JANUARY 1970 2s 6d

tape recorder

NEW SERIES: RECORDING STUDIO TECHNIQUES

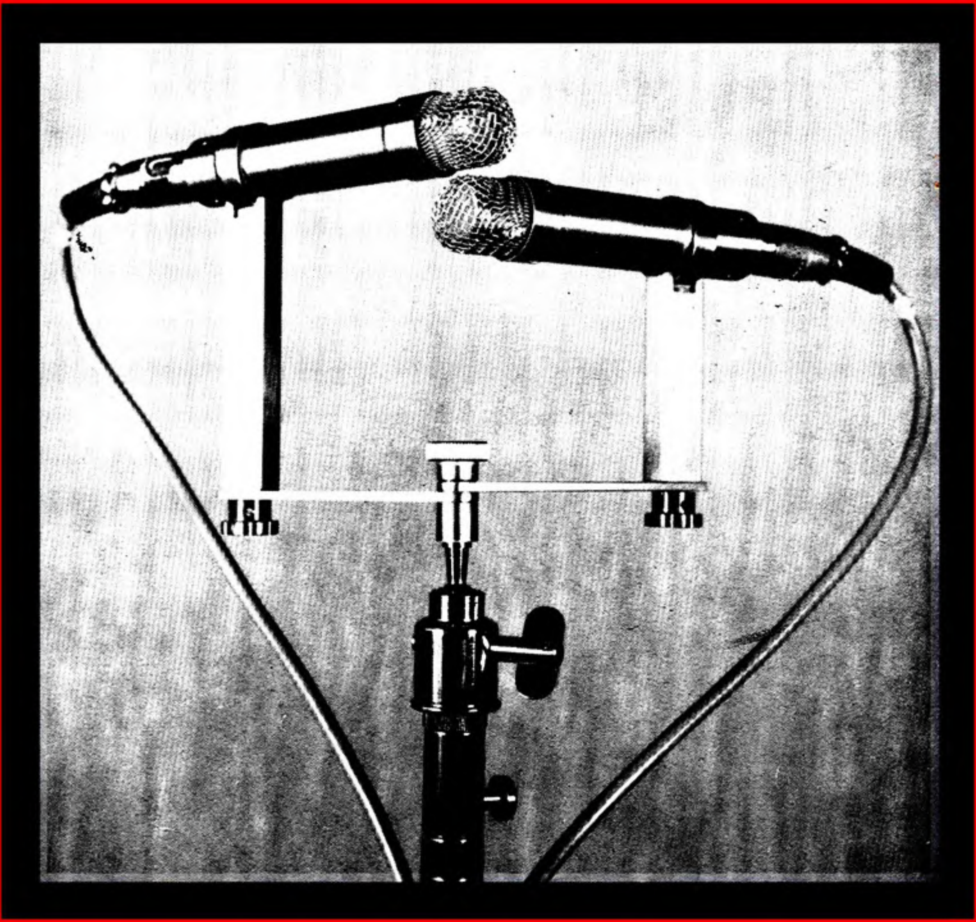
A HYPERCARDIOD CAPACITOR MICROPHONE

INTERVIEW WITH TERENCE LONG

TAPE EQUIPMENT AT THE AMSTERDAM FIRATO

TAPE RECORDER SERVICE: SONY TC250

TELEFUNKEN M250 AND PHILIPS 4307 REVIEW



AKAI's one-micron gap head is responsible for an amazing, important difference in tape recording.
It's the difference between every day, ordinary, performance and highest possible quality perfection—AKAI perfection.
Just what is a one micron gap head? It's a head whose width is one-micron—one astounding micron, to be precise.
Up to now, 2-micron heads or 4-micron heads have been the standards for comparing tape recorders.
But AKAI has pushed forward and narrowed the head-gap—narrowed the distance between tape recording results and actual sound. The result is AKAI perfection. One micron heads have these distinctive advantages over heads with wider gaps:

- (A) They have excellent frequency characteristics even at low tape speed. (This means extremely high intense recording and playback is achieved)
- (B) Clear high pitched tone can be regenerated as a high frequency tone and recorded smoothly. (A high frequency tone is recorded with a low distortion rate.)

