MARCH 1971 15p

STUDIO SOUND

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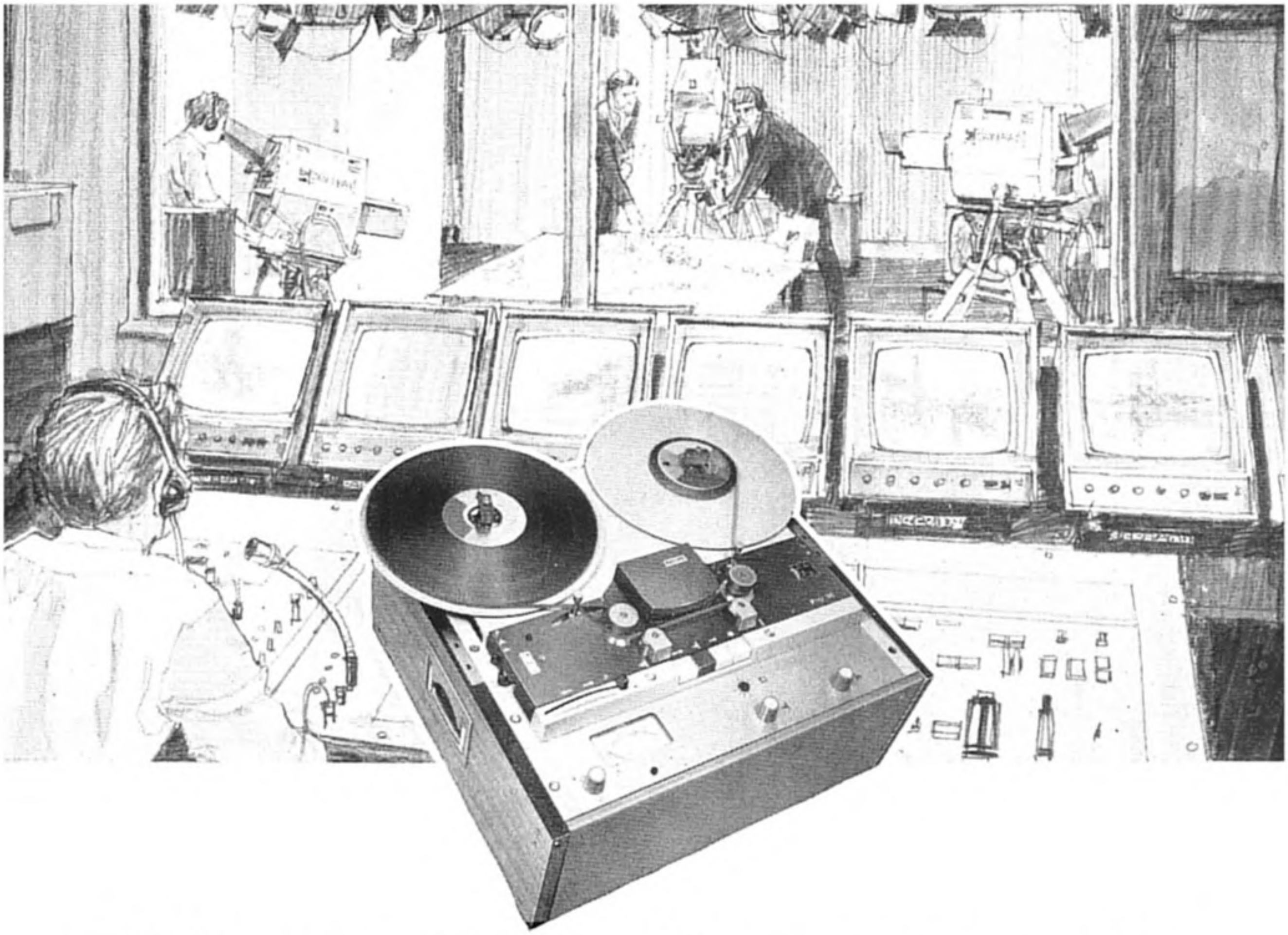

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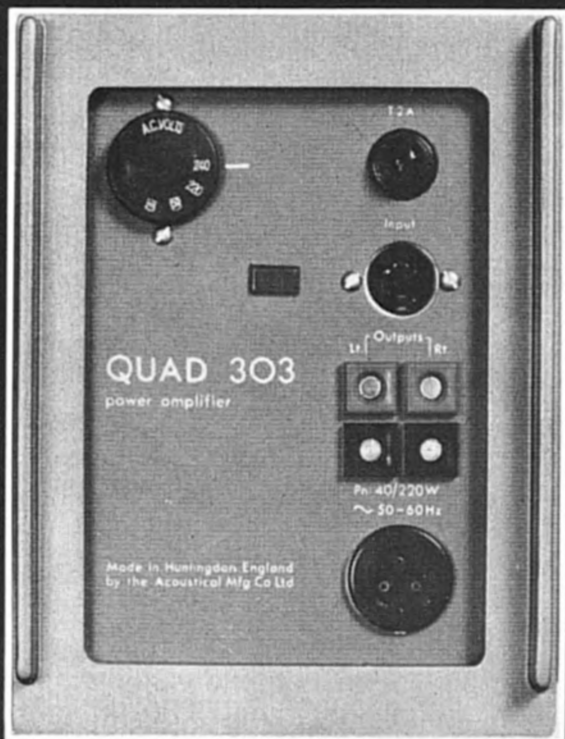
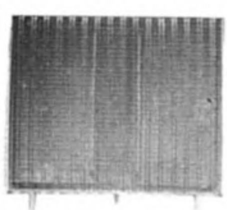
wireless



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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Studio Sound

MARCH 1971 VOLUME 13 NUMBER 3

AND TAPE RECORDER

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COVER PICTURE

Electronic Music Studios' *VCS3* voltage controlled synthesiser. Even without the keyboard, the *VCS3* is a remarkably versatile source of electronic music and may be programmed to play by itself.

SUBSCRIPTION RATES

Annual UK subscription rate for *Studio Sound* is £1.80 (overseas £2.10, $5 or equivalent). Our associate publication *Hi-Fi News* costs £2.82 (overseas £2.65, $6.30 or equivalent). Six-month home subscriptions are 90p *(Studio Sound)* and £1.41 *(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.

THE ACQUISITION of Leevers-Rich Equipment Ltd by Mining & Chemical Products (not to be confused with the Minnesota people) raises new hopes for this country's studio equipment industry. Like so many moderately successful companies, Leevers-Rich were for years victims of a vicious circle that demands capital before expansion, yet can only yield that capital securely as a *result* of expansion.

Ten years ago, two British companies were producing full-scale studio tape equipment: Leevers-Rich and EMI. Recorders for lighter work were produced by Ferrograph, who are still with us, and by Pamphonic, who aren't. EMI stopped production of all tape machines. Unitrack came and rapidly went. Two companies have grown in recent years, Scopetronics and TRD (the latter now merged with Walsall Timing Developments) and, as we mentioned last month, another UK company is preparing to cater for the studio market. Nevertheless, with EMI out of the running, there has been little British competition for Leevers-Rich.

A curious attitude exists in this country, as in others, that products of foreign manufacture tend to be superior to locally produced equivalents. This was reflected by a recent *Which?* survey relating to Consumers Association members' opinions of their cars. Predictably, this found imported cars more satisfactory than locally produced models. Overlooked or ignored by *Which?* was the fact that a comparable survey undertaken on the Continent had the same result—implying that British cars become a better buy after crossing the Channel.

Noting these points, we recently surveyed the attitudes of four individuals towards two semi-pro recorders, the current Ferrograph and Revox. They were all familiar with the machines, having used them over several years, and their views were based on solid experience rather than shallow fancy. Yet these opinions were widely contradictory and showed no obvious bias for or against British or Continental techniques.

One Continental trend we welcome is the firm establishment in Britain of the metric system of measurement. When fully adopted, it will relieve us of an antiquated system involving unnecessarily complex multiples. Fourteen, 16, 36, 112 and 1 760 are merely the tip of an iceberg: the Imperial iceberg. Fog, a few weeks back, 'reduced early-morning visibility at Heathrow to 150 metres, improving later to one mile' according to a BBC news report. You may have noticed similar logic in the popular science journals, where rockets tend to be hauled miles to their launch sites, then placed in kilometre orbits. Sensibly, they manage to avoid the sea and its attendant knot problem. In Croydon, a subway is signposted as 120 metres from a car park, the speed limit in that direction being 30 miles per hour. All indicative of this country's present position half-way between two standards.

British industry, happily, is now largely committed to metrication, though heel-dragging is occurring in some quarters. The Electrical Contractors Association recently protested at the Electric Conduit Systems Manufacturers' decision to stagger the introduction of metric-sized conduits. This will involve quoting for mixed Imperial/metric items of one product in the same installation, the mixture changing each six months over a period of two years before Imperial is phased out completely. The ECSM decision may have been well-intentioned but it leaves engineers in the unhappy position of having to produce adapters, bending-formers and threading-dies for both standards, not to mention the differing cable capacities of the two standards.

Readers wondering why this journal so rapidly went metric may be starting to appreciate our greatest fear—not that this country would stick to, or revert to, Imperial standards but that we would be landed with a wretched mixture of the two. The present government, again probably with good intent, has promoted this unhappy situation by postponing indefinitely the already initiated plan to metricate road signs. The BBC has for several years quoted temperature forecasts in both Fahrenheit and Centigrade, out of this same kindness to inert minds, though where is the evidence that this encourages an understanding of Centigrade more than dropping Fahrenheit altogether?

FEATURE ARTICLES

REGULAR COLUMNS

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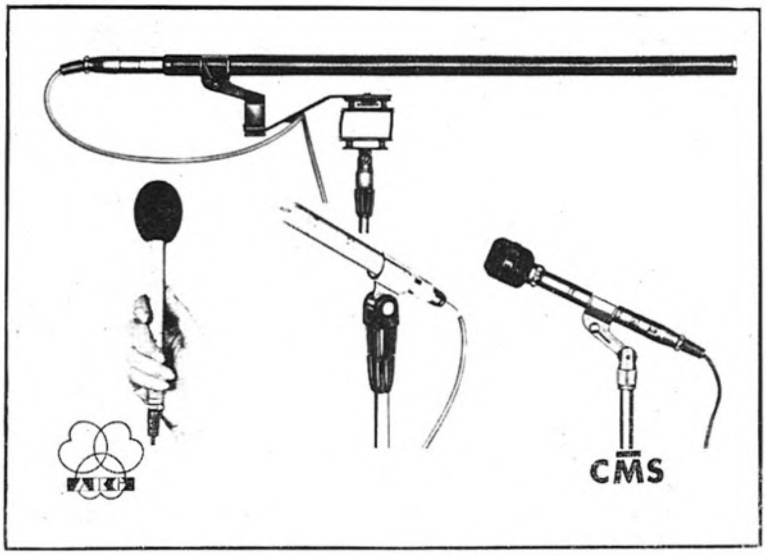

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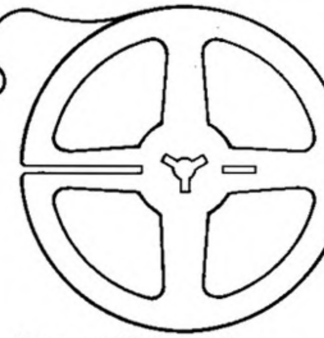

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Events

STUDIO EQUIPMENT SALES

SOUND RECORDING equipment of varying age and status is being marketed by the Jackson Music Group, The Studios, Rickmansworth, Hertfordshire. The group's present list includes Neumann capacitor microphones, a four-channel Studer *J37* (25 mm with 12.5 mm head-block), stereo Ampex, EMI and Teac recorders, Lockwood speakers, Altec *436C* compressor, MSS disc-cutters and a *Coca Cola* freezer. The Jackson motto *Quad erat dolbi non studa dinarius* requires full settlement, including cheque clearance, before plant leaves the premises. The service is being run by Michael Jackson from whom a detailed list is available on request.

APRS SECRETARY

A NEW SECRETARY has been appointed by the Association of Professional Recording Studios, succeeding John Borwick. He is Mr W. J. H. Barrett, who has for many years served with the BBC Transcription Department. All APRS correspondence should now be addressed to 3 Strathrae Gardens, Swiss Cottage, London NW3 4PA.

EVR DEVELOPMENTS

A MAJOR bugbear of Electronic Video Recording —its unsuitability for private recording—has been overcome by Dr Peter Goldmark and Dr William Glenn Jnr, of CBS Laboratories. They have developed a non-electric colour camera which optically separates brightness and chrominance, placing this information in two parallel frame rows of monochrome film. Though still in the research stage, the portable camera could eventually sell for £150, bringing it within reach of limited-scale TV film producers.

Licence agreements have been signed by the EVR Partnership (London) with Hitachi Ltd (Tokyo) and Mitsubishi. The two licencees will manufacture EVR teleplayers, distributing these on an international basis. Other licencees include Motorola (USA), Robert Bosch GmbH (West Germany), and Rank Bush Murphy.

AUDIO ANNUAL 1971

A DISCUSSION of the evolving art of *Electronic Music*, contributed by Tristram Cary, is among feature articles published in the 1971 *Audio Annual*. Michael Gerzon covers the philosophy of quadraphony in *Whither Four Channels?* while Stanley Kelly considers the future of commercially recorded cassettes. Rex Baldock on ears (*Auditory Apparatus*), R. V. Leedham on *Concert Hall Simulation* and Peter Gammond's views on 'good recorded sound' are accompanied by reprints of selected reviews from 1970 issues of *Studio Sound* and *Hi-Fi News*. The annual may be obtained from newsagents and bookstalls for 40p, or post-free from Link House Publications Ltd., Dingwall Avenue, Croydon CR9 2TA.

LEEVERS-RICH ACQUIRED BY MCP

MINING & CHEMICAL Products Ltd, the parent company of MCP Electronics, have acquired Leevers-Rich Equipment Ltd. The link will provide Leevers-Rich with increased financial support and marketing facilities. Mr P. B. Richards remains Managing Director of Leevers-Rich and Mr Norman Leevers remains on the board. They are joined by three MCP directors: Mr P. G. Ribon as Chairman, Mr H. R. Bauer and Mr D. K. Cunningham. Mining & Chemical Products are engaged in refining and supplying rare metals, minerals and high purity compounds. MCP Electronics manufacture thick film hybrid circuit devices and opto-electronic equipment and are UK agents for TRW and Telefunken Semiconductor Divisions.

Conductor Lawrence Foster (left), Pinchas Zukerman and (CBS) Paul Myers in the control room of EMI Studio 1, Abbey Road. Foster conducted the Royal Philharmonic Orchestra during the December 4 recording of Wieniawski's *Violin Concerto in D Minor*.

FEBRUARY REVIEWS

THE PRICE OF the Rank-Weircliffe bulk eraser reviewed last month is £145, not £90 as stated. The Calrec *1050* capacitor microphone is fully balanced and not, like our field-tester at the time of writing, partially unbalanced.

WHY THOSE TAPE CHARACTERISTICS?

OUR APOLOGIES to readers confused by Eric Robjohns' article 'Why So Many Tape Recording Characteristics?' in the February issue. The BSI is, of course, and will probably remain, the *British Standards Institution*, and RIAA still stands for *Record Industries Association of America*. The response curve of a tape replay amplifier is better described as following a 6 dB/octave falling characteristic rather than a bass boost, and head-amplifier coupling and matching problems—which are avoided by correct design—should not have been confused with recording characteristics.

The NAB system is widely used in the British recording industry, though broadcasting authorities use CCIR—now more commonly known as DIN or IEC. Since 1966, CCIR/DIN equalisation for 19 cm/s has been specified as 70 μS. Starting with the HF end as a reference, the bass lift is indeed greater on NAB than CCIR (extreme bass-end roll-off apart) but, as the mid-frequency flux is the same in both cases, it is more correct to say that the *high* frequency response is different: NAB and CCIR upper frequency turnover points are 3.2 kHz and 2.3 kHz respectively. The 3 180 μS NAB time-constant is for low frequencies (3 180μS=50 Hz), not a treble roll-off.

These are the key errors in what we confess to be a rather confusing article, for which we take full responsibility, having accepted the piece with the unfulfilled intention of correcting it fully before publication. It has been suggested that we should have used the article in the April issue and then thanked readers for spotting the deliberate mistakes!

MOSELY ON QUADRAPHONICS

A TALK ON 'Quadraphonic Studio Equipment Design' will be given by John Mosely to AES members on March 9. Command Studios, 201 Piccadilly, is the venue and further information may be obtained from the AES Secretary, 10 Museum Street, London WC1.

THORN TO PRODUCE VIDEOCASSETTE EQUIPMENT

VIDEOCASSETTE EQUIPMENT designed to the Philips VCR colour standard is to be produced by Thorn Electrical Industries. The announcement followed preliminary negotiations with Philips in Eindhoven. Marketing plans have still to be formulated but sales are expected to commence in the first half of 1972, initially restricted to educational applications.

NEXT MONTH

TIM BLACKHAM begins a series of articles on film sound synchronisation, based on the film production of *Fiddler on the Roof*. David Kirk field tests the *VCS3* voltage controlled electronic music synthesiser and Angus McKenzie reviews Telcon Mu-metal foil.

RECORDING STUDIO TECHNIQUES

PART FIFTEEN—LIMITING, COMPRESSION AND EXPANSION *by Angus McKenzie*

THE automatic control of dynamics was originally used by film engineers to match the limited dynamics of optical film. The facility is now very widely used by recording studios in the recording of pops and as a protection for disc cutter heads against sudden peaks.

There are three basic types of dynamic control device. First is the *limiter* which limits any signal of amplitude greater than a set threshold to that threshold or more usually a fraction above it. The second is a *compressor* which compresses the dynamic range above a threshold to a smaller range usually determinable by controls on the device, and the third is the *expander* which expands the range above the threshold to a wider range. Various combinations of the three types of dynamic control are also available. For instance, it is possible to have a compressor which increases the gain at low volume levels and an expander which pushes lower volume levels further down. Various pieces of equipment have also been marketed that combine expansion with limiting to prevent a sound being expanded more than a preset amount.

In the early years of automatic dynamic control, by far the most commonly used devices relied upon the gain of a valve changing when its grid bias was changed. Valves having such vari-mu characteristics unfortunately also had rather a high distortion factor. To overcome this and other inherent faults they were usually used in push-pull pairs, it being necessary not only to select the pairs of valves very carefully but also to set up the individual cathode currents accurately. Devices incorporating these techniques tended to have one particular fault known as thumping, the effect being heard each time there was a gain change. The devices worked by applying a rectified audio signal obtained from the input or output to the grid of the valve which then changed its gain. Some very elaborate valve limiters and compressors were designed and probably the best to be found in Britain were made to a BBC design of approximately 20 years ago.

Different ranges

Equipment such as the Westrex compressor was designed for different compression ranges allowing several dynamic ranges above a preset threshold to be compressed to several preset smaller ranges, examples being 20:1, 10:3, 2:1. The first of these is regarded as limiting in that a signal 20 dB above the threshold would be compressed to only 1 dB above the threshold, and pro rata with other ranges.

In broadcasting it was important for the limiter to act almost instantaneously to protect the transmitter. Since such instantaneous limiting can be noticeable on a transient, and in any case is difficult to design, delay lines were frequently inserted in to a direct path so that this path had its gain reduced a fraction of a second before a peak arrived, thus completely protecting any circuits after the limiter. Even today several broadcasting organisations regard such use of delay lines as vital although I am not fully convinced that they are necessary for FM broadcasting. Several interesting control devices used the properties of small bulbs changing resistance as a voltage applied to them increased, the resistance going up very quickly above a certain voltage threshold. Unfortunately the types of bulb originally used had a very slow attack and decay time by today's standards. Limiting, compression or expansion was not complete until a considerable time had elapsed after the beginning of the peak, and incidentally after damage might have resulted. Such bulbs, having variable resistance depending on their temperature, were only infrequently used and it was not until the discovery of photo-electric resistors and bulbs having almost instantaneous brightness changes that devices using light as a means of dynamic control began to be common. The Fairchild range of compressors used this principle. After the introduction of transistors, and in particular FETs, it became very simple to design effective units having excellent compression characteristics and low distortion combined with fast attack and variable decay times. At the time of writing every conceivable type of automatic dynamic control device is available and prices are steadily dropping.

Probably the most common use of limiting in the studio is with the human voice, allowing a singer to express himself freely, which usually means loudly, without the recording engineer making a dive for his channel gain control. The use of too much limiting in such an application is highly dangerous since, if the level before the limiter is too high, the sound of other instruments entering the vocal mike when the vocalist is not singing can become obtrusive. For such an application expanders have been designed to expand down the signal after a second or two to eliminate this effect and gain recovers instantly as the vocalist continues his performance. Gating circuits which automatically lower the gain by a predetermined amount as soon as the signal drops below a preset threshold are also available. These are not always entirely successful as a slight spit will often be heard as their gain suddenly comes back to normal when the programme continues.

