuring the ratio of the output from that track to the output from the other on a wide range vu meter. The ratio given was 50 dB.

The record/replay response of the recorder was measured for each track at 12 dB below 320 pW/mm, the results being shown in the table.

The results of these tests confirmed the favourable impressions gained using the recorder earlier and show it capable of making very good studio quality recordings.

It is to be noted that, as with other recorders tested earlier, all the figures given are unweighted and wow and flutter is rms. If DIN or NAB weightings were used the figures would be better than those shown, but even as tested the recorder was well within specifications on all counts.

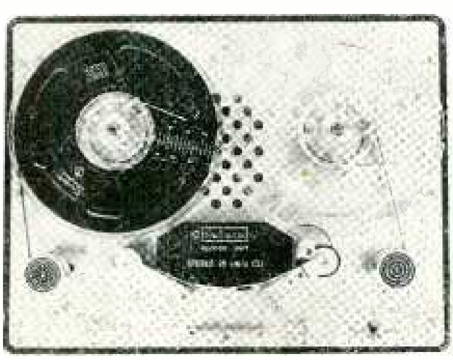

TABLE 1

S/N ratio	54 dB
Crosstalk	50 dB
Distortion	1 kHz 0.1%
	10 kHz 0.2%
	60 Hz 0.06%

TABLE 2 Record/Replay Frequency Response (dB)

	UPPER TRACK	LOWER TRACK
20 Hz	—7	—5
30 Hz	—3	—3
40 Hz	—2	—1
50 Hz	—1	—1
60 Hz	0	0
80 Hz	0	0
100 Hz	+½	0
200 Hz	0	0
400 Hz	0	0
800 Hz	0	0
1 kHz	0	0
2 kHz	+½	+½
4 kHz	+½	+½
6 kHz	+½	+½
8 kHz	0	0
10 kHz	0	0
12 kHz	0	0
14 kHz	—½	0
16 kHz	—½	—½
18 kHz	—½	—1
19 kHz	—1	—1
20 kHz	—2	—2

If more than one speed is required or alternative recording heads needed these can be supplied (i.e. 19 cm/s half track stereo at £57). The recorder under test remained 'lined up' throughout the test period and was so well adjusted when it arrived that no attempt was made to alter any of the settings.

It is felt that a machine of this class should be designed so that it can be adjusted for different types of tape, and checked for optimum performance easily, and the Stellavox is not good in this respect. [NOTE: *The manufacturers take the view that, since this is a portable machine, rough handling would upset any presets which were used. If a user specifies the tape he wishes to use, the necessary alterations can be made by staff at Beaulieu Cinema*—**Ed**]

It is also a pity that the recorder will not take 180 mm spools without the large spool extension fittings. A 130 mm spool lasts so little time at 38 cm/s that 'takes' would have to be very short.

Apart from these two reservations the Stellavox is highly recommendable; it is well made and well designed and capable of producing the highest quality recordings, and it has a most useful ability to accommodate 300 mm NAB spools.

In performance and facilities the Stellavox far outclasses any other portable stereo recorders tested so far and at £525 (half track 38 cm/s stereo) is considered excellent value and is highly recommended.

John Shuttleworth

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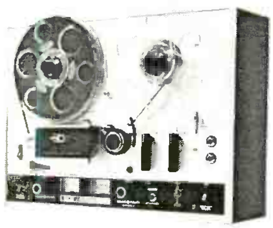

4000D

AKAI TAPE RECORDERS

	SRP	CASH
Akai 1720L	£83·73	£62·50
Akai X 1800SD	153·00	117·85
200D	145·95	112·50
4000D	89·95	62·95
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X2000SD	289·08	222·70

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702/704	220·22	192·95
702H	229·90	201·40
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722H	266·20	233·20
713D	226·27	198·20
713/HD	235·95	206·70
702D/704D	281·93	246·95
722D/724D	308·55	270·30
722HD	318·23	278·75

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TK 141	63·90	51·25
TK 146	68·90	55·95
TK 3200	144·75	118·00
TK 124	44·90	31·00
TK 144	49·95	33·50
TK 149	57·60	41·50

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1302/1304 high spd	259·00	227·50
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1322/1324 high spd	289·00	253·50
1222/1224	259·00	227·50
1222/1224 high spd	299·00	262·25

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M291	173·10	151·45
M250	137·71	120·50
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T260	38·37	31·85
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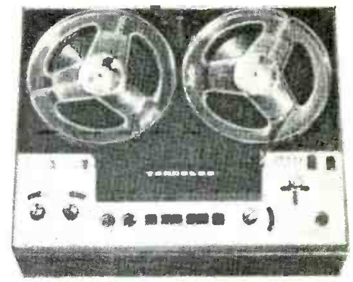

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7″	1200′	1·98	1·30

		SRP	CASH
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5¾″	1200′	1·97	1·30
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4″	600′	1·30	·85
4¼″	900′	1·70	1·11
5″	1200′	1·96	1·30
5¾″	1800′	2·82	1·85
7″	2400′	3·48	2·26
5″	1800′	2·81	1·95
5¾″	2400′	3·47	2·26
7″	3600′	4·33	2·82

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8¼″	2400′	4·21	2·73
10½″	3600′	6·32	4·11
5¾″	1800′	3·16	2·06
7″	2400′	4·45	2·90

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AKAI (cont.)

8 TRACK STEREO

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TANDBERG (cont.)

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1541 4 track	90·50	79·20
1521 3 spd, 4 trk	93·50	81·80
1541F 3 spd 4 track	119·50	104·60
1542	102·00	89·30
1721 2 track	67·00	58·65
1741 4 track	71·50	62·60
4021X	174·00	152·00
4041X 4 track	174·00	152·00
4041X	177·00	155·00
1241 4 track	154·00	121·50
64X	158·50	119·50
1841 4 track	68·00	59·50
3021X 2 track 3 heads	107·00	92·50
3041X 4 track	107·00	89·50
6021X 2 track	188·00	164·50
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