The frequency characteristics resulting from one micron heads are amazing in recording, but certainly more noticeable during playback.
The frequency which can be regenerated is determined—theoretically—by the width of the head-gap (λH). Generally, it is conceded that head output comes to zero when the record pattern wavelength (λs) of the recorded frequency is equal to the head-gap length (λH).
Actually, the frequency ($f\frac{1}{2}$) whose record pattern wave length is twice the head-gap length (λH) can be used for the actual frequency band.
The relationship of the frequency and the head-gap to the tape speed is given in these quotations:
$f=V\sqrt{\lambda S}$···General formula for tape speed frequency and record pattern relationship.
$fo=V\sqrt{\lambda H}$···Frequency at which head output comes to zero.
$f\frac{1}{2}=V/2\times(\lambda H)$··· Actual frequency band.
These equations prove what more and more satisfied AKAI users know—that the narrower the head-gap the higher are the tones that can be regenerated.
Using these equations, let's calculate for a moment.
When tape speed is 9.5cm/s, the actual frequency bands ($f\frac{1}{2}$) will be:
$f\frac{1}{2}=47.5$kHz For one-micron heads
$f\frac{1}{2}=12$kHz For four-micron heads
Let's suppose that a 20kHz tone is to be regenerated. The frequency will be out of the actual frequency band whenever a 4 micron head is used. However, whenever AKAI's one-micron head is used the tone can be regenerated.
Why—you may ask—can only AKAI make one micron heads?
In answering, let's list some of the problems that must be overcome in narrowing head-gaps. First, there is regeneration power degradation, then there is s/n degradation and recording performance deterioration—to mention a few.
These and many other obstacles have been surmounted by AKAI's diversified experience in this and related fields.
From this experience has blossomed AKAI's own, unique technique—technique that leaves absolutely nothing to chance.
Special adhesives and precision plus correct alloy materials for the head-gap have also been distinguished results of AKAI research to successfully narrow wide-gap heads with no defects.
This is all another step-by-step success story in what tape recorder users call "AKAI PERFECTION."

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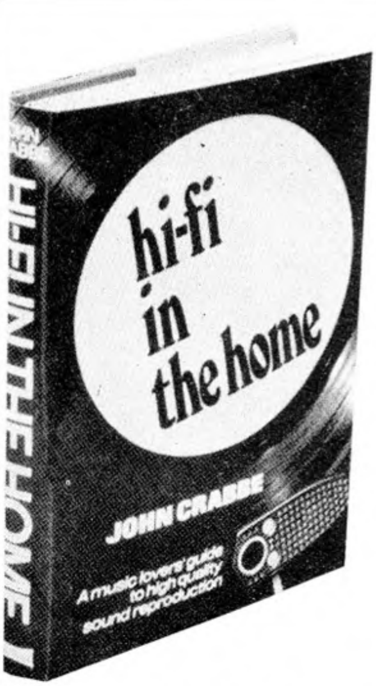

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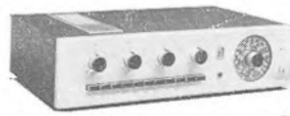

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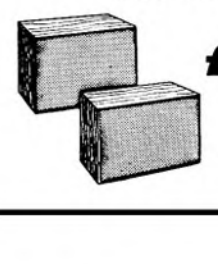

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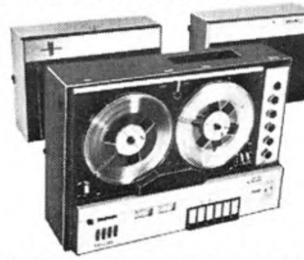