Limiting and compression are frequently used when it is required to increase the average level of a programme although the peak level remains the same. By their use, a considerable increase in apparent volume can be obtained but one thing must be realised: some types of recording level meters, including for example VU meters, will cause the recording level to be somewhat lower since the meter is calibrated in such a way as to under-read a peak by a given amount. If therefore the average volume is nearer the peak, the actual peak recording level will be nearer the level read by the meter and not the level that would be estimated from the meter reading.

By the insertion of equalisation in the side chains of compressors, some most interesting effects are available. A boost in the side chain peaking at 8 kHz together with a fast attack and decay time, can become a useful asset in the reduction of sibilance. Similarly, if it is required to use a considerable amount of treble boost on any microphone, it is useful to apply an extra boost at the same frequency in the side chain, thus preventing HF tape over-modulation without limiting the signal severely at middle or lower frequencies. I have always been surprised to see how few makes of compressor are fitted with variable equalisation in the side chain. In transmitter applications it is usual to insert a boost in the side chain equivalent to the frequency pre-emphasis in the transmitter, provided the limiter is inserted before such pre-emphasis.

The use of expansion has always been regarded as dangerous unless followed by limiting but when well used can be most effective. It was frequently used on strings many years ago by my studio to give an extra prominence when they played slightly louder, allowing quite a small string section to overshadow other sections when necessary. It was found necessary to limit the expansion to not more than 6 dB as any more became uncontrollable in the sound balance.

Voice-over

A most interesting use of compression has been the control of one balance by another, a typical example being the control of the output of a gramophone desk by a continuity disc jockey, often used on Radio One. Such a device is marketed by Feldon Recordings and was demonstrated very successfully at the recent International Broadcasting Convention. The applications of this device are varied. I wish that I could have used one years ago when I was concerned with the recording of sound tracks for TV commercials. It was always difficult to control the volume of music adequately, allowing the all-important speech to be heard clearly. (*continued on page 115*)

TURNTABLE

A column of readers' problems and correspondence

VISUAL MONITORING

From H. D. Ford, 3 Willowbank, Sunbury-on-Thames, Middlesex.

Dear Sir, It was most interesting to read David Robinson's article on visual monitoring in the November issue. I am sure this article will help many people to understand the difference between VU meters and PPMs. However, I do very much feel that Mr Robinson has somewhat confused the issue of aligning magnetic tape recorders for recording level.

Firstly, while I agree that many organisations record tapes to a peak level of 2% or 3% third harmonic distortion at mid frequencies, I do not know of any modern tapes that produce this amount of distortion at a tape flux of 32 mM/mm under the normal operating conditions at professional tape speeds. The majority of 'normal output' tapes give 3% third harmonic distortion at about +5 dB relative to 32 mM/mm and 2% third harmonic distortion at approximately +3.5 dB. It is well established that 0 VU on a standard VU meter should be set to correspond with a level between 8 and 10 dB below 3% third harmonic distortion and it is this fact, not particularly clear from Mr Robinson's article, which causes a great deal of confusion among recording engineers.

When using the line-up tone on American tapes, as Mr Robinson points out, this level should be set to indicate 0 VU and corresponds to a level -4 dB with reference to 32 mM/mm which can easily be shown to be between 8 and 10 dB below 3% third harmonic distortion for the majority of 'normal' output recording tapes.

When using a PPM, an indication of 6 should correspond to 2% or 3% third harmonic distortion which, as has already been said, does not correspond to 32 mM/mm but to about 5 dB above this level. Therefore, when aligning a machine equipped with PPMs, a calibration tape with a flux of 32 mM/mm should produce an indication of approximately 5 on a PPM. Likewise, if an American line-up tone is used, this should be arranged to produce an indication of 4; not as Mr Robinson suggests an indication of 5 which would lead to under-recording to the extent of at least 4 dB.

As will be seen from Angus McKenzie's article in the same issue, adjusting meters as described above will provide optimum results with the majority of modern tapes but in certain circumstances it is permissible to record at even higher levels when using high output tapes such as BASF *LR 56* or Agfa *555*.

Yours faithfully

David Robinson comments:

I am sorry if there has been confusion between alignment, standardisation and metering—I agree that the arguments are difficult to put across.

There are two main reasons for metering—one is to modulate the tape to best advantage for distortion versus noise, the other is for standardisation which is vital to inter-studio exchanges. Both are important but the latter more so with the introduction of noise reduction equipment into professional studios.

It is certainly not true to say that modern tapes produce 2% third harmonic distortion at 32 mM/mm. This sentence should have referred to the tape originally used in setting the reference level—as in the correct description of the Ampex tape which followed. I am most grateful to Mr Ford for pointing this out.

I don't know of any professional studio which aligns its 32 mM/mm tapes for PPM 5, which corresponds to the European lightbeam meter reading of -4dB. There isn't much in the way of hard and fast rules about this but I will mention a few pointers to aligning to PPM 6. The DIN tape (32 mM/mm) is always played back on the continent to read 0 on the light meter, which has a full scale deflection of +5 dB. If PPM 6 is taken as 32 mM/mm, then it has a full scale deflection of 7½ or +5½ to +6 over peak.

This is a pretty tenuous argument, however, and more important is BS 4297:1968 which states that usually (not always, I must add in fairness) mark 4 on the PPM is 0 dBm; i.e. 6 is +8 dBm. 0 VU is +4 dB; there is evidence for the 18.5 mM/mm tape being aligned to PPM 5.

Experiments with mixer operators tend to confirm this difference, although it is strongly dependent on programme characteristics.

Regardless of the type of meter in use, some studios used to record to higher levels using high output tape but have now reverted to standardised conditions since noise reduction equipment (giving 15 dB or high frequency reduction) is in almost universal use. The 5 dB or so higher output at long wavelengths on such tapes is thus traded for increased overload margin—which overcomes the lack of high output at high frequencies which is a disadvantage of high output tapes.

Finally, let me stress heavily that the test tapes used contain not recommend operating levels but reference levels. If a studio wishes to record to a higher level, it is of course free to do so, provided it thinks the resulting sound quality is acceptable; but it would be a pity from the standardisation point of view.

POST OFFICE LINES

From C. R. Kimber (Line Transmission Dept., GPO), 'Trees,' 1 Quarrydale Road, Marlow, Bucks.

Dear Sir, Reading John Fisher's article 'The Quiet Accompanist' in January *Studio Sound*, I was a little disturbed by his comments on Post Office lines.

A GPO local line between exchange and distribution point has no background noise worth speaking of as no amplification takes place. A small amount of induction does take place, however, giving an impulse noise level in the order of 60 to 70 dB below traffic level. As for the frequency response, it is essentially flat up to 20 kHz as the line is unloaded and the attenuation increases proportionally with frequency by the square root of the frequency after the skin effect has taken place.

The frequency response is restricted, not in the local line as Mr Fisher suggests, but in the telephone receiver itself and in the exchange transmission bridge. Junction cables are generally loaded to produce a bandwidth from 300 Hz to 3.4 kHz which is the CCITT minimum requirement for acceptable speech transmission. Amplification does not usually take place over junction cables and noise levels are always better than -50 dBm unweighted.

Over a trunk circuit, however, the noise level increases due to the noise factor of the radio or coax system over which it is routed. Carrier mush is present due to frequency translation processes. Adjacent channel interference (intermodulation) cannot be completely wiped out. The bandwidth is restricted even further to 300 Hz to 3.1 kHz as the channels must be spaced in the frequency spectrum.

In Berkshire Mr Fisher suggests that trunk lines are better than junction lines. For the reasons given, I really do find this very difficult to believe. A circuit routed over a trunk as opposed to one routed over a junction can only be better in one respect and that is in level of speech. This can only occur if you instigate a call between Zone centres, e.g. Reading and Plymouth. The loss between Zone centres is never more than 1 dB.

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Apart from his views on Post Office lines, I found the rest of Mr Fisher's article extremely interesting. *Yours faithfully*

GROPIUS ON WIRE

From T. Lupton, Orchard Close, Winterbrook, Wallingford, Berkshire.

Dear Sir, I have some wire recordings of discussions with the great architect Walter Gropius and I have undertaken to have them transferred to discs for safe keeping. The BBC, Science Museum and British Institute of Recorded Sound have been unable to help with a machine to play these wires and I wonder whether any of your readers would be able to assist. The recordings were made in 1956 and the spools are marked Minifon *Profono P55*.

Yours faithfully

(*continued on page 115*)

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DOLBY B

From A. L. Henrichsen, 75 Kennedy Street, Alexandria, Va 22305, USA.

Dear Sir, It was with considerable interest that I read Angus McKenzie's review of the Dolby 'B' system in the November issue.

As I had the pleasure of spending some time with Dr Dolby in London in September, I have been most interested in testing the B system as well as hearing what others had to say about it. I am curious to know the exact type of Wollensak machine used as Mr McKenzie reports the wow and flutter to be an extraordinary 0.12%. I am using what I had thought to be the best cassette machine available (the Harmon-Kardon Nakamichi *CAD-5*) and have never been able to measure less than 0.19%. Perhaps I should ask how the measurement was made—by the DIN peak-weighted method or by the RMS method? In addition how was the machine modified? I note that the playback amplifier response had been extended. Do I then understand that there was no change to the record equalisation characteristics of the machine?

I have just received one of Agfa's prototype chrome oxide cassettes and hope to conduct some tests to see how it compares with regular iron oxide tapes. To the present time, my experiments have shown that the BASF and Sony *C60 HF* have the least inherent noise of any cassette now available. As the Sony has considerably superior high frequency response to the BASF and only the slightest degree more harmonic distortion, I find it to be the best iron oxide tape now available. I am quite surprised, therefore, when he says the BASF *C90* is superior to the *C60*. I have always found that the *C90* exhibited more distortion than the *C60*. It would be interesting if he could elaborate on this.

I fully agree with the remarks about the use of PPMs. Ampex (USA) first installed PPMs at their duplication facilities over a year ago and introduced their *Ex-Plus* reel-to-reel tape records. I have found that these new tapes are a definite improvement over the same selection recorded before the PPMs were installed. So far as I can determine, there is about a 3 to 4 dB improvement in signal-to noise ratio and most of this seems due to the higher level on the prerecorded tapes. With the three samples of 'before and after' that I have compared, the 'Ex-Plus' tapes not only appear quieter, but also seem to have less distortion (a subjective determination, however). Perhaps this is due to a difference in the raw tape itself.

Yours faithfully

Angus McKenzie comments:

The Dolby B system I have been using was one of the original prototype 505 *units made by Dolby themselves. The Wollensak was also provided by Dolby Laboratories to assist me with my evaluation.*

The playback equalisation was extended to 15 kHz and the bass time constant removed so that there was no bass cut on playback, or in fact boost on recording. Such a boost (some 7 dB at 50 Hz), when present, normally tends to encourage overload at bass frequencies. The bias was carefully set and a 30 Hz to 15 kHz bandwidth was achieved within a close tolerance.

The latest BASF C 90 *cassettes show a considerable improvement over the earlier ones, and I am therefore surprised that you find the Sony tape better. I prefer the* C 90 *cassette to the* C60 *because of its better wrapround characteristics.*

The wow and flutter figure of 0.12% was a peak-weighted Din figure. I would agree that Nakamichi decks are not as good as this, one I tried recently being approximately 0.2% which I still consider reasonable for a cassette machine.

With reference to your remarks about PPMs, it has been interesting recently to compare the levels of several makes of cassette records issued in Britain. Whereas almost every Decca cassette peaks very close to 32 mM/mm, usually a dB or two below this, many other makes peaked far above and showed severe distortion, while others were considerably under-recorded. I certainly agree with Ampex's use of PPMs since, in the duplication stage, one must consider the maximum recorded flux that one can get on to the tape at any one time and not the average volume of the music.

One important matter which is sometimes overlooked is the necessity for coupling the outputs of side chains of limiters when two or more are in use for controlling stereo capsules. After amplification, a peak picked up on one channel, if not equally picked up on the other, will cause an immediate displacement of the stereo spread. If the two side chains are linked, a peak on one channel only will cause a simultaneous reduction of gain in both channels, retaining the stereo positioning. Disc cutting equipment in particular always uses such linking, and also includes side-chain boosts at very low frequencies to limit the stylus excursion amplitude, and at high frequencies to limit velocity. Controls are also provided allowing different settings of limiting for lateral and vertical components.

Although automatic dynamic control and pop music recording seem almost inseparable classical music recording can only suffer unless compression is most skilfully done. All too often I have heard recordings such as a recent issue of Bruckner's *Fifth Symphony* in which the magnificent sound of the brass section is compressed when playing loudly, bringing reverberation up at the end of each note. Many prerecorded cassettes recently produced have had too much compression applied in an effort to lift the music out of the hiss. Comparing one recent cassette with its disc counterpart level for level at least 10 dB compression to the cassette was noted, a ridiculous amount to use on music.

Since it is possible to overload reverberation devices such as the EMT plate, engineers frequently like to limit the signal being sent for reverberation. Such limiting will not greatly affect the reverberation time in the sound path but compression can very greatly increase the effective reverberation if used in the return path. One engineer reported recently his view that two limiters with their side chains paralleled might cause slight intermodulation between the two channels. He suggested that if one limiter is allowed to limit the sum channel and the other the difference channel, and there was not much pure difference information, the limiting characteristics would result in less intermodulation between the channels.

Special effects

Many studios have obtained special effects by using the Dolby *A 301* system unconventionally, cutting out at will any combination of frequency bands in the compression characteristic. On a number of occasions recently, cutting engineers and record producers have actually cut pop singles in the Dolbyed state to reduce still further the dynamic range, if they thought the recording lacked presence, although the very thought makes me shudder since in my opinion any such adjustment should have been introduced at the recording or reduction.

Finally, two interesting expander devices from the past are worth mentioning, both designed for use in a playback chain. The H. H. Scott *Dynaural Noise Suppressor* employed a circuit with a fairly fast attack and a slowish decay time. Applied equalisation cut high and low frequencies such that the amount of equalisation was proportional to the reciprocal of the volume. Designed specifically for 78s it reduced record scratch and rumble in quiet passages. The designer claimed that, when instruments were playing more quietly, their harmonics tend to be less, becoming almost inaudible. Although I do not agree with the manufacturer's claim of 20 years ago, nevertheless some records did sound better through the device.

A recently marketed expander known as the *Null-a-Tron* was the subject of even wider claims. After testing one of the earlier models I found that a signal only 20 dB down from peak volume completely disappeared whereas a signal further down came back again. After modifying the unit to prevent this, it then became slightly successful on some material although, because it relied on lilliput bulbs for its operation, arranged in a bridge circuit, the attack and decay times were highly irregular and the effect of two stereo channels caused the stereo images to wander all over the place.

All these more unconventional devices, however, must take their place in history. Readers would be well advised to keep a watch on any developments since these are coming thick and fast. The latest, which I hope to review shortly, is a limiter which recognises the slope of the incoming transient as well as its height, thus obviating the necessity for a delay line. The distributor claims that a sine burst of 1 Hz 2dB above threshold can be limited to the threshold with a visible perfect trace on the scope. Can one expect better?

Why Coincident Microphones?

By Michael Gerzon

IN the February *Studio Sound*, Bob Auger gave an eloquent and persuasive defence of multimicrophone recording techniques for classical music. However, many of his points are somewhat debatable, and a few are downright wrong. There seems to be a need to state the case for coincident microphone techniques. Up to now, only defenders of multimike techniques seem to have stated the 'objective' reasons for their standpoint, coincident enthusiasts tending to confine themselves to subjective assertions that they get more 'realistic' or 'pleasant' results.

No assessment can be purely objective, as the results one wants depend on what sort of musical effect one is after. This in turn requires an examination of the effect of various technical and psychoacoustical points on the aesthetics of music. Therefore a statement of one's subjective standpoint is important. The first such statement, that few will disagree with, is that even the best two-channel stereo is incapable of sounding very much like the real thing. If one accepts this, then it is clearly a subjective judgement to say that such-and-such a technique is most 'realistic' as different people will disagree about which absent qualities of sound are most important.

Bob Auger believes that the recorded sound should sound *better* than reality, since it is heard in the home, not at a concert. Yes, well what is 'better'? Let me state, as my articles of faith if you like, those aspects of multimike recording that I do *not* consider 'better'. If you disagree on these points, then you clearly find a very different meaning in classical music from me.

I do not consider music 'better' if the musical balance between musicians is made different from their original carefully judged intentions, or if an instrument (e.g. harp, harpsichord continuo) is made clearly audible when it is only intended to 'colour' the sound without being too distinct, or if a soloist is made to drown out the interplay of accompanying instruments in order to make him or her 'audible' all the time. It is not 'better' if all the orchestra is made to lie in a line between the speakers rather than being spread out in space behind them; it is not 'better' if undue prominence is given to the front of the orchestra relative to the back. It is not 'better' if the blended quality of orchestral transients is greatly modified, to the extent of changing the rhythmic attack, by the elimination caused by multimiking of the usual acoustic time delay of sound from the back of the orchestra.

It is not 'better' if the unpleasant harsh high harmonics of strings and woodwinds that are normally sprayed harmlessly into the air above the heads of the audience are picked up by high-up mikes. It is not 'better' if acoustics which have strongly influenced and modified the musicians' performance are greatly altered in quality. It is not 'better' that the continuous spread of live stereo sound is replaced by a relatively small number of discrete but poorly defined islands of sound. It is not 'better' that the performance of great musicians should be modified greatly merely so as to conform to whatever happens to be the preferred hi-fi sound of the day, especially if this means that many subtleties of dynamics, rhythm, tone colour and reaction to live ambience are not perceptible to even the most knowledgeable of musical listeners.

In short, I do not believe that it is 'better' to disguise the inevitable imperfections of a human performance and not to be able to hear what the musical intentions of the players were. Most British multimike recordings capture the 'gross' qualities of the musical performances, i.e. the approximate dynamics, the basic rhythms, and the approximate balance between groups of orchestral instruments. Often lost are the subtle qualities of musical performances, such as the balance within a group of instruments, the musical use of acoustics to round off imprecise attack and to fill in staccato phrasing, the merging together of groups of instruments as a homogeneous whole when required, the arrival of a soloist's sound slightly earlier than that of the main orchestra, the avoidance of subjective mono distortion effects given by a small degree of spatial separation between nearby instruments, the alteration of tone colour, balance, attack and rhythm caused by the musicians adapting to the qualities of the live acoustics.

It is a strange fact that most of these subtleties of musicianship are well preserved on many pre-war electrical 78s, despite their technical imperfections and the then current fashion of recording orchestras in extremely dry studios. When played with no, or moderate filtering on correctly equalised top-quality equipment (e.g. Decca *ffss 78* head, Quad valve amp, Quad *ESLs*), it will be found that a sense of distance has been well captured, that the musical balance has not been tampered with, and that many of the more subtle qualities of the original sound can still be heard behind the crackling curtain of scratch. The magical quality of the blend in the Cortot/Thibaud/Casals Schubert *Trio No. 1* is often heard live, but rarely on record. Or listen to the light yet firm quality of Schnabel's piano against the harsh rustic blend of the orchestra under Sargent in Beethoven's *Emperor*. Or compare the infinite charm and delicacy of Elgar's performance of the *Wand of Youth Suites* with the garish technicolor of Boult's modern recording.

The recordings were almost certainly made with a single omnidirectional microphone. This technique can hardly be excelled for mono, especially as the all-round sensitivity to reverberation prevents any room-mode from being over-prominent.

Many of the subtler musical qualities were also captured by early coincident-mike stereo recordings, but often not so convincingly. The very best of the EMI *Stereosonic* recordings had a sense of space, an undistorted instrumental balance and tonal quality, and the quality of orchestral attack was well preserved. Unfortunately, many of these recordings suffered from faults such as modulation noise and a relatively dirty sound, and the stereo image quality was not always convincing. Nevertheless, it is easy to listen through the imperfections of these recordings and gauge the performer's intentions. Many Supraphon and Philips recordings of more recent vintage are also coincident-mike, although they suffer from varying degrees of dynamic compression.

Modern music particularly suffers from the lack of reverberant information, incorrect balance and wrong tone colours that seem to be inevitable with multimike recordings. An example of what good coincident recording can do is the Philips disc *SAL 3539*, in which Dorati's performance of the allegedly difficult Webern *Op. 10* orchestral pieces has a sweet mellifluous quality very different from the 'plink-plonk' sound usually given by multimike recordings of Webern. It is in modern music that the gross musical effects of even skilful multimike recordings are most apparent, as the necessary reverberation-fill-in between staccato sounds is rendered impossible by the 'presence' so sought after by multimike engineers, and adding separately recorded or artificial reverb muddies the sound unacceptably.

Some multimike recordings suffer from faults that could easily be avoided if the principles of stereophony, as expounded in N. V. Franssen's readable Philips book 'Stereophony', were better understood. In particular, ambience mikes are often used for stereo or four-channel, placed more than 10 m further from the orchestra than the main mikes; as is (or should be) well known, this causes the sound to be heard twice in a 'double-image' effect which can render the sound very confusing and fatiguing. With choirs or solo singers, distances of as little as 4 m can cause the double-image effect. This effect also rears its head when spot-mikes are used to reinforce the image given by a more distant main stereo pair, and the delayed echo can often be suppressed only by turning up the spot-mike gain ludicrously so as to swamp it. The double-image effect is severely troublesome when large choirs are recorded with orchestras by multimike techniques, as mikes have to be placed at a reasonable distance from choirs to get the internal choir balance right, but have to be placed close to avoid picking up sounds intended for other microphones. The result is either poor internal balance in the choir, or a double-image effect that manifests itself in a confused and muddy choral texture, or both.

The real argument against multimike technique is that it is incapable of making a recording in which the original tone colours, balance between instruments, reverberation effect and attack quality are preserved sufficiently well to hear their effect on the original musical performance. A remarkable example of what can happen when people are exposed to an actual coincident microphone recording is provided by the exclamations of musical revelation with which the Supraphon (Crossroads in USA) coincident mike recording of the Berg violin concerto was greeted in both Britain and America. Never before had the critics heard the glorious subleties of Berg's orchestration in a

(*continued on page 119*)

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West Germany: U. J. Fiszman, 34 Rödelheimer Str., 6 Frankfurt/Main. Tel. 778844. Switzerland: Spitzer Electronic, Bachstr. 2-6, CH-4104 Oberwil/DL. Tel. 477766. Belgium and Luxembourg: Gramophone S.A., 171 Boulevard Maurico Lommonnior, Bruxelles. Tel. 129815. Holland: N. V. Bovema-E.M.I., Zijlweg 142-144, Haarlem. Tel. 319247. France: DICOROP, Avenue Germaine, 06-Cagnes Sur Mer. Tel. 803877. Italy: Selvi s.n.c., 32 Via Felice Casati, 20124 Milano. Tel. 661213. Sweden: Arthur Rydin, Spangavagen 399-401, 16 355 Spanga. Tel. 08/7600320. Finland: Hankkija, Helsinki. Tel. 642833.

DENHAM & MORLEY (OVERSEAS) LTD., 453 CALEDONIAN RD, LONDON, N.1. TEL: 607 6568 recording, and most attributed this to the recording. It is worthwhile looking up these reviews, especially in *High Fidelity*.

However, if coincident microphone techniques are used, they must be done correctly for best effect. One suspects that many engineers turn to spaced or multimike techniques after failing to follow the rules of good coincident recording and getting inconsistent results. Almost all coincident techniques will give quite good results sometimes; the problem is to get good results all the time. The first rule is that the coincident microphones should have a polar response that does not vary much with frequency, especially in the treble. In particular this can rule out many of the most popular professional stereo mikes, such as the variable characteristic types. The effect of using mikes that become more directional in the extreme treble is that of an orchestra close at the edges and distant in the middle, because of the mid-stage sound's poorer treble.

A second rule is that the angle between the microphones should be chosen carefully. If the microphones are angled too widely apart, the edges of the stereo stage become overprominent, which upsets the musical balance, and distracting pools of echo appear at the edges, which severely reduces the centre-stage image sharpness and depth. If the microphones are angled too narrowly apart, the sense of sound spread characteristic of good stereo is diminished, and the stereo effect is disappointing. The basic rule which seems to work is that there should be an even spread of reverberation across the whole stereo stage, being concentrated neither in the middle nor at the edges. This requirement is extremely difficult to fulfil with spaced and multimike recordings. Theoretical computations and practical experience agree here, and show that good coincident cardioids should be angled 120° apart, although this gives a narrowish direct stereo image. The gain of the S signal in an M-S recording should be such as to cause a sound 70.5° off the axis of the cardioid to be reproduced from only one speaker, and figure-of-eights should be angled 90° apart. It is also possible to use closely-angled cardioids with out-phase crosstalk introduced between their outputs; if the cardioids are 90° apart, the sum signal should be cut by 4 dB, if 60° apart, by 8 dB, and if 40° apart, by 12 dB. With this technique it is necessary to ensure that the cardioids used are matched well and are as coincident as possible.

Another requirement for best results is that some of the *reverberation* should come from 'off the end of the stereo image', i.e. be slightly out of phase. This helps to increase the apparent width and space of the stereo although usually all direct sound will seem to come only from between the speakers. This rules out 120° cardioids for the finest and most consistent results; in any case they give a narrow stereo image.

It is found that the most satisfactory of all stereo images is obtained by the classic Blumlein technique, i.e. the use of 90°-angled crossed figure-of-eights. (It is incorrect to call other coincident techniques 'Blumlein', as his original patent application only referred to the use of 'moving strip', i.e. ribbon, velocity microphones). Blumlein recordings have a most remarkable stereo stability, giving a well-centred image almost everywhere in the listening room. This freedom from the stereo seat is a great relief from the severe discipline imposed by multimike recordings. Not only is the sound stable, but the stereo resolution is exceptionally good, with fine details of placement being clearly audible. This is notable, as good multimike recordings seem superficially 'analytic' but aren't, while Blumlein recordings don't seem superficially 'analytic', but are, in the sense that one can hear a lot of what has been recorded. Possibly the most surprising feature of Blumlein recordings is the fact that it is possible to gauge quite accurately how far away from the microphones a sound was, this being the only two-channel technique that seems to capture depth and distance well.

Having an omnidirectional horizontal stereo energy pick-up, the Blumlein technique captures an accurate musical balance, and seems to be the stereo technique giving results most comparable to omni mono recording technique. There is, of course, one fly in the ointment. Figure-of-eight recordings sometimes seem to have a slightly 'swimmy' quality. It is a matter of taste whether one feels it worthwhile sacrificing all the above advantages to get rid of occasional 'swimminess' or not but, if the ability to judge the original sound is important, figure-of-eights seem superior to other coincident techniques.

It is most regrettable that an ideal figure-of-eight microphone appears not to exist; most capacitor figure-of-eights having a poor treble polar response. The best mike that I know for Blumlein recording is the BBC-type STC *4038* ribbon. While this gives good results as it is, it is improved by electronically equalising the gentle bass and treble roll-offs (Nearly all professional microphones can be improved by equalising their frequency response.) The *4038* does have a slightly coloured quality, absent in the best capacitor mikes, and it is conceivable that such small imperfections are responsible for the occasional swimminess. The impecunious amateur should note that cheap figure-of-eights seem to be superior to other microphones in their price range, and a pair of Reslo *RBT* seems a good initial choice.

Careful placement

Having optimised our coincident mike technique, we can only get the best results by careful placement. The rule here is so astonishing and difficult that many engineers seem to think that balancing up twenty or so mikes is a lot quicker. The rule is to walk around during a rehearsal or first run-through, find out what position makes the *music* sound best live, and then place the microphones at that precise point at ear height! This rule has been tested experimentally by the (initially sceptical) author and by others, and works excellently. Sometimes a best position cannot be found, and then one has to choose a compromise position; in any case the process need not take more than five or 10 minutes. One must resist the temptation to move the mikes closer unless the live sound is better closer.

Subjectively, the sound of a Blumlein recording can only be impressive if the live sound is; more often it is unassuming but livable-with if one's interest is in listening to the performance.

In his article, Bob Auger claims that it is necessary to record multitrack and with maximum clarity so that 'the original tape can be taken out of the vault and redubbed later in an attempt to copy the sound fashion of the time'. Perhaps he will enlighten us with a further article on how a multitrack recording can be redubbed to sound like, say, a Blumlein recording; this is certainly way beyond the ability of present-day techniques. An astonishing sentence of his reads 'it should be remembered that one can always "cloud-over" the sound, or subtract "presence" during dubbing, but it is very hard to conjure up information not there in the first place'. This is true enough but contains the barely concealed assumption that reverberation is just something that can be added and which 'clouds-over' the sound. As observed above, the effect of the reverberation present on good coincident microphone recordings is quite the reverse; it provides extra information that allows the ears to resolve the stereo image more accurately (a phenomenon that is well-documented for live sounds) and to deduce the distance of each sound. As far as reprocessing multitrack recordings goes, it is indeed very hard to conjure up information (such as the original live pattern of reverberation) not there in the first place!

The ears use reverberation in a fundamental, though poorly understood, way to deduce spacial position and the particular 'quality' and directional properties of stereophonic reverberation seem far more important than the mere quantity or duration. The only way in which a Blumlein recording essentially differs from an 'ideal' multimike recording is in the presence of a pattern of reverberation related precisely to the original sound, and yet this is what gives Blumlein recordings their remarkable qualities.

An example of coincident mike qualities is given by the Philips *SAL 3644* recording of Debussy's *Sonata* for flute, viola and harp, in which one can easily distinguish which end of the flute is which, despite the total chamber group occupying only a third of the stereo stage. With one's eyes shut, one hears them playing, a natural distance away, in a concert hall.

Bob Auger also remarks that he can't understand why the Dolby A system is not in universal professional use. While we tread here on exceedingly controversial grounds, it should be remarked that, despite the undoubted engineering excellence of this device, there are those who are not totally convinced that it introduces no side-effects. In particular, one series of tests showed that it seemed to eliminate the above-listed virtues of Blumlein technique recordings, making the reverberation sound muddy and seemingly unrelated to the direct sound; in fairness, these results could have been due to misalignments in the tape machines. It is rare for commercial recordings of orchestral music to be made using a rigorous unadulterated Blumlein technique nowadays so this fault, even if it exists, may not have been observed elsewhere.

Coincident techniques have special virtue for four-channel stereo, as they seem to give a larger convincing listening area than spaced techniques. At first one would expect the 'precedence effect' (the early sound catches the ear) to make spaced microphones preferable in this respect, but experience contradicts this expectation. Furthermore, contrary to Bob,

(continued on page 140)

Keith Wicks visits Gemini Recording Studios and interviews Philip Cecil

inside gemini

Left: Philip Cecil at the Gemini mixer.
Top right: Shari Apple at piano.
Middle right: General view of mixer.
Bottom right: Tony Apple (guitar) and wife.

GEMINI Studios at 15 Cricklewood Broadway are run by two enthusiasts—Philip Cecil and Tony Apple. Before going any farther, I must point out that compared with most London studios, Gemini are not very well equipped. They do not pretend to be able to deal with large orchestras, and they do not provide multitrack facilities. What they do offer is an excellent service for groups who cannot afford the luxuries of the major studios. The charge for mono or stereo recording is incredibly low at £3.50 per hour. The price is even more remarkable considering the extras thrown in. There are miscellaneous musical instruments available at no extra charge and sometimes musicians are supplied as well.

I visited the studio in December and spoke to Philip Cecil:

KW *How did Gemini start?*

PC Well, I've always been interested in tape recording. When I got hold of a B & O *2000*, friends started to come and ask to be recorded, and the thing just grew from there.

I did more and more of this work until it seemed a good idea to do the thing properly. I then decided to move into a studio.

KW *When did that happen?*

PC It must have been a couple of years ago that we thought of going professional. We eventually found this place which was used by Dubreq. They first operated a studio, then went into making stylophones, but outgrew the premises and moved up the road. We've been here about a year, and have been open for about nine months.

KW *What can you tell me about your partner, Tony Apple?*

PC I met him through musical friends. He had a lot of audio equipment including the speakers which are now in the control room, and he also had about a thousand records. He is more musically inclined, whereas I tend to deal with the recording side.

KW *What are the dimensions of your studio and control room?*

PC The studio is about seven by five metres, and four metres high. The control room is about two by three metres, and just over two metres high.

KW *What microphones do you use in the studio?*

PC AKG almost exclusively. Two *D20*, two *D12*, two *D202*, and a *D119*. These are all cardioids but we do have a couple of figure-of-eight ribbon microphones.

KW *How many microphone sockets in the studio?*

PC We have lines to feed 18 signals to the control room, though at the moment that's more than the number of channels on the mixer.

KW *How many channels are there?*

PC Ten. Each channel has a preset gain, treble, middle, and bass, echo send, pan, and foldback level control. There's just one foldback system.

KW *What do you use for echo?*

PC We have a Grampian *636* spring unit. Plates are very expensive but I have been considering the possibility of building one.

KW *I see you have PPMs and VU meters on the desk.*

PC I found the original VUs very difficult to reconcile with the PPMs on the recorders. That was the basic problem. Having worked with both, I found I preferred PPMs, so we installed PPMs in the desk. Both types of meter are useful, so the VUs were left where they were.

KW *Who made your desk?*

PC Allen and Heath of Gower Street. They took over AB Audio who were in the mixer business.

KW *And your tape machines?*

PC We have two TRD stereo recorders. These are four-speed machines—38 down to 4.75 cm/s. Beneath each machine is mounted a Teletronix limiter. It's very good.

KW *How do you use your limiters?*

PC They're linked as a stereo pair and are normally directly before the tape recorder.

KW *Are the limiters set so that they just deal with the occasional unexpected high peaks?*

PC Well it depends on the music and on the effect required. Normally I like to record with just a few dB of limiting but, if people say they want it really *heavy*, then I limit it a lot more. On the other hand, for acoustic guitar and light voices, I leave the limiting right off if possible.

KW *Are there any special techniques you use when recording?*

PC Probably, but it's a bit hard to recognize them. On piano we sometimes use a microphone underneath. We find there's less spillage with virtually no loss of quality.

KW *So you get better separation. Don't you get any noise from the pedal mechanism?*

PC No. The mike's a cardioid and the pedals are at the back of it, so you don't get any pedal noise at all.

KW *And for recording electric guitar—do you use direct injection?*

PC I have in the past, but at the moment we always stick a mike in front of the guitar amplifier. We find this is very successful. It means that you get the tonal properties of the amp and speaker which are often very significant.

KW *Some studios use a mixture of direct feed and mike feed.*

PC Yes. I've done this with bass guitar. You can get a very good sound.

KW *And what do you use for monitoring?*

PC The monitoring amplifiers are Radford. For driving the speakers we have an *STA25*, which is 25 W per channel. In the control room we have a pair of 30 cm Goodmans speakers. They're the old version of what is now called *Magnum K*. We find them very good indeed. In the studio we have 38 cm Tannoys—not the *Monitor Gold*, the older version.

KW *What cabinets do you use for the Tannoys?*

PC I'm not sure who made them. I'm not too happy with them at the moment because they're a little weak at the bass end. Apart from that they're very good though. I intend to try remounting them sometime to improve the bass response.

KW *Are these run from the STA25 amplifier as well?*

PC We can switch the sound either to the studio or the control room speakers. We normally play tapes through the studio speakers rather than have people coming into the control room as it would be a bit crowded.

KW *What about headphone monitoring?*

PC We use a Radford *STA15* amplifier.

KW *Tell me about the sessions you have here. Are they mainly for demo discs?*

PC Yes, mainly demo sessions, although we have the occasional customer doing masters. Steve Laine did an LP here, and Wizz Jones recorded a couple of tracks.

KW *Your rates are extremely cheap. Why is this?*

PC We're trying to get customers. It's very hard at the beginning. We find that very few people come to us just because we advertise but quite a high proportion of people who do come return.

KW *When you have collected a number of clients will your rates go up?*

PC Yes. I'm not sure when it will be but they will probably go up to £4.50 per hour eventually.

KW *That's still very cheap.*

PC We think it's cheap too!

KW *Are you looking for financial backing in order to expand?*

PC No. We went into this thing right from the beginning with the idea that we would rather finance everything ourselves rather than use someone else's money. We have in fact turned down two offers of money. At one stage we were going to do video recording, and someone was going to finance us, but we decided against it in the end because we didn't want to use foreign money.

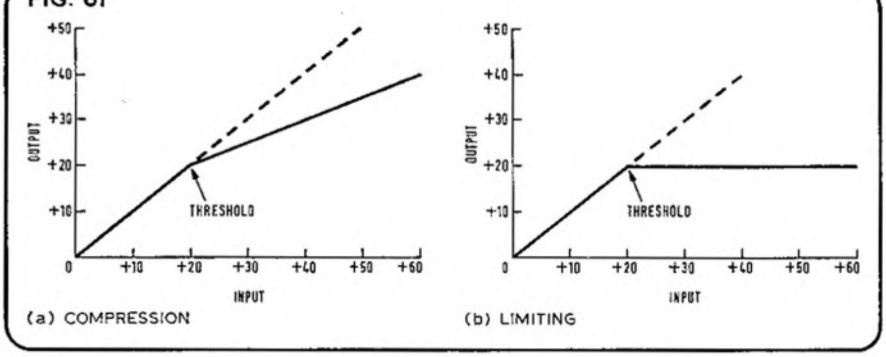
KW *What sort of video recording would that have been?*

PC The idea was to provide a service to actors or people who were going to appear on television, so that they could develop their screen techniques.

The other plan we have is for a record label. We know somebody who is able to get hold of pressing and distribution rights but we still have to decide what sort of things we're going to record and where we'll do it. We would need an eight-track machine for this, or at least a four-track.

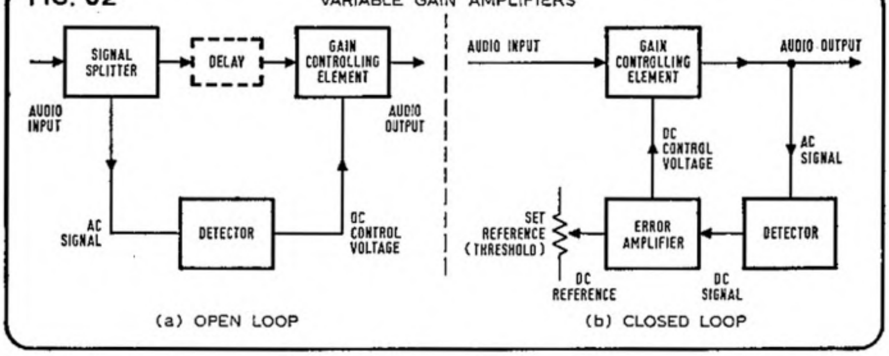
KW *Maybe in a year or two I'll be visiting you again to see what has developed. I hope everything works out well.*

FIG. 61



(a) COMPRESSION (b) LIMITING

FIG. 62 VARIABLE GAIN AMPLIFIERS



(a) OPEN LOOP (b) CLOSED LOOP

FIG. 63 GAIN REDUCTION IN A COMPRESSOR

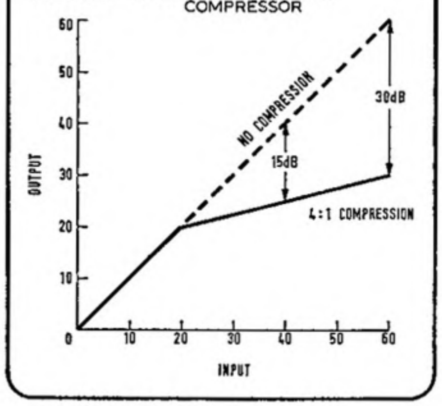
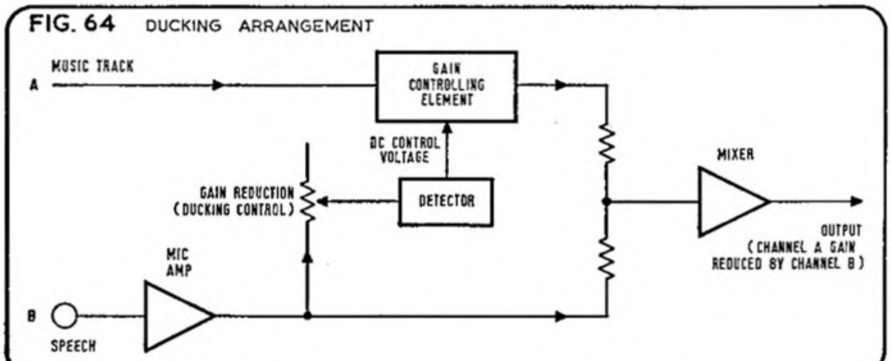


FIG. 64 DUCKING ARRANGEMENT



A HIGH QUALITY MIXER

David Robinson

PART 10

LIMITERS AND COMPRESSORS

IT seems inevitable if unfortunate that there will be errors in a series of the length of this project; perhaps the only encouraging fact is that most of the mistakes have been either very obvious or of a type which does not affect the performance of the mixer. However, one in the tone control stage, fig. 24, is important. The bass control, VR1, should be 50 K linear and not 500 K as printed. Our apologies to those who have struggled with this circuit. A minor error also on this circuit is that the value of the output capacitor C11 is not shown; it should be 25 μf at 25 V.