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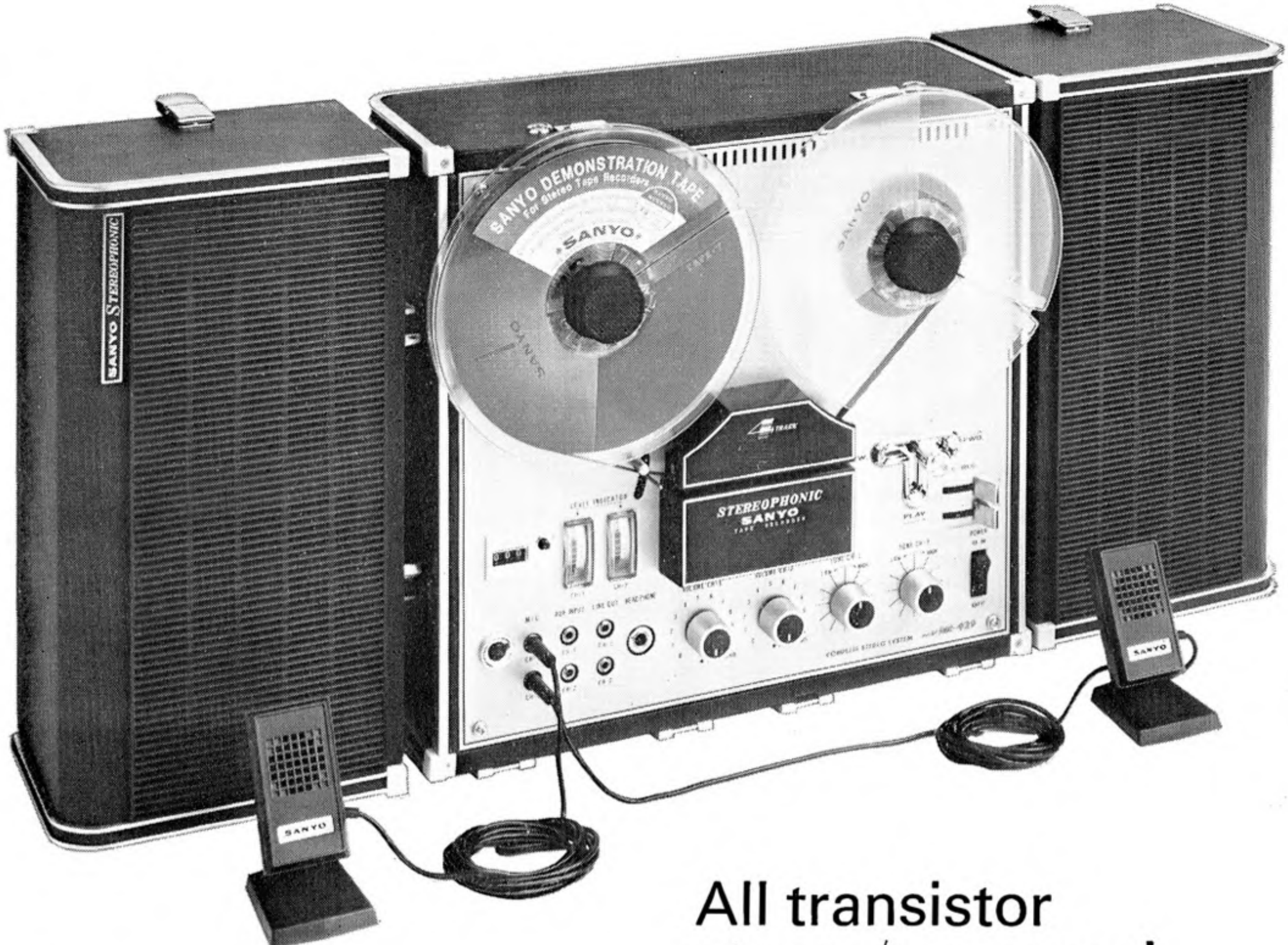

Model MR-929

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SPECIFICATIONS

Recording System: AC bias
Erasing System: AC erase
Reel Size: 7″ dia.
Speeds:
$7\frac{1}{2}$ in/sec (19 cm/sec),
$3\frac{3}{4}$ in/sec (9.5 cm/sec)
Playing Time:
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30 min. x 2 at $7\frac{1}{2}$ in/sec with 7″ (18 cm), 1,200 ft. (360m) tape
1 hour x 2 at $3\frac{3}{4}$ in/sec with 7″ (18 cm), 1,200 ft. (360 m) tape
monaural
30 min. x 4 at $7\frac{1}{2}$ in/sec with 7″ (18 cm), 1,200 ft. (360 m) tape
1 hour x 4 at $3\frac{3}{4}$ in/sec with 7″ (18 cm), 1,200 ft. (360 m) tape
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Power Output:
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Two 4″ free-edge permanent speaker boxes.
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JANUARY 1970 VOLUME 12 NUMBER 1

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COVER PICTURE

To Terry Long, John Shuttleworth, Ralph West and (because he lacks a decent mixer) David Kirk, our cover photo portrays something of a religious symbol. To the rest of us it shows a stereo pair of Trevor Attewell's capacitor microphones, described for constructors in this issue.