This part of the series is concerned with limiters and compressors; some experimental circuits are shown but I must stress these are only guidelines to the further work which has to be done on each to make them into properly engineered designs. The reason for this approach is that the requirements for gain-controlled devices differ so widely from situation to situation that it is not possible to produce a universal design. This being so, the solution adopted here is to suggest that commercial devices are brought and installed into the mixer, and this can easily be arranged within the basic modular conception. While the current tendency is towards having a limiter/compressor per channel, I feel that this is not the best solution; it certainly has economic drawbacks. More usually each group (or output) will have a limiter either built-in or available for patching into the circuit. With the mixer design, of course, either solution is easy to apply.

To start the discussion, the terms 'compressor', 'limiter', and 'threshold' must be defined. There are several ways of going about these definitions, but the most common are:

compressor: a device where the output increases at a slower rate than the input.

limiter: the output of a limiter is essentially constant regardless of input level, once a threshold is passed.

threshold: the point on the input/output transfer curve where the characteristic departs from a linear dB curve.

Fig. 61 illustrates these points more clearly. **Fig. 61a** shows compression; +20 is the threshold, and thereafter the output rises by 10 dB for every 20 dB increase in the input level. Thus it is known as a 2:1 compression ratio. Typical compression ratios are 2:1, 4:1, and 5:1. **Fig. 61b** shows a limiting characteristic, again with +20 as the threshold. Typical limiting amplifiers have 25:1 slopes, and this represents the normally required characteristics. There are devices available with 100:1 slopes but these are only used for special effects.

There are two methods of producing varying gain amplifiers—the open loop and the closed loop (or feedback) method (**fig. 62**). The advantage of the first of these is that there is no possibility of any oscillation, which can occur with feedback systems. The disadvantage is that to match a stated characteristic, which is essential for stereo, the attenuation law of the gain controlling element must be determined exactly. This is not easy to achieve. One further significant advantage is that a delay line can be introduced into the main signal path after the side chain has been tapped off. This allows the control voltage to be applied to the gain controlling element *before* the signal to be controlled has arrived. and so avoids the possibility of any overshoots. Audio delays of the necessary millisecond range are difficult to build but such devices have been made. One such is described in a BBC Engineering Monograph No. 70, Oct. 1967, by Shorter, Manson, and Stebbings, which also has an elegant solution to the problem of determining the characteristics of the gain controlling element in an open loop situation. A second monograph, No. 77 March 1969 (Shorter and Manson) concerns automatic control of studio levels and discusses the various requirements.

The design of limiters and compressors is complex. Perhaps the most difficult aspect is in the attack and decay times of the gain variation. For a limiter, the attack time wants to be very fast to avoid the system distortion (which the limiter is designed to overcome) but this produces unwanted audio sidebands modulating the programme input. For a compressor this rate of change can be slower—the slower, the less noticeable is the gain change. Release or decay times are long, usually to avoid the device becoming obtrusive—the ear is more sensitive to changes in this direction. The point to remember is that the amount of gain change is related to the compression ratio. **Fig. 63** shows this point for a 4:1 compression ratio. At an input of 60 dB the output is reduced by 30 dB; as the input signal is reduced, the gain of the compressor is increased; thus the noise (either in the device or in the incoming signal) will rise and fall by the amount of gain change —if this is a quick change, then the resulting pumping or breathing noise produced is very objectionable. If the audio spectrum is filled by the material being compressed, then the music itself will mask the breathing—but as soon as only high or low notes are present (or acoustically-transparent sounds such as guitar or piano are used) then the noise is not masked by the signal. This of course leads to one solution—to split the audio band into sections and provide separate independent compressors for each section. This concept has been commercially developed by Altec Lansing in their model *9473A* limiter.

Multiple time constants can also be used to produce devices which respond very quickly to sudden changes in level, but slowly to small changes, which helps the pumping effect. If these circuits are designed to respond quickly to increasing signal changes only, we have a circuit which will measure the maximum signal and refer other changes to this predetermined peak. Such circuits have been used in disc cutting or broadcasting when the material is available before transfer occurs, e.g., it has already been recorded on to tape previously. Monograph 77 goes into greater detail on this aspect.

Limiters and compressors can be modified to produce different characteristics at different levels or frequencies by introducing suitable networks into the side chain detection circuits. Thus HF-only limiters are produced by introducing high pass filters into the side chain; compressors turned into limiters by increasing the side chain gain considerably as the DC control voltage rises. De-essers are HF-only limiters used to remove sibilants from speech.

In some applications the control voltage to the gain controlling element is derived from a different source to the signal passing through the element—for example a voice track being added to a music track can be arranged to reduce the music track gain automatically. Such use is known as 'ducking'. This is obviously an open loop situation, but the disadvantages mentioned earlier do not apply in this application; **fig. 64** shows the layout of such an arrangement.

After this short discussion of the philosophies of these devices, let us consider a few circuits for producing the gain variation. Motor driven potentiometers are excellent from both signal-to-noise ratio and distortion aspects but unfortunately are not practical for several counts—speed for one. Another theoretically good device is the photosensitive cell; a circuit is shown in **fig. 65.** However, this scheme is not commendable since the response time of the photosensitive cell is very long—some hundreds of milliseconds, which is unsatisfactory for large amounts of gain reduction. Both these methods have complete isolation of control signal from programme signal.

(continued on page 125)

FIG. 65 LAMP – PHOTORESISTOR GAIN VARIATION DEVICE

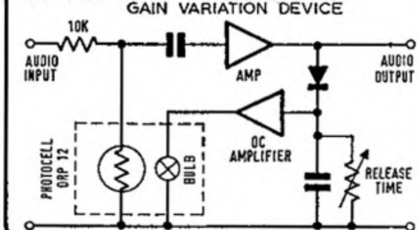


FIG. 66 SEMICONDUCTOR FORWARD BIASED JUNCTION CHARACTERISTICS

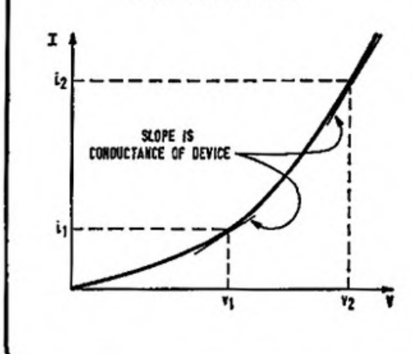
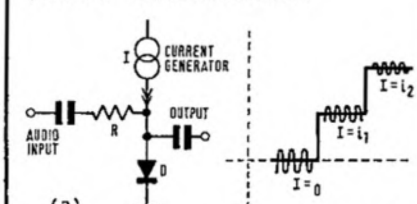


FIG. 67 DIODE ATTENUATOR



(a) CIRCUIT (b) OUTPUT SIGNAL

FIG. 68 BALANCED DIODE ATTENUATOR

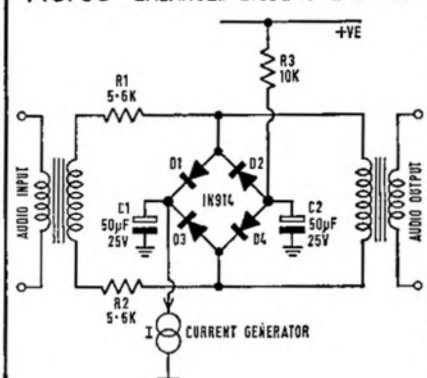
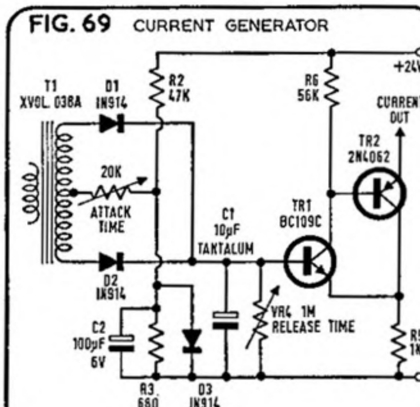


FIG. 69 CURRENT GENERATOR



The Grundig TK147 is a hush-hush job

The TK 147, a four-track, fully automatic stereo machine, is one of Grundig's silent breed of tape recorders. The one sound we don't want you to hear out of the TK 147 is the TK 147. So we've designed it with that in mind. Because at Grundig we like to be at least several jumps ahead of the rest of the crowd. The TK 147 is built to an exclusive Grundig design with an elaborate electronic circuit that keeps noise to a minimum.

But that's just the start. This superior design also keeps the distortion level low and frequency response and dynamic range high, whatever the conditions, the composition or the volume of the recording.
And how d'you like the sound of that? You can get superb stereo playback results by connecting it to a Grundig Stereogram or external stereo power amplifier and loudspeaker.

Wherever you look, you'll find clear evidence of Grundig's superb craftsmanship and attention to detail which results in a sound quality that is unmistakably better.

Listen to the hush-hush TK 147 soon - it's something to make a noise about. TK 147 - £96.4.0.

The valve was well suited to acting as a variable gain element ; vari-mu devices were used in many such equipments. Semiconductors are not so suited. One parameter which can be used is the variation in forward resistance of a diode with forward current, shown in **fig. 66.** The slope of the DC transfer curve represents the conductance, or 1/resistance. A small AC signal can thus be added to the DC in the manner of **fig. 67.** An attenuator is formed by R and D. With no current flowing, the diode is off and has a high resistance. As the current increases the diode slope resistance decreases and so the audio output is reduced. Note the two defects: the AC signal must be small, such that over the AC excursion the transfer curve is essentially linear to prevent the curved diode characteristic from distorting the signal. And the change in resistance is accompanied by a large change in DC level, many times greater than the AC component (**fig. 67b**). This latter produces a great thump in the signal and is not acceptable.

To avoid the thump, a balanced circuit must be used, and one is described in **fig. 68.** In this case, if the diode pairs are matched, the DC voltage change in one diode (D1, say) is balanced out by a similar change in the other (D3). Notice how DC isolation is achieved by transformers; the circuit can be re-arranged with more complexity to avoid transformers. A suitable current generator can be derived from the PPM circuit of fig. 42, as in **fig. 69.**

With integrated circuits obtainable fairly cheaply, a suitable ready-matched circuit can be made up from the RCA *CA3054* which has two long-tailed pair amplifiers, inherently prematched and fabricated from a single chip. The principle here is similar relying on the emitter diode. As a rule of thumb the emitter resistance r_e is $26/i_e$ ohms (with i_e in milliamps), and the gain of the transistor R_c/r_e. To avoid DC thumps in the collector circuit (**fig. 70**) the two pairs are cross connected so that an increase in current in Tr1 is balanced exactly by a reduction in Tr6; the DC shift at the junction of the two collectors is thus zero. The gain of each stage is $R_6/2r_e$, or $R_6.i_e/52$. A 20 dB range is easily obtainable.

With the introduction of the FET, problems are much easier. The FET is inherently symmetrical—that is, its characteristics in both forward and reverse directions are identical. It is thus balanced, and an AC signal can be applied directly to the device. The important characteristics are shown in **fig. 71.** For small AC signals, the characteristics are linear, and it is easily seen that, as the gate-source volts are increased, so the dynamic slope resistance increases; the limit is reached when the gate voltage cuts the device off, and this stage is known as the pitch-off voltage.

The FET can be used as a voltage-controlled attenuator or to control the gain of an amplifier directly. The first method produces circuits which are easy to adapt for special purposes and which produce better results; the second method is the simpler. An attenuator circuit is shown in **fig. 72;** the FET resistance varies from 1 M to 1 K. R_1 together with this resistance change controls the maximum amount of attenuation produced. If the control voltage is derived from the output signal, we have a compressor/limiter circuit.

FIG. 70 TRANSISTOR ARRAY COMPRESSOR

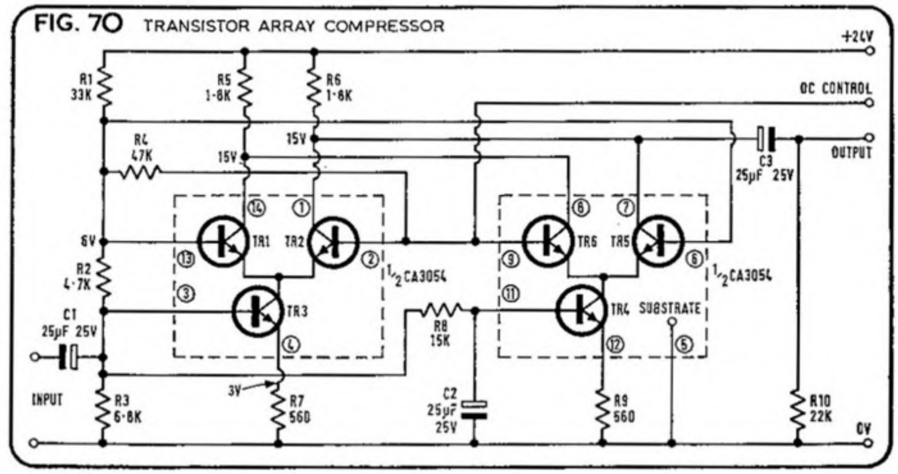


FIG. 71 FET CHARACTERISTICS NEAR ORIGIN

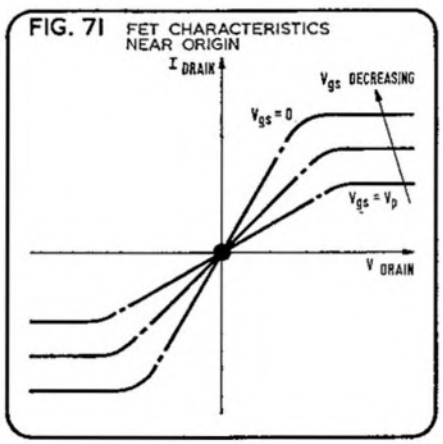


FIG. 72 FET ATTENUATOR

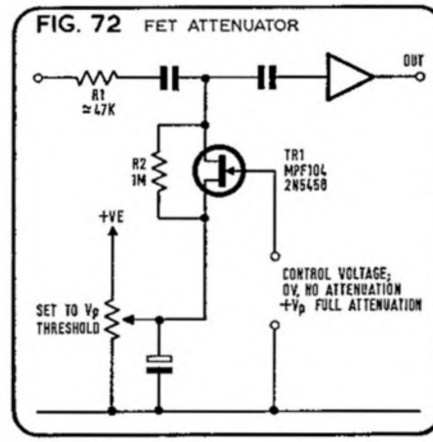


FIG. 73 DISTORTION COMPENSATION IN FET ATTENUATORS

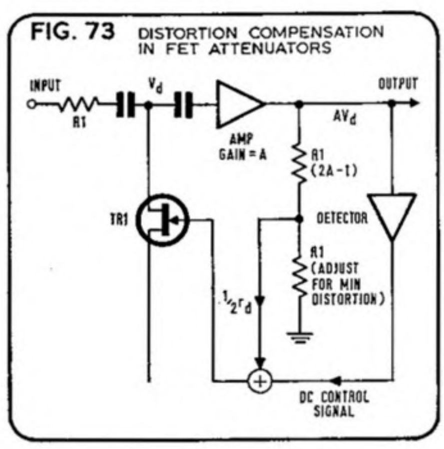
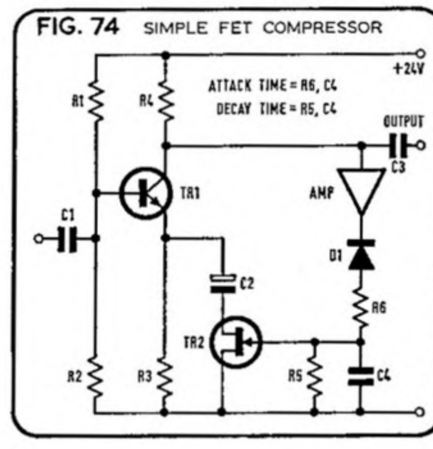


FIG. 74 SIMPLE FET COMPRESSOR



One of the problems with the FET is that it cannot take an audio signal of much greater than 100 mV if the second harmonic distortion is to remain low, particularly in the region of high resistance. If we keep to this low voltage, too much noise is introduced by the circuits. The solution is to correct for non-linearity of the FET. The most common method of correcting second harmonic distortion is to operate two devices in push-pull to cancel the distortion but working out the circuit for this leads to another simpler method. If half the AC signal on the drain is added to the control signal, this is equivalent to push-pull operation, and the second harmonic is reduced by some 20 dB. **Fig. 73** shows the principle and one possible method of applying this feedback. There are, however, many circuit configurations which will produce the same result. The resulting distortion is very small and mainly third harmonic, which too can be removed if required by introducing equal and opposite amounts via, say, back-to-back diodes. Interested readers are referred to AES preprint No. 713 by John P. Jarvis.

(continued on page 127)

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5¾" LP	1,200'	39/5	1.28	25/6	36/4	1.23	24/6
5¾" DP	1,800'	56/5	1.83	36/6	56/10	1.84	36/9
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5" TP	1,800'	61/9	2.00	40/-			
5¾" SP	900'				34/4	1.23	24/6
5¾" LP	1,200'	43/5	1.44	28/9	45/7	1.60	32/-
5¾" DP	1,800'	61/11	2.03	40/6	63/1	2.23	44/6
5¾" TP	2,400'	76/5	2.45	49/-			
7" SP	1,200'				43/-	1.53	30/6
7" LP	1,800'	62/1	2.00	40/-	60/-	2.10	42/-
7" DP	2,400'	76/7	2.45	49/-	89/-	3.13	62/6
7" TP	3,600'	95/1	3.08	61/6			
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C120		33/7	0.93	18/8	33/7	0.93	18/8

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5"	600'	6/-	17/6	5"	900'	8/-	23/6	5"	1200'	12/6	37/-	5"	1/9
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FIG. 75 I C COMPRESSOR CIRCUIT

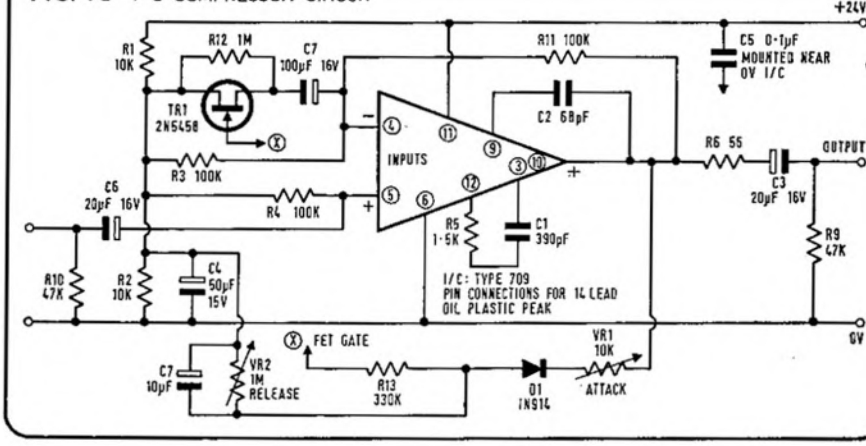
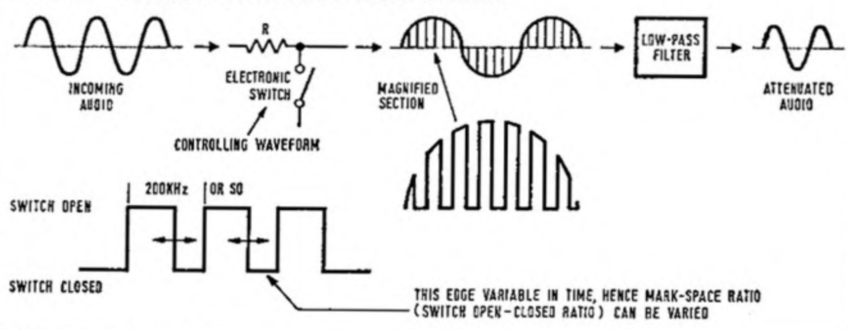


FIG. 77 SWITCHING COMPRESSOR BLOCK DIAGRAM



The simplest circuit referred to above is shown in **fig. 74.** With no input signal there is no gate voltage on the FET, so the source-drain resistance is low and the stage gain high. As the input signal increases, a negative gate voltage is developed which turns off the FET, increasing the AC emitter load and hence reducing the gain.

An experimental circuit using an IC (**fig. 75**) was built to test another method of gain reduction. The results obtained show this circuit has promise and would repay further investigation, although my own feeling is that best results would be obtained by development of **fig. 73.** The IC circuit has a good overload characteristic, and produces compression from input signals as low as –30 dB. Compression curves are gradual with a maximum slope of 10:1, and a slope in the operating region of 5:1. To increase these figures to produce limiting action would require gain in the side chain. To give variable attack and decay times would also need more circuitry in this part of the design.

Another interesting method of gain reduction is based on sampling techniques. If we chop an audio signal at a rate well above the highest audio, we effectively reduce its energy. Passing the resulting signal through a low-gain filter removes the chopping action, leaving an attenuated audio signal. **Fig. 77** shows the principle. If the mark-space ratio of the chopping signal is varied, the level of audio varies in sympathy. The system can be made to work on a limiter or compressor by taking the output of the low pass filter and, after detection, applying it to control the pulse generator. Using these techniques it is easy to arrange for almost any law, both compression, and expansion, and even noise-gate effects by cutting the gain drastically at very low signal levels. The most comprehensive embodiment of the principles is the EMT *156* compressor, whose block diagram is reproduced in **fig. 78** and characteristics in **fig. 79.** There should be no problem in stereo tracking since the filters can be made very accurately and the switching device is either on or off. For this latter, a FET is ideal, and techniques used in instrumentation chopper circuits (e.g. shunt/series choppers with compensation for capacitive control signal breakthrough) will produce excellent results.

In all cases, metering to indicate the gain reduction can be arranged by applying the control voltage and a voltage equal to the no-signal control voltage to the inputs of a simple differential amplifier; the output can then be fed to a suitable meter which can be easily calibrated.

Finally let me add again that the compressor circuits given are purely experimental, aimed at pointing to possible ways of achieving the desired results. I cannot undertake to answer any queries on these or suggest ways in which they can be developed.

Next month will start with some thoughts on IC amplifiers, but the main part of the article will be devoted to readers' questions and problems, together with suggested solutions to the latter.

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Lamps, photocells, transistors, etc.: Henry's Radio Ltd.

AES Preprints: Audio Engineering Society Inc, Room 428, 60 East 42nd Street, New York, NY 10017, USA. Price: 85c each (non-members); 50c (members). Postage extra.

FIG. 76 COMPRESSION CHARACTERISTIC OF FIG. 75

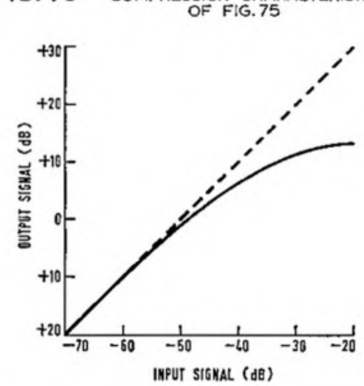


FIG. 78 BLOCK DIAGRAM OF EMT SWITCHING COMPRESSOR

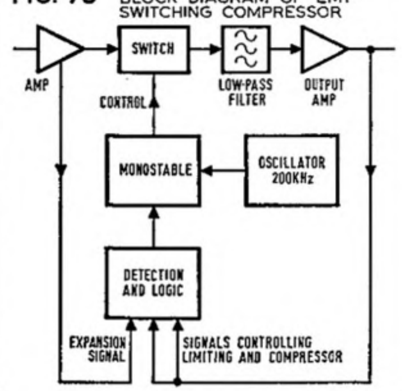
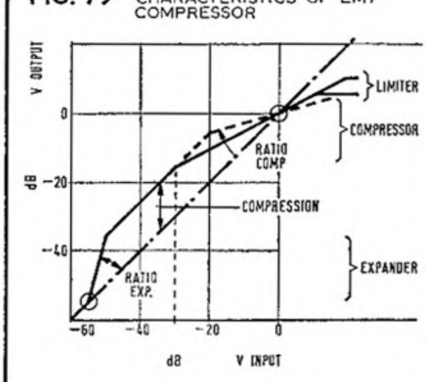


FIG. 79 CHARACTERISTICS OF EMT COMPRESSOR



CHROME

An investigation into the relative advantages of chromium dioxide and ferric oxide tape coatings

by Angus McKenzie

IT is probably true to say that ferric oxide tape has been developed as far as it is ever likely to be. Better binders may be discovered and slight improvements in performance might be obtained by adding ferrites to the mix. There are unfortunately very few magnetic compounds known. Chromium dioxide and chromium bromide, $CrBr_3$, are comparatively well known, having received a certain amount of publicity in chemistry journals about 20 years ago. One of the rare earth elements in the lanthanum group, named europium, also has magnetic compounds which might be worth investigating for audio purposes although their production would be phenomenally expensive.

Chromium dioxide (CrO_2) is a most unusual chemical in that chromium is forced to have a valency of 4 instead of its more usual 6 or 3. For this reason it is rather difficult to prepare although stable at normal temperatures. Although the manufacturing process actually used for CrO_2 would appear to be secret, I must assume that a similar process is used to that quoted in most text books: passing oxygen at between 200 and 300 atmospheres pressure over chromium trioxide (CrO_3) which is heated to around 450°C. The application of the heat tends to break down the trioxide whereas the presence of the oxygen prevents the breakdown going too far. Otherwise Cr_2O_3 would be formed, which does not have magnetic properties. This latter chemical is in any case formed when chromium dioxide is raised in the open air to a high temperature, although one would have to exceed the Curie point for this to happen. Whereas ferric oxide tape varies in colour from a light brown to almost black, depending on the size of the oxide particles, in general chromium dioxide appears to be black even when seen as larger crystals. Presumably because of its very high cost, all the 6.25 mm tape samples that have been made available in Britain for test purposes have only had a very thin oxide coating of 4.5 μm on a plastic backing of 22 μm. The thickness of this tape therefore corresponds fairly closely to double play tape, although the backing itself is almost as thick as LP tape. Ordinary LP tape, incidentally, has a plastic backing of approximately 25 μm with an oxide coating of 10 μm whereas DP tape has a backing of 16 μm usually with the same oxide coating of 10 μm. Many engineers who have evaluated chromium dioxide tape and have not known of this difference in coating thickness may well have misjudged the material since the output of the tape at middle and low frequencies would appear to be more or less proportional to the coating thickness, provided that one adjusts the bias accordingly and the coating is not too thick.

Two samples of 6.25 mm tape on 18 cm spools originating from Du-Pont in the States were tested thoroughly. At all reasonable levels of bias, the 9.5 cm/s performance was compared with that of BASF *LP35LH* and later *TP18LH* tape. The resultant figures must be interpreted very carefully. At first, before knowing that the coating was so thin, I was not impressed with the 3% third harmonic of 1 kHz being only 1.75 dB above 0 dB (32 mM/mm). Increasing the bias to a level rather higher than I might have expected, a point of +3 dB was obtained for the same distortion.

Let me say now that the advantages of chromium dioxide over normal tape primarily appear at lower tape speeds or where it is is required to record very short wave lengths, for example in instrumentation and video applications. Particularly great benefits appear to be gained when used in cassettes but all these benefits are not without their disadvantages, as will be seen. With normal tape, choosing the correct bias point for recording at lower speeds is very difficult since the bias required for lowest 1 kHz distortion can be at least 4 dB higher, i.e., 60%, than that required for maximum output at high audio frequencies.

Although chromium dioxide definitely needs a higher bias than iron oxide, the HF fall-off effect is nowhere near so marked. A test example of this will prove the point. Cassettes of BASF *C90* low noise were compared with chromium dioxide cassettes made by Memorex

CENTRE FREQUENCY OF MEASURED NOISE OCTAVE	CASSETTE REPLAY AMP NOISE	BASF C90 CASSETTE	EARLY MEMOREX CHROME CASSETTE	RECENT MEMOREX CHROME CASSETTE	AGFA CHROME CASSETTE	6·25 mm TAPE REPLAY AMP NOISE	6·25 mm BASF LP35LH TAPE	6·25 mm BASF LGS35 TAPE	6·25 mm CHROME TAPE
125 Kz	**	**	**	**	**	–74	–70	–70	–68·5
250 Hz	**	**	**	**	**	–77	–72	–71	–72
500 Hz	–72	–70	–70	–70	–69	–80	–72	–71	–72
1 kHz	–74·5	–70·25	–70	–70	–68·5	–82	–72	–70	–72·5
2 kHz	–74	–68	–67·5	–67	–66·5	–82	–71	–69	–71
4 kHz	–70	–65	–63	–62·5	–63	–78·5	–68	–65·5	–66
8 kHz	–65·5	–64	–60	–60·5	–61·5	–71·5	–65	–63·5	–61·5
16 kHz	–61	–60	–55·5	–58·5	–59	–64	–62	–62	–60
dBa weighted noise	–59·5	–58·5	–55	–55·5	–56	–67	–62	–59·5	–60

** *Readings not recorded as hum on record amp influenced results.*

and Agfa. A Wollensak cassette recorder was used.

The BASF *C90* cassette had an overall frequency response of ± 1 dB from 30 Hz to 15 kHz with reference to 333 Hz with the bias set to 25 mV at a particular test point. At this bias, the overall response of an early sample of Memorex chromium dioxide tape was 10 dB up at 10 kHz and 13 dB up at 15 kHz, whereas the BASF tape was 1 dB down at the latter frequency. This difference is of course quite remarkable. With the other chromium dioxide tape, the response at 10 kHz was 8.5 dB up and the response at 15 kHz 10.5 kHz up at the same bias. When the bias was increased by 2.5 dB, the ordinary BASF cassette fell 15 dB at 15 kHz. The bias points for medium and short wavelengths are in fact closer together. A 10 kHz saturation signal was then applied to both the BASF *C90* and the chromium dioxide cassettes. Approximately 7.5 dB more level could be recorded on the latter.

The noise spectra of the different cassettes in one-octave sections were then compared with the noise spectrum of the replay amplifier itself, all the cassette noise measurements being made with optimum biased tape and no input signal. The BASF low noise cassette, at the HF end, generated less noise than the replay amplifier. All the chromium dioxide samples produced more HF noise than the BASF cassette, particularly in the 4 and 8 kHz octaves. The best of the chromium dioxide cassettes in fact had approximately the same dBA weighted noise as the replay amplifier so that, when the tape ran past the head, the noise level increased by about 3 dB. The actual differences between tapes in different octaves showed far more clearly when 6.25 mm tape was used.

Cassette noise is not as important as the ability of the chromium dioxide cassette to accept a very much higher recording level at high frequencies, the available signal-to-noise ratio in the 8 kHz octave, for instance, being approximately 46 dB for the best chromium dioxide and 39 dB for the BASF *C90*. This ratio is the difference between the maximum 10 kHz signal which could be recorded and the dBa weighted noise figure of unrecorded bias tape moving past the replay head, both referred to the same peak level. Since the distortion at medium wavelengths was fairly similar, it would appear that the chromium dioxide gives a substantially better signal-to-noise ratio. It should be noted of course that the chromium dioxide tapes would exhibit audibly a slightly higher hiss level, but on the other hand they have considerably greater power handling capacity at higher frequencies. This in fact means that a wider dynamic range can be accommodated, particularly on prerecorded cassettes, allowing the engineers in the latter case to use less HF compression than would otherwise be necessary. Serious consideration should now be given to changing the replay equalisation curve for chromium dioxide tape, lowering the replay amplifier hiss level while still keeping within the capability of the tape. A curve of 70 μS, the same as the DIN curve for 19 cm/s, would be a good compromise. The bass cut normally used for 4.75 cm/s could be changed for all cassettes from 1 590 μS to 3 180 μS, moving the 3 dB replay bass cut point from 100 Hz to 50 Hz, thus preventing the necessity for boosting so much bass on record which in the past has frequently caused overload distortion of these frequencies.

As I previously explained, the 6.25 mm chromium dioxide tape compared very favourably with triple play *LH* tape with its 6 μm oxide thickness against chromium dioxide's 4.5 μm. With a suitable bias, it was found possible to record for the same distortion at middle frequencies 1 dB higher level on the chromium dioxide than on the conventional triple play tape, despite the latter having a thicker coating. At high frequencies as with cassettes, the 9.5 cm/s difference was more marked, being normally nearly 10 dB when each tape was biased for optimum overall performance.

As far as the domestic consumer is concerned it would be fairer to compare chromium dioxide 6.25 mm tape with DP *LH* tape and, in this case, the latter's considerably thicker oxide coating would appear to give a better overall performance because of the 3 dB extra level that could be accommodated at middle frequencies. For chromium dioxide in its present form to be preferable to ordinary tape, it would be necessary to change the replay curve to almost a pure 6 dB per octave, i.e., no HF turnover at all, and in addition to record at a lower level, keeping the distortion down at middle frequencies. Since the majority of domestic tape recorders would then have hum problems on replay, the 50% or 60% additional cost of chromium dioxide tape would not be justified. Provided the cost would not be too much higher, a very considerable advantage would be gained by increasing the chromium dioxide coating thickness on 6.25 mm tape to 10 μm which would then make it dramatically better than conventional tape, even at 19 cm/s although again the replay curve would have to be altered to get the greatest benefit.

It is interesting to remember that BASF *LH* tape is itself 3 dB quieter than the older *PES 35* tape made by the same manufacturer, so it can be said that the tape noise of chromium dioxide sounds very similar to the average LP tape made four years ago, its difference being its phenomenal power handling capacity at higher frequencies.

For high speed cassette duplicating, it would appear that a higher level can be applied to **chromium dioxide tape when a relatively wide record gap is used. Bearing this Dolby B system in mind, I am sure that it will be possible eventually to produce cassette records of a quality hardly dreamed of even two years ago. The main problem will be the limitation of frequency response at the top end, for I doubt whether frequencies far in excess of 12 kHz will be practical since most high speed cassette duplicators operate at 32 times normal speed, necessitating the recording of frequencies in excess of 400 kHz.**

To sum up the above, I consider that attempting to use chromium dioxide on an ordinary domestic tape recorder is pointless since such a machine will probably not have enough bias available and in any case will have the wrong replay amplifier response. Since chromium dioxide at 9.5 and 4.75 cm/s shows a boost of some 10 dB at 10 kHz over normal tape, this would require severe tone correction or heavy modifications in the record amplifier. This would only be worthwhile on a conventional recorder if the chromium dioxide coating were made appreciably thicker by the manufacturers but such a change could result in a 550 m reel costing at least £5. Japanese cassette decks with chromium dioxide switches (which increase both the record level and the bias by 2 dB whilst altering the replay characteristic) are already available in Britain. Unfortunately most domestic cassette machines distort seriously at recording levels giving a replay flux in excess of 20 mM/mm. Even my Wollensak is guilty in this respect, let alone a Nakamichi deck which I have recently tried. This will not stop prerecorded tapes of a higher level being played back satisfactorily.

Modulation noise and print-through have not been particularly evident with chromium dioxide tape, although long term print-through characteristics have yet to be determined.

For domestic cassette machines it is perhaps unfortunate that the very high average inductance for replay heads necessary to overcome replay amplifier noise is not compatible with the ideally much lower inductance required for recording. Lower inductance heads may eventually be used with a head lift transformer for replay. It should then be possible for the domestic user to obtain the full benefit of chromium tape.

Frequency Response Curves

FREQUENCY	BASF LP35LH 6·25 mm TAPE	EARLY MEMOREX CASSETTE	EARLY MEMOREX CASSETTE BIASED +4 dB	RECENT MEMOREX CASSETTE	AGFA CHROME CASSETTE
440 Hz	0	0	0	0	0
1 kHz	0·5	1	0	1	0·75
6.3 kHz	0	7·5	2	7	5
8 kHz	–0·25	8·5	3	8	5·75
10 kHz	–0·5	10	3	8·5	6·5
12 kHz	–0·75	11·25	3	9	8
15 kHz	–1	12·5	3·5	10·5	10

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AUDIO ANNUAL 1971

Produced by HI-FI NEWS and STUDIO SOUND

40p

Again – by popular request – we have devoted a big section to reprints of equipment reviews which have appeared in Hi-Fi News and Studio Sound over the past year. These reviews have a well-deserved reputation for reliability and they are sure to be of lasting interest. In addition, there are feature articles on:

- Cassettes and the future of commercial recording
- Simulating concert halls in the laboratory
- Electronic music – a composer's approach
- Auditory apparatus – how our ears work
- What is good recorded sound? 'Developments in quadrophony'

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STUDIO DIARY

BY KEITH WICKS

At **Spot Productions** in South Molton Street, Dave Maynerd engineered a session featuring Billy Fury, who was putting down tracks for an LP. John Hudson has been busy with a Titanic LP produced by Paul Lynton and a Dubliners LP produced by Phil Coulter. John also engineered an LP for Alan Klein, ex-lead singer with the New Vauderville Band. Producer on this was Tommy Sanderson.

Sound of Maidenhead, at the moment with a small studio, are about to expand into new premises. Run by technical director Ian Webb, in partnership with John Aston, a former radio pirate, Sound have a four-track Ampex and hope soon to buy an eight-track Leevers-Rich. Film equipment (16 mm) with rock and roll facilities will also be available. As manufacturers of studio equipment, they naturally use one of their own desks. This has 16 input channels. The studio will be biased towards commercial radio requirements, half the studio space being set aside for this purpose. John Aston and a couple of ex-pirate friends have obtained the necessary financial backing, and are already equipped with a mobile unit. Housed in a Bedford van, the equipment consists of an eight-channel two-group desk, twin 40 cm turntables, a Spotmaster cassette machine and a modified Leevers-Rich two-track recorder.

From **Trident** comes news that they have added a second 3 M 16-track machine with associated Dolby *A301* units so they can now run two independent 16-track operations. Another improvement has resulted from the installation of new acoustic screens, made to BBC specifications by Wenham and Fowler. Malcombe Toft, Trident's studio manager, is very pleased with the improvement in separation obtained with these screens. Recent events at the studio include recording for Vanity Fair, and some work on the George Harrison album *All Things Must Pass*. This has just been released and is selling well. Trident did some of the recording and all the mixing for this LP.

Acorn Records announce that they are in the process of moving to new studios near Woodstock in Oxfordshire and hope to be operational on March 1.

The **Impulse Organisation** in Northumberland are reorganising their premises. A new 21 m² control room has been built. The old control room has been converted to a drum booth, a facility they have wanted for a long time. New hardware includes a 12-channel, four-output mixer with equalisation, echo-send, limiting, and compression on all channels. Visual monitoring is by means of four main VU meters and, for aural monitoring, a 100 W stereo amplifier feeds two speakers housed in cabinets made by Ski Electronics, one of Impulse's associate companies.

Impulse have been busy lately with mobiles, demos and TV jingles, and are currently recording an LP for Lindisfarne, due to be released by Charisma in the spring. Due for release in February is what Impulse describe as a 'contemporary/traditional folk/rock LP' entitled *Take Off Your Head and Listen*. This consists of folk club recordings as well as studio material. The record will be released on Rubber Records, Impulse's own label.

An entertaining evening was had at **Command Studios** in London when Eddie Kennedy presented two new Marquee Martin Agency groups, Anno Domini and Stud. The music, the luxury of Command's Studio One, and Eddie Kennedy's hospitality, combined admirably.

At Soho's **Marquee Studios,** Curved Air, after great success with their first album, have been putting the finishing touches to material for a maxi single. Engineer/producer was Colin Caldwell, and the disc is due for release very soon. Dandelion Records have been using a lot of studio time to complete albums by their artists. **Phil Dunne** has been busy engineering sessions for Medicine Head, The Siren, Stack Waddy, and Beau. John Peel produced for Beau, and Keith Ralph for the Medicine Head. Lesley Duncan, singer/songwriter wife of arranger Jimmy Horowitz, was in the studio with her husband, mixing an album to be released in March. Others at the studio have included Atomic Rooster, and Keith Potger, formerly of the Seekers. Marquee's special facility of being able to record from their adjoining club was used by German Television. A performance starring The Faces was recorded on 16-track and also filmed by the television organisation. The material will be used to produce a half-hour performance.

At **Recorded Sound,** Richard Harris made a single with Maurice Gibb producing. Julie Ege has just finished her first single—John Lennon's *Love*—and Tony Palmer has been recording the New Generation Singers for Polydor Records. Tony is soon to produce a Victor Sylvester record at the studio.

Over in Dublin, **Bill Russell Films** are starting a recording studio to be called **Atlantic Sound.** Although modest by London standards, the studio is relatively well equipped for that area. The mixing console is by Allen & Heath, and recorders are by Revox, Ferrograph, and Kudelski. Other equipment includes AKG microphones, a Grampian reverberation unit, and a tape delay system. The studio, which is still being built, will be unusual because the walls do not meet at right angles. This is a great advantage acoustically, but is rather uncommon as most studios have to be built into existing parallel-sided rooms. Plans for expansion are ambitious and it is hoped to instal an eight-track machine along with a Dolby system and an Alice mixer before the end of the year.