SUBSCRIPTION RATES

Annual subscription rates to *Tape Recorder* and its associated journal *Hi-Fi News* are 30s. (36s. overseas) and 47s. respectively, U.S.A. $4.30 & $5.60. Six-month home subscriptions are 15s. (*Tape Recorder*) and 24s. (*Hi-Fi News*), from Link House Publications Ltd., Dingwall Avenue, Croydon, CR9 2TA.

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

WE HAVE RECEIVED several letters during the last few weeks asking where four-channel 6.25 mm audio heads can be obtained at a reasonable price. The cheapest appears to be the *CX44-RP102* produced by Marriott Magnetics Ltd.* This is a record/play head and costs, one off, £17 10s. Other companies also produce them, but from their price one would think they were made of platinum.

These letters reflect a growing interest in four-channel sound recording, not for its multitracking properties but as a medium for simultaneous four-channel reproduction. The interest may stem from the four-channel demonstration given by 3M at the last Hotel Russell Audio Fair. Similar demonstrations were given in the USA at the time, although little was promised to the public in the way of commercial development. Now, nearly two years later, Vanguard have announced in New York that four-channel 6.25 mm stereo tapes will shortly be available to anyone prepared to assemble their own playback equipment. Four-channel FM broadcasts began in Boston on September 27, utilising the multiplex stereo facilities of two separate stations.

Both the 3M and Vanguard four-channel systems, and also the Boston transmissions, require a loudspeaker placed in each corner of a rectangular room. This can be used to place the listener in the middle of an auditorium and is reported (Edward Tatnall Canby, December *Hi-Fi News*) to create 'a surprisingly realistic sense [of being] located right in the middle of the large audience at [Boston] Symphony Hall'. Later in the same article, Mr. Canby describes 'a 'visual' distortion of that system's ability to approach more nearly the literal concert situation . . . the lady who sang out in front of us seemed about forty feet tall, with a head as big as a weather balloon'. This reference to apparent vertical characteristics is curious, and clearly a comment on inadequate presentation, as the prime limitation of the American loudspeaker layout is that its reproduction characteristics are limited to a 360° horizontal plane.

Four-channel stereo is the inevitable successor to two-channel reproduction and we look forward to its early arrival. Equally inevitable is the adoption of tape as the multi-channel medium, either 6.25 mm open-reel 19 cm/s tape (it is too much to expect 38 cm/s) or 3.8 mm 4.75 cm/s Compact Cassettes. Both DGG and Decca, it is reported, are now producing two-channel Musicassettes with chromium dioxide tape, and a four-channel record/play head to suit the narrow tape should be within the resources of Philips. The result should be a very serious threat indeed to the LP disc. We hope, however, that the powers that be have the sense to accommodate the last remaining plane, the vertical dimension, either by using five channels or repositioning the proposed four. Granville Cooper has postulated a more sensible arrangement of the four-channel system than is being used in the USA. He suggests placing the listener in the centre of a tetrahedron formed by two conventional stereo speakers half-way up the 'front' wall and a further two at the rear, one at floor level, the above it at ceiling level. Four-microphone Blumlein technique from the intended listener location would result in realistic reproduction of a complete hemisphere of sound at the central listening point.

There is scope here for practical experiments with the 4-channel-and-over multitrack recorders currently being used to produce two-channel stereo masters. For the less well equipped, a 4-channel Revox *HS77* with staggered twin-segment ¼-track heads is expected to be on the market shortly. The marriage of two ¼-track two-channel recorders, with staggered heads or a four-channel Marriott, offers a fascinating subject for the home enthusiast. How about it?

* *Waterside Works, Ponsharden, Penryn, Cornwall.*

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WORLD OF TAPE

AMPEX CASSETTES

THE PRODUCTION OF recorded cassettes has been commenced by Ampex at their Nivelles plant, Belgium. Work on 8-track cartridge records will start shortly. A new marketing organisation has been established in Reading to handle distribution of the records throughout Britain and the Continent, Ampex Stereo Tapes Europe. General Manager is Gerry Hall, formerly Manager of Administrative Services for the Europe, Africa and Middle East area of Ampex International. Formed in 1959, Ampex Stereo Tapes currently produces and markets some 6,500 stereo tape selections under the Ampex label from 34 independent recording companies. The division also provides a duplicating service for other recording companies.

MINIFLUX MANUALS

THE FIRST VOLUME in a series of Miniflux Manuals is now available at 31s. including postage from Miniflux Electronics Ltd., 8 Hale Lane, London N.W.7. It includes sections on equalisation standards, head matching for low-noise operation, frequency response measurement techniques, and a number of constructional projects one of which is a stereo IC/transistor hybrid amplifier employing 44 transistors.