In Gosport Street, **Advision** have just finished another Shirley Bassey LP and are now involved with a Petula Clark album. They are soon to start work on another LP with Emerson, Lake and Palmer.

Art Record Productions of Surrey have just finished a master for Agapus entitled *Please Don't Step On My Feet*, which should be released around mid February.

One of the busiest studios this month has been **IBC** in Portland Place. Recordings there have included the Equals' new single, *Black Skinned Blue Eyed Boy*, engineered by Brian Stott; some work for Track Recordings featuring The Who, and engineered by Lyon Shaw; and a Brass Monkey album engineered by John Pantry. Mike Claydon was at the desk doing some Graham Bennett sessions for A and M Records. Space does not permit mention of all the names at IBC during the last month, and this state of affairs is likely to continue for a while. The pressure should soon be somewhat relieved when IBC take delivery of their second 16-track Ampex *MM 1000* with associated Dolbys for Studio Two. Work has now started on Studio One's new desk which will have 32 inputs and 32 outputs. Rather than take the intermediate step of 24 tracks, Mike Claydon thinks it is possible that they may go from 16- to 32-track recording. (Opportunity here for an enterprising British firm.)

Beck Amplification's new Wellingborough premises have been named **Beck Recording Studios.** All their recording is now done in stereo, and cutting equipment has recently been installed.

Yorkshire's **Calder Recordings** have been heavily booked for some time by Astron Music Promotions. This month sees the completion of two albums and 18 EPs for their dance music label. Requiem have laid some tracks for their first release on the new Carlins label. In addition, the studio has been busy with mobile and demo work.

AIR Studios at Oxford Circus have been extremely busy with a lot of jingle work, and also albums for Stan Getz, the Hollies, Cilla Black, Jimmy Tarbuck, Procul Harum, the Fortunes, the Strawbs, Tyrannosaurus Rex, Caravan and Hype, to name a few.

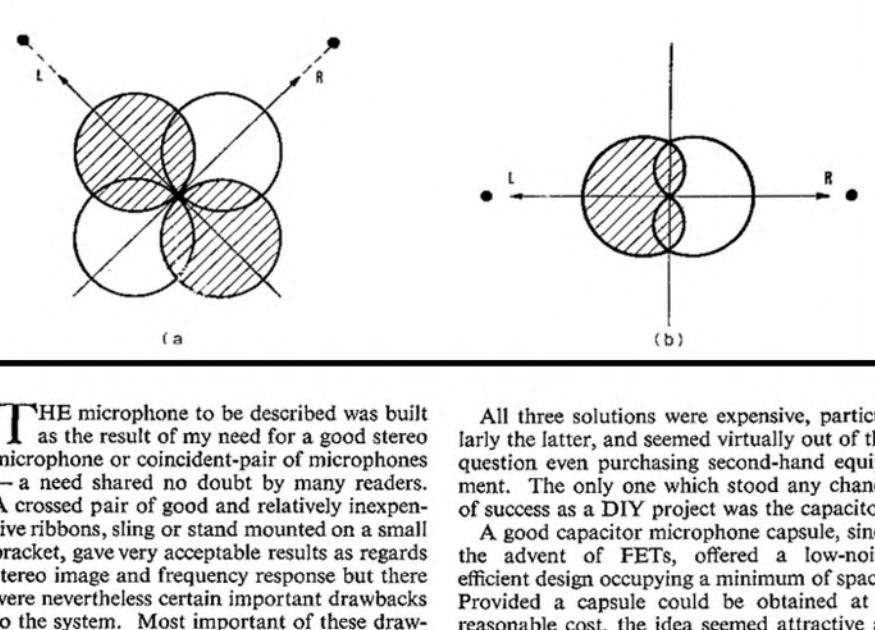
Finally, news from Milan. Thomas Gallia of **Sonart** reports that they have recently started quadraphonic recording. The firm makes recordings throughout Europe using Telefunken, Ampex, Studer, Neumann, Schoeps and Dolby equipment. In Milan, Thomas is 'collaborator' in the **Studio Angelicum,** where they have been recording symphony and choral works in their large theatre, which has a volume of 10 000 m³.

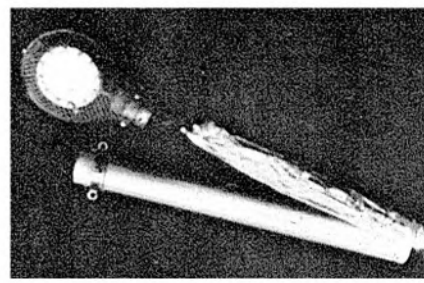
A Stereo Capacitor Microphone

part one mechanical construction

BY JOHN FISHER

FIG. 1





THE microphone to be described was built as the result of my need for a good stereo microphone or coincident-pair of microphones — a need shared no doubt by many readers. A crossed pair of good and relatively inexpensive ribbons, sling or stand mounted on a small bracket, gave very acceptable results as regards stereo image and frequency response but there were nevertheless certain important drawbacks to the system. Most important of these drawbacks was the difficulty of getting a signal-to-noise ratio that fully exploited modern low-noise tapes and tape machines, despite the use of low-noise microphone amplifiers.

A further, and probably less decisive, problem was that of keeping the microphones as unobtrusive as possible. The arrangement used with the two ribbons seldom caused adverse comment when slung, but was sometimes less popular when it had to be mounted on a stand in front of an audience.

Basically there were three solutions:

(1) A pair of more efficient ribbons such as the STC *4038*, capable of excellent results but rather large.

(2) A pair of good moving-coil cardioids such as the AKG *D202*, mounted with their axes crossed at 120 to 180°, again capable of good results but still fairly large and heavy.

(3) A crossed pair of miniature cardioid capacitor mikes or a stereo capacitor such as the AKG *C24*.

All three solutions were expensive, particularly the latter, and seemed virtually out of the question even purchasing second-hand equipment. The only one which stood any chance of success as a DIY project was the capacitor.

A good capacitor microphone capsule, since the advent of FETs, offered a low-noise efficient design occupying a minimum of space. Provided a capsule could be obtained at a reasonable cost, the idea seemed attractive as a DIY project. I had many fruitless attempts at making a suitable capsule with inadequate facilities and skills, and had no success in obtaining a commercial capsule. (Trevor Attewell has partly solved that problem.) Through the kind offices of another contributor, I eventually succeeded in obtaining a pair of capsules made up to the design mentioned above, at a realistic price.

Readers will probably be most familiar with the idea of crossed and coincident figure-of-eight ribbons for stereo. The mathematics of the resulting stereo signal can be looked at in several ways (which it is not my intention to pursue!), but the result can equally well be seen diagrammatically in **fig. 1**. With the mike axes at right-angles, an object will appear to come from the right of the sound stage when it is on the axis of the R microphone *and on the null of the L*. If the angle between the axes is reduced, sounds on the original sound-stage will appear closer together as they are nearer to the axes of both microphones, but the extremes of the new sound stage will be occupied by sounds from farther out *on the null of the other channel's mike*. In the same way, with a pair of crossed cardioids, a sound will appear from the left of the sound stage when it is on the null of the R mike and vice versa. If a pair of cardioids are arranged back to back and moved in close over the conductor's head, the strings on the left of the orchestra will be on the null of the R mike and will therefore appear fully left. The strings on the right of the orchestra will be on the null of the L mike and therefore appear fully right. For various reasons, including imperfections in the polar response of the cardioid capsules, the resulting stereo image may be less precise with crossed cardioids than with crossed figure-of-eight units. With good mikes it can be perfectly satisfactory, however, and in practical conditions probably every bit as good as crossed figure-of-eights. Certainly this arrangement is in frequent professional use, particularly with pairs of mono *C12A* being used as stereo pairs.

Since a variable polar diagram capsule essentially consists of two cardioid-response halves back-to-back, it seems an attractive idea to economise and use a single capsule to produce a back-to-back cardioid stereo pair, with the added advantage of saving size by using only the one capsule and doing away with the extra mounting and swivel arrangements necessary on a *C24*-type mike. I claim no originality for the idea but, when I began construction, I had still been unable to establish whether anyone had tried out the idea, although experience of back-to-back *C12A* mikes suggested that it should work well enough.

The success of the microphone depends on the polar diagrams being as near-perfect cardioids for the two halves as possible, with the polar diagrams of the two halves well maintained to high and low frequencies; any deviations from flat response should so far as possible be identical in both channels. In fact, the two halves of the capsule must be virtually identical. A check was carried out when the capsules were being made, not only on the dimensions being as near identical as possible put on the dynamic capacitance (without the capacitance of the fixing rings, etc) being as close as possible for the two halves. In fact on one capsule there was a capacitance error of something under 10%; this, and presumably other cumulative tolerances, accounted for a 3 dB difference in sensitivity between the two halves. Fortunately, however, it was found that with the gain of the corresponding channels corrected in the head amplifiers, the two channels are virtually indistinguishable, implying that in other respects the two halves have very similar performance. Tolerances on the other capsule was much closer.

The capsule was based on the Debenham, Robinson and Stebbings design published in September 1963 *Hi-Fi News*. Copies of the relevant diagrams are available on request from the *Studio Sound* editorial office.

Two gauze capsule shields were produced, the first with all surfaces curved in an attempt to minimise the effects of reflections, the second and possibly more attractive in appearance having squared-off sides and ends. To date the majority of tests have been done with the first shield, pending an opportunity to carry out precise tests on the effect of the shields on performance.

The capsule shields are made of copper gauze, copper tube and strip, with a plastic insulating insert to carry the capsule. The copper gauze was pressed to shape in a wooden mould, the operation taking seconds once the simple mould is carved and shaped. The edges of the two gauze halves are soldered to prevent them fraying, and one half shell is soldered into one half of the copper-strip frame of the shield. The amplifier ends of the two half shells are soldered to two half-rings of strip copper which clamp the two ends to the copper tube within. The plastic insert (an Evostik tube cap) is forced into the tube and drilled to take the mounting pillar of the capsule and the three leads. The capsule mount is cemented to the plastic with Araldite.

The ends of the two half shells are locked through the strengthening strip with a short 10 BA bolt, and the half rings are cramped to the copper inner tube with 10 BA bolts tapped into the tube. The inner tube is also tapped 8 BA to take the securing screws which fasten the microphone head to the amplifier case.

The amplifier case, which forms the main body or handle of the microphone, is polished hard aluminium alloy tubing, with countersunk clearance holes at the head end for nickel-plated 8 BA bolts tapped into the copper tube of the microphone head. At the other end (fig. 3), a five-pin DIN socket, of the type normally used with a retaining clip to fasten it to a panel, is secured by three 8 BA nickel-plated cheesehead bolts, one tapped into the body of the socket and two locked against it, tapped into the aluminium casing. The bolts serve as retaining catches as well for the suspension ring, a piece of copper tube a sliding fit over the aluminium. A small rubber band prevents the ring slipping round and along when the mike is not suspended. To the suspension ring are soldered four brass 6 BA nuts, drilled out and with one face filed flat to serve as suspension points. This whole forms a neat and simple arrangement for suspending the microphone vertically from a sling cable, or from a boom.

The securing bolt penetrates the DIN socket at the keying ridge in the plug and socket centre. A small notch must be filed out of the microphone plug to allow it to be pushed fully home into the socket.

When soldering the copper gauze to the case, some care is needed not to run solder beyond the area covered by the stiffening strip. The stiffening strip should be kept as narrow as possible to minimise its effect on the polar and frequency response of the capsule. A fairly thin and open gauze should be used for the same reasons.

To be continued

FIG. 2 CAPSULE SHIELD

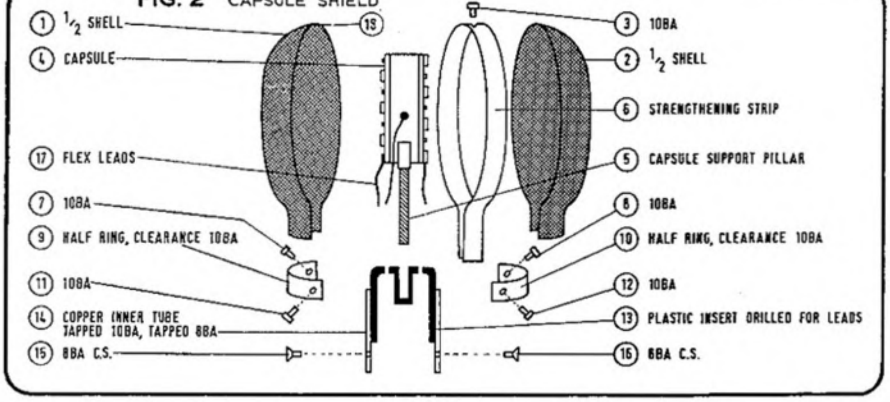


FIG. 3 SOCKET END OF CASE

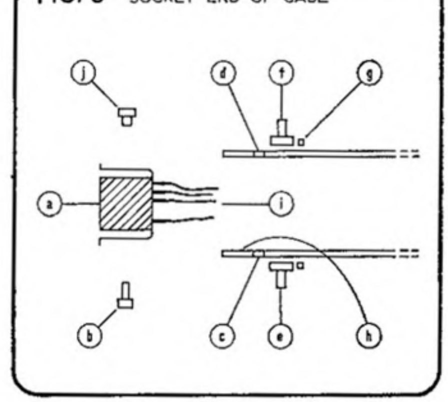


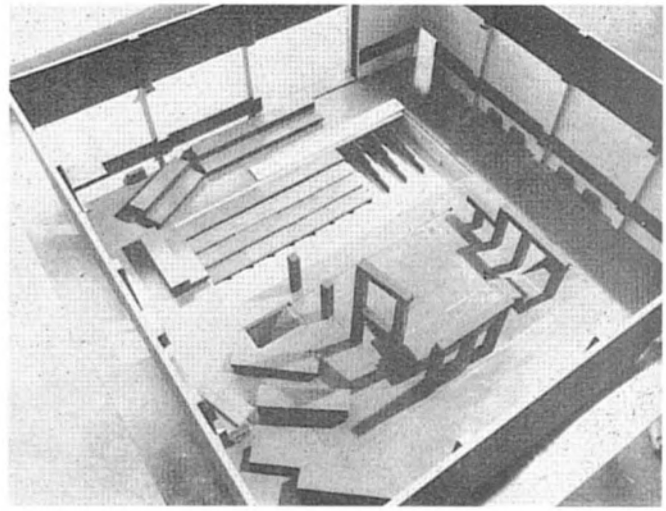
Fig. 2 detail MATERIAL AND NOTES

1	Copper gauze, 1/16" mesh } Pressed to shape in mould
2	" " " " } 60 mm x 42 mm
3	10 BA x ⅛" nickel-brass.
4	Capsule—see text.
5	" " "
6	5 mm x 500 µm copper strip, 10 BA
7	10 BA x 2.5 mm.
8	10 BA x 2.5 mm nickel-brass.
9	5 mm x 500 µm copper strip, drilled 10 BA
10	" " " " "
11	10 BA x 2.5 mm nickel-brass
12	" " "
13	Plastic insert—Evostik tube cap, force fit, 3 x 1/16" drilled.
14	⅝" outer diameter copper tube tapped 4 x 10 BA, 2 x 8 BA.
15	8 BA CS x 4 mm
16	" "
17	Three off very fine flex leads, as used on model cars.
18	Araldite to secure capsule in plastic plug.
19	10 BA washer soldered to ½ shell.

Fig. 3 detail MATERIAL AND NOTES

a	Five-pin 180° DIN socket, tapped 8 BA.
b	8 BA nickel-brass, length to penetrate socket.
c	¾" outer diameter hard aluminium alloy tube.
d	¾" internal diameter copper tube.
e	} 4 x 6 BA nuts, drilled clear of thread and
f	} one face filed off to solder.
g	Small rubber band.
h	3 x 8 BA, two tapped, one clearance.
i	Fine flex model leads.
j	2 x 8 BA nickel brass, length to grip socket.

Control room lighting, sound and cine.



Studio model seen from south-west, showing partly excavated pit, some seating units, control room and workshop doors.

theatresound

EACH issue of *Studio Sound*, besides many other interesting technical articles, has shown some examples of commercial recording studios. We hope it will interest readers to know how somewhat similar equipment is used and has been derived for a rather different purpose.

The Theatre Studio is 25 m square and 8 m high. In the centre of this space is a pit 16 m square and 2 m deep. There is a great deal of flexible furniture which, in conjunction with the pit, allows a wide variety of different stages to be simulated: Elizabethan, open stage, in the round, or what have you. Many other performer-audience activities can be accommodated with ease. We have had chamber music, jazz and lecture shapes, and also use it as a TV studio. We are staging an opera early in 1971. The building resembles a large TV studio, except we prefer to build theatres not sets.

The original University requirements stated that the studio was to be equipped with versatile stage lighting, projection and sound equipment. A Strand Electric lighting system has been installed: 100-way luminous preset console, a 20-way portable preset desk, thyristor dimmers and all the associated spots, etc. There is a 100-way patch system on the small desk to control any of the 100 thyristor dimmers.

Projection consists of two Bell & Howell 16 mm cine units, two 4 kW and two 2 kW still projectors, and a 35 mm Pradovit with bleep track gear. The sound and lighting systems are distributed to a flexible 'walk round' accessibility ceiling structure, including eight easily movable gantries, each of which can carry six people or the equivalent weight of equipment. Virtually any piece of lighting or sound gear can be placed anywhere at ceiling or floor level, quickly and easily.

The control room is situated on the north wall and contains the lighting control, some projection equipment, sound gear, sound library, film editing and office space. The sound desk is a mirror image of the master lighting console and is placed in full view and to one side of a large studio window space. The auxiliary gear tape decks, film projectors, radio, gram and small line amplifier rack are all on trollies.

Theatre sound varies in a number of ways from broadcast, film and recording studio practice, in that preparing cue tapes and playing them back are two quite different conditions. This is the sort of variation one can expect:

Preparing the cue tape: Recording from any source via the mixer into as many stereo or mono tapes as the show demands. This can involve complicated mixing from mikes, tape loops, grams, and auxiliary electronic gear. The basics thus produced need to be manipulated, adding echo, edited and re-edited; one may even need to build up electronic music. Each channel must be able to accept and process all types of input, routeing these mixtures to suitable groups for recording. Some theatre sound manufacturers have a habit of locking specific inputs to tape, mikes or gram, which can make things difficult when building an elaborate sound script. It is preferable to record from prefade outputs (not always possible or thought of) in order to obtain the optimum monitoring level without affecting the recording level, besides the other advantages prefade offers.

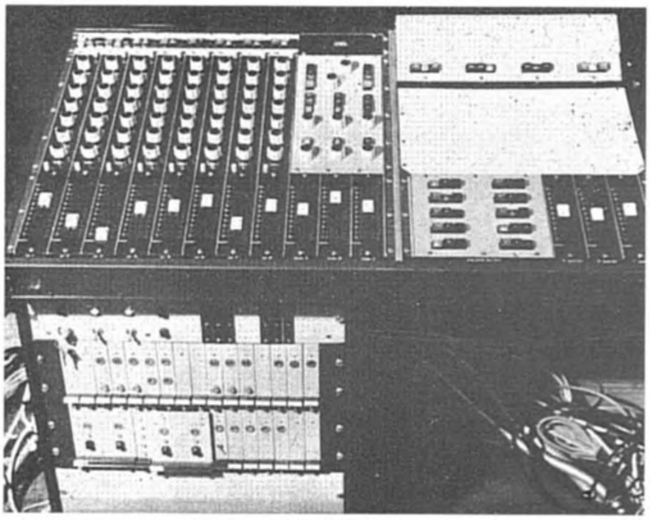
Playback for the show: Having built up the tape, the playback involves a complete repatch of all the channels to new conditions. It is sensible to use only tape or live mike at this stage, use of grams live during a show invites trouble. Even in the most economical systems basic common sense must be the rule, otherwise the operator spends his time fighting the gear instead of playing the show.

The mixer was custom-built by Calan Electronics Ltd. Colin Watson, the managing director, worked with us on the requirements and applied his excellent recording studio design techniques to the problems we posed. Our part of the design lay in supplying practical experience with the various types of equipment found in theatres, the snags we have found when trying to build up a sound plot, and the things we felt it desirable to aim for. The writer's experience when working on the design layout for sound gear in the Liverpool Playhouse and other systems was a useful background. There was also the question of quality. As with Liverpool, we decided to move above PA standards.

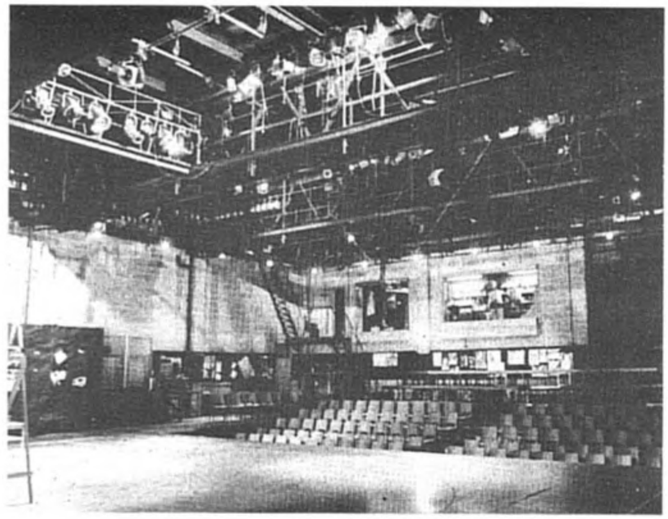
Eight channel

This mixer is an eight channel, three group solid state unit. All channel, echo and master faders are EMT flat units, seen in quite a number of Continental theatres.

Each channel can accept mikes at 50 and 200



General view of mixer.



View of main theatre studio from south-east.

Ivor Dykes outlines the development of Lancaster University's Nuffield Theatre Studio

ohms and has a full range of pre-attenuation. They can also accept line signals at 0 dBm and +8 dBm (with the exception of tape and film, the auxiliary gear is brought up to this level by means of external line amplifiers). Any channel fader can remote start any of the tape decks at -70 dBm virtually instantaneously. The channels also have access to the line up tone oscillator at A 440 Hz. This we changed from 1 kHz as being less annoying during line up and useful as an audience warning tone. Active bass and treble controls, and a ±10 dB presence control operating at 2, 3, 5, 8 kHz. An echo send pot completes each channel processor unit.

The master routeing matrix control is done by means of three self-illuminated colour coded pushes per channel. By means of these the channel can be off, switched to any of the three masters, to any two, or to all three together. The coding is A amber, B red and C green for ABC masters. One can see at a glance which channel is linked to any master even in dim operating conditions.

Three double-spring line reverb units built into the desk are controlled by AB and C group send pots and EMT echo slider returns. A special push adjacent to C echo return allows summation of A and B clean feed signals and feeds it through C echo return to C master. The ambiophony thus produced has been found quite useful. A VU meter which can be switched to any of the three echo returns completes the echo section.

Each master feeds a *Quad* 50 W amplifier built into the desk. These three outputs are then fed to the output matrix, again self illuminated colour coded pushes; three in each of ten groups connect the amplifiers on 100 V line to the speakers. One of the surprises Colin Watson gave us was a preset arrangement for this matrix; if a second push is operated in any group the push will stay down but not light up. Pressing the lit button will transfer a speaker to a new master. This can be done with any of the ten groups, a type of one-cue-ahead facility. Visual monitoring is by means of a VU meter per master, with an added trick whereby one can read the internal signal level or, by means of a pad to the main amplifier, the output power.

Dual monitoring

A dual monitoring system is used—speakers and phones. For the speakers there are three pushes per master: off, internal output, and external amplifier. By this means the direct output of the desk can be monitored or that speaker can be connected to an external mike and amplifier to monitor the show directly from the auditorium.

For the phone monitors there are dual jacks on the side of the desk with four pushes and a level pot for each ear. Three of the buttons are colour coded and route any selection of masters to that particular ear. The fourth button decides if the monitoring shall be pre or post fade. This system is remarkably useful in a recording session. For example, while the show is being monitored on speakers for other operators in the control room, one can with phones check the masters or combinations of them on either or both ears, before or while the signals are going out.

The desk itself is built on the module system. Quite a number of the modules are identical and interchangeable, with a good deal more integrated circuits than single transistors. All the matrixing is done with reed switches and there are two alternative identical stabilised power supply modules. With the exception of the patch panel and line amplifier rack for radio and gram, everything is inside the quite small desk.

The patch panel is fixed to the wall next to the desk and holds all the input and output terminations between the desk, the main studio and the control room. There are 20 mike and 20 studio speaker sockets. The mikes run through the studio in stereo pairs (some quads) in a herringbone distribution, with a useful number dropped down the walls to floor level. A stereo pair is extended to be available both in the control room and in the workshop. The loudspeakers occupy the walls and centre at ceiling and floor levels. All mike and speaker plugs and sockets are Cannon *XL*.

The panel also contains clean-feed/recording-take-off prefade jacks. There are dual jacks per master at 0 dBm, and the phone jacks are extended so that we can record in the same pattern as the signals that appear on the phone monitors.

This is also the location of the remote starting jacks, stereo radio and gram sockets. With the exception of the speaker feeds, everything is run in twin balanced lines.

(*continued overleaf*)

Your Local Dealer

We chose Revox *A77* tape units less main amplifiers. One reason for this choice was the servo system fitted; certainly for our purpose this speed stability is essential. A number of theatres use a British made semi-professional machine which, although solid and reliable, does not have this mechanism. Tape speed instability recently led to embarrassing moments for a West End show. The other snag with this British machine is that a music tape master often cannot be played back on other available machines without frequency shift.

The Swiss machines cover our needs well. Obviously if we had more money we would have got something even better, but there are limitations. We can get 'full track' operation, there are plenty of tricks and an alternative type of echo. The fast (and remote) start facilities are a boon. With three machines over the past two and a half years we have had about six faults serviced by ourselves and only had to return one module to Messrs Hammond.

Up to date for gram we have used a *Deram* cartridge on a *Lenco* variable speed motor (very useful). Assembling a show tape presents the pick up with a lot of tough work. For one cue tape the number of lifts and drops can be quite high and accidents could be very expensive with a delicate cartridge. We are about to instal a good magnetic head for transcription work.

The range of speakers we use comprises four Tannoy *Monitor Golds* in *York* cabinets, tapped at 25 W, four Wharfedale *RS12DD* chassis in two 56 litre (2 cubic feet) reflex cabinets, and two *Super Lintons*, mainly for control room use, though we are thinking of Tannoys for this location. The black sheep are two column speakers which don't compare at all with the other units.

Our mike situation is not yet up to full strength. There are four AKG *202*, an STC *4038* and an AKG lavalier. We would like a pair of capacitors (or two pairs) and possibly another pair of *202* (highly regarded). Money is a problem.

Long term planning

For the type of work we are doing and hope to do, the gear is panning out well, despite the odd worry. In many ways we feel this is due to the opportunity we had for long term planning. The director, Kenneth Parrott, and the writer spent a great deal of time thinking of different approaches. We had difficulty in finding an organisation which would build what we wanted, when we wanted it and at the required quality. There were many sessions with Colin Watson in discussing ideas; we had to find commonsense ways to simplify the quite complicated things we needed. There was not the money a broadcast or other big company would have; we had to save money by buying piecemeal auxiliary gear at as near trade prices as possible. By this means we reckon to have saved about £1 000, which helped with the costly item: the desk.

Artistically the gear is easy to handle considering its complexity and the sound is very good. A number of touring professional companies have used it 'first time' easily and well.

Figs 1 and 2, circuit diagram and preset controls guide, fell foul of the postal strike and will be published next month.

tape recorder service

Uher 4000L

By H. W. Hellyer

FOR quite a long time now I have had requests to do a servicing article on Uher models. A lot of information has been amassed with that end in view.

The circuit of the *4000L* differs from its predecessors in three main ways: first, the use of silicon low-noise transistors in the input stage; second, in the use of a transformerless output stage and third, most important, in the use of an electronically controlled motor.

If you want to read about the earlier models, and catch up with review and field test opinions on this one, I suggest you turn to the September 1962, May 1963 and November 1966 issues of *Tape Recorder*, where Messrs Tutchings and Kirk had a lot of cogent comments to make. These repay a close study. I intend to refer to both from time to time.

One of the things apparent from a study of the circuit is that it is not startlingly *avant garde*. You may get even more of a shock if you look at the circuit of a Nagra. The point seems to be that with careful overall design it is possible to turn out a product of exceptionally good performance. Getting at the circuit is not an arduous task. The lower cover comes away simply, a protector panel can be unclipped from its press studs and then the main printed circuit board can be swung to a 90° position for initial tests. Replacing some of the parts may be a little more difficult and it is ironical that much of the fault-proving testing—until one is familiar with the harness runs—lies beneath the tangle of wires and in the multiplicity of joints.

One or two precautions have to be taken when testing for faults. The most fundamental of these is to use the positive connection of the battery terminals as the earth line, and not the chassis. Take another look at the circuit, locate C12, and you can see why. In a confined space, with a compact layout encompassed with metal work, the screening effect could well give way to a noise-producing system if random earth points were made, so the principle is to make a common line return and bond this, for audio signals, to chassis.

TV sound detection

This leads to one possible fault—the old one of detected TV signals when in the vicinity of a transmitter. The cure may be to bypass C12 with a 0.001 μF polyester capacitor. In addition one could fit a 1 K resistor in the base line of the input transistor, between the R7/R13 junction and the base itself. Physically, this component should be mounted at the end of the print lug where the base wire is inserted, entering the hole from which the wire is removed, this wire then being taken to the upper end of the vertically mounted resistor.

When testing the *4000*, it is vital to start with the record level indication setting. So many other adjustments depend on this, and an error here can be cumulative. To set up, first feed a 1 kHz signal to pins 1 and 2 of the radio input socket at 10 mV, and read off 1.4 V (using VVM or similar high-Z instrument) at pins 3 and 2 of the accessories socket. This is the six-pin DIN socket marked with a triangle on the cabinet. The Uher is switched to record and the selector to radio. To get this output, adjust the recording level control and leave it set. Then set the meter preset R11 for a zero dB reading on the VU meter. R11 is situated on the reverse of the PC panel adjacent to the 'U' of the legend 'Uher'.

After this, with zero dB as reference, the necessary input for frequency response

measurement can be judged. This should be 20 dB below full modulation level; one tenth below the input level needed to get a 0 dB indication. The sensitivity figures at the radio socket are from 1 to 100 mV but the actual figure will be nearer 20 mV in most cases.

The remote pause is a relay short-circuited to ground, completing activating circuit, by pins 4 and 3 of the auxiliaries and microphone sockets.

Power switch

The *4000L* is only complicated in the way its switching sequence is laid out. Both Alec Tutchings and David Kirk had cause to complain about the separation of power-off switch from the mode selector. This necessity to neutralise the speed selector has caught out many a *4000* user. The switch is K8 on the circuit diagram, from the negative pole of the battery, through switch K10 (which is part of the auxiliaries socket and will be closed until a plug is inserted in this socket), from the centre pin of that socket and to the 6 V power line of the recorder. Note that there is a 7 V zener diode across this line. Actually, the limit voltages are 7.3 to 7.7 V so there is no worry about dragging the power line down until the switch on the socket fails.

Unfortunately, this has happened a few times, and if some handy chap does the usual 'emergency' trick of shorting the end contacts, using the *4000* on external supplies may well result in the zener diode suffering. It is tucked away awkwardly in the front left corner, beneath some congested harness wiring. The action is by a lug being pushed aside when the plug is inserted to the remote socket (the one marked with the triangle). This movement is supposed to be no more than 500 μm, which is pretty small, so there is little room for adjustment. But there *is* some adjustment. The switch blade assembly is on a bracket which has slotted feet and to get at it one needs to slacken off the loudspeaker socket. Another switch that can lead to bother is the little joker hidden in the battery compartment. The idea of this one is to accept the charger via pin five of the six-pin socket but only when the rechargeable storage battery is inserted. The position of the plunger is cunningly arranged to respond to the flat side of a storage battery but miss the rounded sides of ordinary separate cells. (Attempts to recharge these can result in a gory mess.) The blades of this switch can be adjusted by bending the backing pieces—never be tempted to bend the switch blades themselves. The switch is accessible through the top deck, when the cover is removed.

The relay is a double action type. A heavy current momentarily flows to attract the armature, when a holding contact (a in the circuit) opens and puts one section of the winding, in series with the other, allowing just enough current to flow to hold the armature in. Now this condition obtains when pins three and four of the remote socket or two and three of the microphone socket are short-circuited. But it

(continued overleaf)

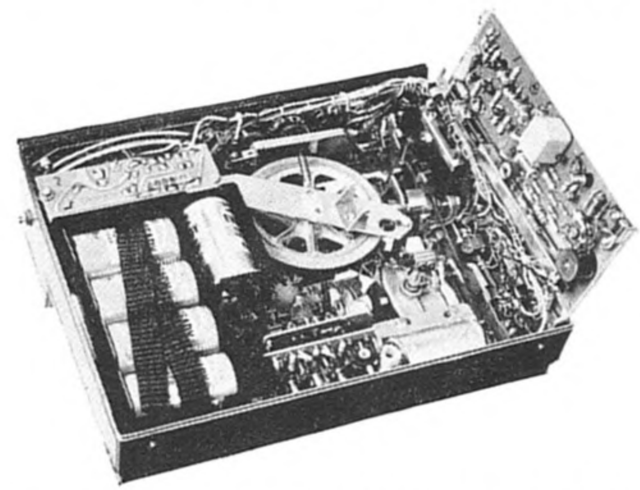
is not always noticed and, if the complaint with your *4000L* is that it runs batteries down heavily on record, but not so badly on play, ask yourself whether your operating technique does not consist of much 'holding' with the microphone switch. To make sure, monitor the current drawn by the machine. If it exceeds 550 mA, look for a relay contact that is not opening efficiently. Look for a possible leakage through C39—although I confess to never having had this one, despite several relay faults.

gives us this clearance when the pause key is operated.

The line-up controls are quite accessible and the least we can do is explain what each of these preset resistors is supposed to do. R11 we have already dealt with. Closely associated with this one is R20, which sets the battery life indication for the meter, brought into circuit when the recording level control is pulled and held. With a 4.8 V supply, the meter should read zero dB, i.e., about 80% of full scale deflection.

R19 is the negative feedback adjustment of the input stages, and needs setting only if a head or preamp transistor has been changed. Adjustment depends first on the recording level setting being correct, and an undistorted sine-

Internal view of Uher portable showing hinged circuit board and battery compartment.



The usual trouble is contact points, and a clearance of 100 μm is required. Again, the only adjustment is the bending of the backing strips. I have never found this operation to be entirely satisfactory and avoid it wherever possible. We had a great deal of this to do on older Grundig recorders and used always to carry a stock of spare 'spring sets', finding this more economic than attempting to undo the 'bend and twist' efforts of our predecessors.

It is necessary to ensure that the pressure roller pull is right and the clearance adequate with the pause key depressed. An adjustment at the right-hand end of the roller arm

wave being read off at the line out socket (pin three of the five-pin 180° DIN socket). If this is in order, R11 can be set for replay of the 1 kHz recording to give 1 V at the same point, undistorted. Remember that the monitor signal was 1.4 V—don't try to adjust for the same, or you may end with some queer HF waveforms. This is one of the factors we shall have to leave until next month, along with the motor control, speed adjustment and the output stage setting. My own experience has been that the mechanics of this model give far more trouble than its quite modest circuitry, and a closer look is certainly merited.

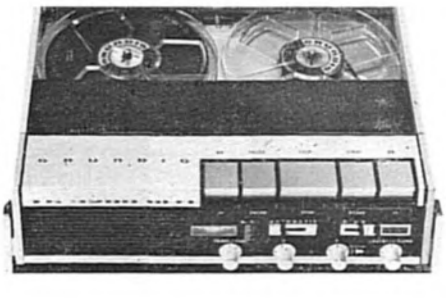
Function	*Impedance*	*Sensitivity*	*Pins*	*Plug*
INPUTS				
Microphone	2 K	0.1 mV-20 mV	3/2	5-pin DIN 180° (Mic)
Radio	47 K	1 mV-100 mV	1/2	5-pin DIN 180°
Phono	1 M	40 mV-4 V	3/2	5-pin DIN 180°
OUTPUTS				
Line	15 K	1 V	3/2	5-pin DIN 180° (switched/Play)
Loudspeaker	4 ohms	2 V	1/2	2-pole DIN L/S
Headphone	75 or 400 ohms	—	L/S socket	

AUXILIARIES
Power supply 5 x 1.5 V *HP2* or equivalent, or
Z211 Dryfit storage battery, or
Z114 mains-operated power unit, or
K711 6 and 12 volts car adapter cable and
K712 24 volts car adapter cable

equipment reviews

GRUNDIG TK3200 BATTERY PORTABLE

MANUFACTURER'S SPECIFICATION (19 cm/s.) Half-track mono battery tape recorder operating at 19, 9.5 and 4.75 cm/s. **Power requirement:** Six *HPU2* cells or equivalent; accumulators or external 9 V mains unit (Type *TN12A/N14*). **Wow and flutter:** 0.1%. **Signal-to-noise ratio:** 50 dB. **Frequency range:** 40 Hz to 16 kHz. Automatic and manual gain control. **Inputs:** 220 μV to 22 mV at 10 K (microphone and radio/diode). **Outputs:** 500 mV at 15 K and 2 W at 4 ohms. **Spool capacity:** 14.5 cm. **Dimensions:** 310 x 240 x 45 mm. **Weight:** 5.5 kg. **Price:** £178.15. **Distributor:** Grundig (GB) Ltd, London SE 26.



I WAS most surprised to find that the Grundig *TK3200* is sold in ½-track mono form only, which immediately removes it from the professional field for most applications. While the BBC frequently use 9.5 cm/s ½-track heads because of the difficulty of azimuthing, most professional reportage involves full-track heads and 19 cm/s. Grundig make provision on the recorder for using spools of 14.5 cm diameter which would allow a continuous recording time of three hours at the slowest speed if DP tape were used. This assumes that the machine is capable of operating for that period without slowing down. Unfortunately the power consumed by the motor and electronics appears to be rather high and the batteries ran down quickly, although the speed constancy was extremely good until the volts started to fall. I would therefore consider accumulator cells imperative though they were not supplied for review. I cannot say what the life of these would be. The machine's size and weight, in my opinion, make it a little impractical to carry around all day long for market research, its weight being approximately 50% greater than the Uher *4200*. The machine can be carried with a handle of the type used on the Uher, and a carrying case with shoulder strap is available.

The *TK3200* is very nice to handle and mechanically quite superb with wow and flutter figures measuring, to a peak weighted DIN specification, 0.08% at 19 cm/s and 0.13% at 9.5 cm/s. The figure for 9.5 is the same as that of the Uher at 19 cm/s. The tape guide arrangements too are well engineered, and the spool clamps very neat. The recorder has a built in speaker with a monitor amplifier including bass and treble tone controls. The amplifier output was checked and found to be considerably below specification when used with batteries: approximately 500 mW.

Despite the fact that the manufacturers recommend the use of batteries, they clearly state that accumulators are available and it was rather a mystery that these were not sent for review. Ordinary batteries seemed to polarise with a continuous high load from the motor, which incidentally uses 12 transistors and seven diodes in its regulator circuit. Speed accuracy of the motor even on batteries was astonishing being within .2% of nominal with brand new batteries. After replaying continuously for approximately 1¾ hours at 19 cm/s, the speed began to drop very fast. After resting for one hour the machine assumed normal operating speed, but again lost speed towards the middle of the reel. A day later, on the same batteries, the machine came up to speed, losing speed again about a third the way through a reel of tape. Not only was the speed accuracy at 19 cm/s exceptional, it was maintained at the two slower speeds being, within .2%, by far the highest accuracy of any portable machine I have ever used.

The performance of the electronics is excellent in some ways and very poor in others. It is a mystery why more trouble was not taken in the design of the replay circuits to give a flatter response. On replaying a NAB 19 cm/s test tape, the response had a shelf down of 3 dB below 60 Hz with 125 Hz 1.25 dB down with reference to 1 kHz. The HF response also showed a shelf drop of 3 dB above 10 kHz. I had the impression that the time constant on replay was nearer 35 μS than the 50 μS it should be. The bass loss is inexcusable since the NAB curve already has a 3 dB cut at 50 Hz. The irregularities of the response however are not the only snags with the replay amplifier. At first I could not believe the extremely bad 32 mM/mm replay signal-to-noise reading, this ratio being only 36 dB when measured flat from 5 Hz to 100 kHz. Applying an 18 dB per octave bass cut below 20 Hz increased the signal-to-noise ratio to 45 dB. Such appalling rumble and flicker noise could seriously harm some low power bass woofers if the replay gain of an external amplifier were turned up. At 9.5 cm/s the bass response showed a distinct fall of approximately 3 dB below the correct curve, and similarly the high frequency end showed a step down of approximately 3 dB from 6 kHz to 14 kHz. Dare I suggest that these irregularities of response might have been an attempt to remove some of the rumble that could otherwise have been worse? Bearing in mind that Uher manage to obtain considerably better results with very simple but effective circuitry, I cannot see why Grundig could not do likewise.

On the record side the story is very different. The record response at 19 cm/s is very good, being within +1 dB of the NAB curve when a recorded tape is played back on a studio machine, with the exception of a 2 dB boost in the region of 60 Hz. 16 kHz was 1 dB down. The overall response at 9.5 cm/s follows a similar pattern with a 2 dB boost at 60 Hz and a top roll-off of 3 dB at 15 kHz, which could have been corrected by slightly adjusting the bias. At 4.8 cm/s the overall response was approximately 3 dB down at 6 kHz and 10 dB down at 8 kHz.

The record amplifier has the facility of switching in a compressor with suitable time constants for both music and speech. Alternatively the control can be left out and the recording volume control set to give a correct recording level on to the tape. In both cases a moving-coil meter with an edgewise movement monitors the recorded level. The accuracy of the meter sensitivity was checked and found to be inconsistent with a setting that would allow the average user to record the correct peak level on the tape, full scale deflection being +2 dB, this being equivalent to 2 dB above 32 mM/mm. In my opinion the sensitivity of the meter should be increased by approximately 4 dB with zero on the meter as equivalent to NAB level, i.e. 4 dB below 32 mM/mm. The compressor worked very well, reducing shouting to a reasonable level whilst at the same time bringing up quiet speech. This would make the recorder particularly suitable for market research work and the recording of conferences, if only other considerations did not condemn it. The Grundig hand mike supplied was of good quality and incorporated a switch remotely controlling the tape transport, stopping and starting it by relays, which were very effective. Although the machine is supplied with a number of input and output sockets, for some odd reason it is impossible to use the line out socket (which precedes the replay gain control) whilst the machine is recording. This makes it rather difficult to azimuth the heads and to carry out frequency response measurements whilst the machine is recording. It also of course means that it is impossible to set the bias accurately unless one puts a meter on the loudspeaker output of the machine. The response of this output is dependent upon the position of the bass and treble tone controls, thus making it unsuitable for measuring response at all.

The reader may wonder why I have left out a more detailed description of the machine. The reason is I cannot really recommend that the *TK3200* be seriously considered for use in the UK since the price, even if the design faults are rectified, is much too high for the facilities offered. For the price asked I would expect accumulator cells to be included, plus a charger and carrying case, in addition to a far more satisfactory performance. The real professional will obviously want to spend more and buy a Nagra or Stellavox. The semi-professional should find the mono or stereo Uher easier to handle and the keen amateur would hardly be likely to spend £180 for a ½-track mono machine.

(continued overleaf)

TK3200 REVIEW CONTINUED

On the other hand, I feel strongly that this machine could have tremendous potential if the various design points were put right, and the machine were ½-track stereo. Under these circumstances, with its superb mechanical construction and brilliant engineering, an even higher price could be asked. Grundig should have carried out some market research before bringing out this model which does not seem to fit the requirements fully of any particular user.

I communicated my findings to Grundig (Great Britain) and at very short notice they brought another machine for me to check. I am sorry to say that this had precisely the same faults. On further investigation it appeared that the extraordinary rumble was not present on either machine when used with the mains power supply. The batteries were then checked in a Uher and were not found defective in any way. A 2 500 mF capacitor placed across the battery supply failed to make any improvement. The current consumption was measured and varied between 340 and 550 mA, depending on the mode of operation. The bass roll-off on replay was explained by the manufacturer's use of the wrong bass time constant: 1 500 μS instead of 3 180 μS, the reason for this being quite inexplicable. The treble time constant component appeared to be such as to give a value half way between NAB and DIN at 19 cm/s. Since the 19 and 9.5 cm/s replay responses were wrong on both samples, it may be assumed that a 0.01 μF capacitor in the time-constant network must be of insufficiently high tolerance, its value possibly being as low as 0.007 μF, which would give the values measured. No tolerance is specified for this component in the components list although, in my opinion, it should be at least 5%. **Angus McKenzie**

WHY COINCIDENT MICROPHONES ? CONTINUED

simultaneous recording for both two and four channel coincident stereo is perfectly practical. All one does is record with four small cardioid or hypercardioid microphones whose capsules are in close proximity pointing along the four axes of a tetrehedron. Simple matrixing of the recorded signal will then yield Blumlein stereo and, depending on the effect required, the four signals may be fed to the four speakers either directly or via matrixing. While there seems to be no reason *not* to include height information in the recording, even if it is not normally used on playback, a horizontal-only recording can easily be made using just three coincident cardioids angled at 120° from one another with matrixing, and an excellent Blumlein stereo can also be obtained by matrixing the resultant recording.

It may well be worth a multitrack engineer's while to devote a couple of tracks to a Blumlein recording; even if the Blumlein recording is not to his taste, its difference signal makes an excellent ambience signal, so the tracks are not wasted, and it widens the options available. As suggested below, having such a recording may cater for future public taste, and the clincher is that Blumlein recordings may be converted to four-channel by a Hafler-type matrixing scheme.

In conclusion, it is my belief that modern multimike techniques of recording not only damage many of the subtleties that lead to profound musical enjoyment, but are actually harmful in a purely commercial sense. By producing records with a glamorous 'hi-fi' sound, one certainly excites the record buying public into purchasing the latest recorded marvels, at least at first. The trouble is that many record collectors seem to lose interest in collecting after a while, as the novelty of the 'hi-fi' is not enough to sustain interest, and the remaining effect prevents a full satisfaction and involvement with deeper aspects of the music. People tend to blame the ennui on to insipid musical performances, without realising what the recording technique has done to the music. Indeed, my own active interest in recording coincided with the realisation that many performers who I had thought grossly superficial and unmusical on record were in fact subtle and profound; yet their recordings were often praised as pinnacles of the art in *Hi-Fi News* and *The Gramophone*.

It is often difficult for the active recordist, musician, or critic to realise the effect of multimike recording techniques on most musical but not musicological listeners, as the expert's knowledge allows him to compensate unconsciously for the musical distortions caused by the recording; the listener has no such crutch to lean on, and can only revel in the gorgeous sound until he eventually grows tired of superficialities. It is significant that in the USA, where multimike tendencies have gone further, a slump has hit the classical recording industry, although this has always done relatively poorly. One would have thought that any audience weaned on to classical music would have been 'hooked', and with the dearth of live concerts in the USA, would have persisted in buying records. That such a dramatic slump has occurred indicates something profoundly wrong. Perhaps in its efforts to 'improve' on reality, the record industry is killing off the long-term musical interest so necessary for its continued health.

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Tandberg 6000X 3 sp. 2/4 Tr. Stereo
Telefunken 205 3 sp. 4 Tr. Stereo
Telefunken 203 Studio
Phillips N.4505 3 sp. 4 Tr. Stereo
Philips Pro. 12 2 sp. 2 Tr. Stereo
Ferrograph 702/4

COMPLETE TAPE RECORDERS
*Kellar Dolby Cassette
*Akai 1710W Stereo
*Akai M.9 Stereo
*Akai 4000 3 sp. 4 Tr. Stereo
*Brenell Mk. 6
*Ferrograph 713
*Ferrograph 722/4
Grundig 141 4 Tr. Mono
Grundig TK.121 2 Tr. Mono
Grundig 146 4 Tr. Mono Auto.
Philips 4307 4 Tr. Single Speed Mono
Philips 4308 2 sp. 4 Tr. Mono
Philips Stereo 4404 2 sp. 4 Tr.
Philips Stereo Auto Cassette 2401
Philips Stereo Cassette 2400
Philips 4407 3 sp. 4 Tr. Stereo
*Philips 4408 Prof. 3 sp. 3 Tr. Stereo
*Revox 1222/4 Stereo
*Sony 630 4 Tr. 3 sp. Stereo
Sony 252 4 Tr. 3 sp. Stereo
*Tandberg 15 2 or 4 Tr./2 sp./Mono
*Tandberg Series 4000 3 sp. 2/4 Tr. St.
Telefunken 204 T.S.
*Telefunken M207 2 sp. 4 Tr. Stereo
Telefunken 501 4 Tr.
Telefunken 203 Stereo/Mono 2 sp. 4 Tr.
Telefunken 201 Mono 4 Tr.
*Uher 714 4 Tr. Mono
*Uher Royal de Luxe 4 Tr. 4 sp. St.
*Uher Varicord 263 Stereo

BATTERY PORTABLE AND CASSETTE
Philips N2202 Cassette
Philips RR392 Cassette/AM FM Radio
Philips RR290 Cassette/AM Radio
Tandberg Series 11-2
Grundig Cassette C.200
Aiwa Cassette Batt./Mains
Philips 2205 Batt./Mains Cassette
Pye Cassette
Sharp 505 2 Tr./2 sp./BM
Sony TC800 B
Telefunken 302 4 Tr. 2 sp. Mono
*Uher 4000L 4 Tr. 2 sp. Mono
*Uher 4200/4400 2/4 Tr. sp. Stereo
POWER PACKS, by Philips, Stella, Telefunken and Uher

DOLBY CASSETTE RECORDERS
*Wharfedale
*Kellar

● MICROPHONES by
AKG, Grampian, Reslo, Acos, Telefunken, Beyer, Sennheiser, etc.

* Microphone extra

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5¾" L.P. 1150 ft. (A)	75p
5¾" Standard 850 ft. (A)	63p
5" D.P. 1200 ft. (P)	88p
5" L.P. 900 ft. (P)	63p
5" Standard 400 ft. (P)	50p
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Musicassettes by Decca, EMI, Polydor, Philips, etc. ALSO 8 Tr. pre-recorded cartridges.

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● AMPLIFIERS
Quad, Rogers, Arena, Philips, Goodman, Nikko, Leak, Armstrong, Tripletone, Tandberg, Teleton.

● TUNERS
Quad, Rogers, Leak, Armstrong, Tripletone, Arena, Nikko, Goodman, Huldra.

● LOUDSPEAKERS
Quad, Rogers, Kef, Wharfedale, Goodman, Tannoy, Lowther, Leak, Tandberg, Arena, Celestion, Kelestron.

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STEREO AMPLIFIERS

	Rec. Retail Price	Comet Price
ARMSTRONG 521	56·00	44·50
*DULCI 207	25·00	17·00
DULCI 207M	30·00	21·00
FERROGRAPH F307	59·00	48·00
GOODMANS Maxamp	54·00	38·00
LEAK Stereo 30 Plus	56·50	44·75
LEAK Stereo 30 Plus, in teak case	62·50	49·50
LEAK Stereo 70	69·00	55·00
LEAK Stereo 70, in teak case	75·00	59·50
*LINEAR LT 66	21·00	17·00
METROSOUND ST20	36·00	28·00
PHILIPS RH 591	76·75	59·00
PHILIPS RH 590	51·75	39·50
PHILIPS RH 580	28·00	22·00
PIONEER SA500	62·10	43·00
PIONEER SA700	98·00	70·00
PIONEER SA900	134·10	97·00
PIONEER Reverberation	45·50	33·00
ROGERS Ravensbourne	59·50	47·00
ROGERS Ravensbourne (cased)	64·00	50·00
ROGERS Ravensbrook Mk. II	47·50	38·00
ROGERS Ravensbrook (cased) Mk. II	52·50	42·00
SINCLAIR 2000	30·45	23·00
SINCLAIR PROJECT 60/2 x Z30/PZ5	23.90	17·00
SINCLAIR PROJECT 60/2 x Z50/PZ8/ trans.	32·88	23·50
SINCLAIR Neoteric	61·95	46·00
SINCLAIR 3000	45·00	36·00
TELETON 203E	28·75	20·00
TELETON GA 101 30w RMS	37·50	28·50
VOLTEX 100 w. Stereo Discotheque, eight electronically mixed inputs	185·00	139·00

Starred items above take ceramic cartridges only. All others take both ceramic and magnetic cartridges.

TUNERS

	Rec. Retail Price	Comet Price
*ARMSTRONG 523 AM/FM	53·76	45·00
*ARMSTRONG 524 FM	41·89	35·00
ARMSTRONG M8 Decoder	9·50	8·00
*DULCI FMT. 7 FM	22·05	18·00
DULCI FMT. 7S Stereo	31·00	25·25
GOODMANS Stereomax	82·52	49·95
LEAK Stereofetic Chassis	66·50	52·00
LEAK Stereofetic in teak case	72·50	59·00
PHILIPS RH 690	44·50	35·50
PHILIPS RH 691	89·00	75·50
PIONEER TX500 AM/FM	77·94	64·00
PIONEER TX900 AM/FM	153·69	125·00
ROGERS Ravensbourne	61·89	50·00
ROGERS Ravensbrook	45·01	40·00
ROGERS Ravensbrook (cased)	51·26	43·00
*SINCLAIR 2000	26·73	19·25
SINCLAIR Project 60	25·00	21·00
TELETON GT 101	45·50	34·00
TELETON 201X FM	36·00	30·00

All above Tuners are complete with MPX Stereo Decoder except where starred.

TUNER/AMPLIFIERS

	Rec. Retail Price	Comet Price
AKAI 6600	142·53	112·00
ARENA R500	82·00	67·00
ARENA 2400	90·30	72·00
ARENA 2600 Stereo AM/FM	111·30	94·00
ARENA 2700	105·00	85·00
ARENA T1500F	72·45	60·00
ARENA T9000	303·45	258·00
ARMSTRONG M8 Decoder	9·50	8·00
ARMSTRONG 525	91·89	77·00
ARMSTRONG 526	104·71	87·00
GOODMANS 3000	77·73	53·00
*PHILIPS RH 781	74·98	55·00
PHILIPS RH 790	135·00	109·00
PIONEER KX330 AM/FM/SW	78·62	63·00
PIONEER SX770 AM/FM	160·43	126·00
PIONEER SX990 AM/FM	194·74	150·00
*TELETON F2000	51·50	32·00
TELETON 7 AT 20	105·00	80·00

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	Rec. Retail Price	Comet Price
TELETON 10AT1 150w. RMS	160·00	109·00
TELETON TFS50	75·50	56·00
*TELETON R.8000 with Speakers	63·25	50·00
TELETON CR55	120·00	95·00
WHARFEDALE 100.1	131·25	105·00

Starred items above take ceramic cartridges only. All others take both ceramic and magnetic cartridges.

All the above Tuners and Tuner/Amplifiers include MPX Stereo Decoder with the exception of Armstrong where decoder is extra as listed.

PICKUP ARMS

	Rec. Retail Price	Comet Price
GOLDRING Lenco L75	12·33	10·50
GOLDRING Lenco L69	9·29	7·00
SME 3009 with S2 Shell	31·31	26·00
SME 3012 with S2 Shell	33·36	29·00

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TURNTABLES

GARRARD SP25, fully wired with Goldring G800 Magnetic Cartridge. Complete with base, plinth and cover — Special price ... ... 20·98

	Rec. Retail Price	Comet Price
DUAL 1219 transcription	60·40	50·00
DUAL 1209 transcription	42·62	35·00
GARRARD SP25 Mk. III	16·45	11·90
GARRARD SL65 B	21·25	15·90
GARRARD SL75 B	38·95	28·50
GARRARD SL95 B	53·27	38·50
GARRARD 401	38·01	29·50
GARRARD SL72 B	32·77	26·90
GARRARD 3500, with GKS Cartridge	17·23	12·90
Base and Cover to fit GARRARD SP25, SL55, SL65B and 3500	Special price	4·00
GARRARD 40B	13·84	10·97
GARRARD AP76	28·88	21·50
GOLDRING 705/P with 850 Cartridge and Cover	26·00	23·90
GOLDRING GL69 Mk. II	26·63	22·50
GOLDRING GL69 P Mk. II	35·14	29·50
GOLDRING GL75	36·41	33·90
GOLDRING GL75 P	46·94	41·90
GOLDRING Covers for 69P and 75P	4·21	3·50
GOLDRING C99—plinth and cover for G99	11·45	9·90
GOLDRING G99	26·00	23·90
GOODMANS 3025	37·74	26·90
McDONALD MP 60	15·75	12·25
McDONALD 610	20·00	15·90
Base and Cover for McDONALD MP 60 and 610	Special price	4·50
PHILIPS 228	20·00	17·00
PHILIPS GA 146	31·50	25·00
PHILIPS 217	33·00	28·00
PHILIPS 202 Electronic	69·00	57·50
PIONEER PL 12A	50·90	39·95
THORENS TX 25 cover	8·22	6·53
THORENS TD125	75·89	62·00
THORENS TD150A Mk.II	43·63	33·00
THORENS TD125AB	120·20	100·00
THORENS TD150AB Mk.II	47·43	41·00
THORENS TXII Cover	4·11	3·75

SPEAKERS

	Rec. Retail Price	Comet Price
ARENA HT 16	13·00	10·95
B & W Model 70	139·50	115·00
B & W DM3	63·00	53·00
B & W DM1	32·00	25·50
CELESTION Ditton 120	24·00	18·00
CELESTION Ditton 15	29·00	23·00
CELESTION Ditton 25	59·85	47·00
GOODMANS Minister	22·45	19·00
GOODMANS Magister	57·00	45·00
GOODMANS Maxim	20·39	16·75
GOODMANS Mezzo 3	30·90	23·90
GOODMANS Magnum K2	40·10	29·90
KEF Celeste	29·00	21·50
KEF Concord	43·50	33·00
KEF Concerto	53·50	42·00
KEF Cresta	22·17	18·00
KELETRON KN 654/3 3 speaker system (pair)	19·00	14·97
KELETRON KN 824/3 3 speaker system (pair)	23·00	18·97
KELETRON KN 104/3 3 speaker system	16·75	12·97
KELETRON KN 123/3 3 speaker system	18·75	15·97
KELETRON KN 120/4 4 speaker system	24·50	18·97
LEAK 200	24·95	17·90
LEAK 300	32·50	23·50
LEAK 600	49·50	36·90
LOWTHER Acousta (with PM6)	45·50	38·50
LOWTHER Acousta (with PM7)	53·00	46·00
LOWTHER Ideal Baffle	35·50	30·00
METROSOUND HFS 20	18·50	13·50
PHILIPS RH481	11·00	9·25
PHILIPS RH482	18·00	15·00
SINCLAIR Q16	8·98	8·00
STE-MA 275 3 speaker system	23·10	15·00
WHARFEDALE Speakers		
Airedale	69·50	56·00
Denton	19·95	15·90
Super Linton	24·95	20·50
Melton	32·50	25·50
Dovedale 3	42·50	32·50
Rosedale	65·00	52·50
Triton (pair)	59·90	46·90
Unit 3 Speaker Kit	13·00	10·50
Unit 4 Speaker Kit	18·00	14·25
Unit 5 Speaker Kit	26·00	20·50

TAPE RECORDERS AND TAPE DECKS

	Rec. Retail Price	Comet Price
AKAI X200D	190·00	160·00
AKAI 1800SD	199·42	167·00
AKAI 4000 4-track Stereo	124·90	100·00
AKAI 4000 D 4-track Stereo deck	89·96	70·00
FERGUSON 3246 4-track	43·00	34·00
FERROGRAPH 722	242·54	199·00
FERROGRAPH 724	242·54	199·00
FERROGRAPH 702/W 2 track tape deck	207·35	175·00
FERROGRAPH 704/W 4 track tape deck	207·35	175·00
GRUNDIG TK 121 (Twin-track)	56·85	44·00
GRUNDIG TK 149 4-track	57·64	48·00
PHILIPS 4500 4-Track Stereo Tape Deck	126·00	99·00
PHILIPS 4408 4-Track Stereo	139·00	109·00
TELETON FXB 510 D 4-track Stereo	62·50	48·00
TELETON 5L40 Twin Track Battery/Mains	38·50	25·00
TOSHIBA GT 840 S	110·00	80·00
TOSHIBA GT 601v Twin Track	45·15	30·00
TOSHIBA 850 SA	94·00	60·00

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at 3¾ and 7½ ips ensuring maximum speed constancy.

Fully comprehensive mixing facilities.

● **Solid state electronics**
are used throughout. Modular construction ensures trouble-free maintenance and replacement of parts.

● **Relay operated transport control**
operated by illuminated push buttons requiring only fingertip operation.

● **Interchangeable head assembly**
comprising half-track, stereo, erase, record and playback heads, is mounted on a single rigid plate fixed to the main chassis. It is normally not necessary to replace or adjust heads during the normal life of the machine.

● **Two channel monitoring and VU-meter amplifier**
can be switched to two modes. In the 'before-tape' mode the amplifier is connected to the output of the mixer, while in the 'off-tape' mode it is connected to the output of the replay amplifier. Two large VU-meters calibrated to international standard are provided.

Broadcast-studio versions Models 28B and 28C are provided with tape speeds of 15 and 7½ ips, but have no mixing or monitoring and VU-meter amplifier. Model 28B is equipped with full-track heads. Model 28C has two-track heads and track selector switch.

CONTACT: BRIAN ENGLISH

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