TOSHIBA PRICES

FOLLOWING A SATISFACTORY reception for Toshiba equipment at the October Audio Fair, Hanimex have appointed agents to handle distribution in Scotland, Tyneside and Northern Ireland. These are Michael Black Ltd., 2 West Regent Street, Glasgow; Michael Black Ltd., 127 New Bridge Street, Newcastle on Tyne 1; and Wilmor & Co., Lorne Street, Lisburn Road, Belfast 9.

Reduced prices of five Toshiba recorders (former prices in brackets) are: *KT23P* £6 19s. 6d. (£29 8s.); *GT21P* £37 16s. (£40 19s.); *GT601V* £45 3s. (£48 6s.); *GT701V* £57 15s. (£63); *GT840S* £110 (£119 14s.).

ELCOM INSTALLATION AT ITN

SOUND MIXING equipment, production desk and grams unit at the recently opened ITN studio in Wells Street were commissioned from Elcom. The central control room installation illustrated below comprises five Garrard **301** turntables, Gaydon groove locators fitted with Decca *XMS* **78/*B*** pickup heads, an ITN-modified Ferrograph **7** and a 24-channel mixer/production-desk. A similar installation is incorporated in an adjacent studio while a 12-channel mixer and a third grams unit occupy the dubbing studio control room. The talkback circuit feeds 65 stations, each with warning lights. This may be linked to a public address facility and fed by the GPO speaking clock.

MIXERS—BKSTS SYMPOSIUM

RUPERT NEVE, Richard Swettenham, A. O. Moore (Elcom) and Michael Batchelor (EMI) are contributing to a BKSTS symposium in the afternoon and evening of January 28. The talks come under the title 'Sound Control Consoles'. Venue has not been decided at the time of writing but details may be obtained from Paul McGurk, BKSTS, 110-112 Victoria House, Vernon Place, London W.C.1 (Tel. 01-242-8400).

NEW NAME FOR 'TAPE RECORDER'

READERS WHO missed last month's leader article are reminded that, from next month, our title will be *Studio Sound & Tape Recorder*. The *Tape Recorder* title will retain prominence in the February, March and April issues, after which *Studio Sound* will dominate the cover artwork.

BATRC PRIZE-GIVING

OUR APOLOGIES are due to the Federation of British Tape Recordists and Clubs for associating them with the British Amateur Tape Recording Contest prize-giving in our December issue. We would certainly not wish the blame for any shortcomings in the mechanics of the prize-giving to be laid with the Federation.

PEARL MICROPHONES

TWO NEW CAPACITOR microphones produced in Sweden by Pearl are now being imported by Jagor Interelectric Ltd., Mercury House, Hanger Green, Ealing, London W.5. The *DC-20* omni-directional and *DC-21* cardioid incorporate FET amplifiers and operate from a 500 to 800 A μ67.5V battery supply. A 6 m cable and stand adapter are supplied.

GRAVITY COMMUNICATION?

PHILIPS COMPACT CASSETTES are being employed in the Hawker Siddeley *Harrier* vertical take-off jet as a method of communicating from pilot to ground. A Davall *1200* Cockpit Voice Recorder/Reproducer has been developed for the purpose. The Davall is voice-activated, starting to record when the pilot commences talking and halting five seconds after he finishes. Signals from ground received via the radio communication channel may also be recorded when required. When radio silence is to be maintained, a cassette containing the pilot's report may be dropped to a ground commander and reproduced on a standard Philips recorder.

TAPE CORRESPONDENCE

A THIRTY-TWO PAGE illustrated booklet entitled *Tips for Tapespondents—International Message Making* has been produced by the Worldwide Tapetalk tape correspondence organisation. Subjects covered include the problems of $\frac{1}{2}$-track/$\frac{1}{4}$-track exchanges, equipment maintenance, indexing and postage. Copies are available to non-members at 2s. 6d. plus 4d. postage, or free to new members from 25 The Gardens, Harrow HA1 4HE.

TAPE RECORDER PRODUCTION

PRODUCTION OF TAPE recorders in June 1969 was 5% lower than in June 1968 and, in the first six months of this year, showed a decrease of 4% over the same period last year. Deliveries of British made machines were 7% lower in value during June than in the same month of 1968, while deliveries of foreign machines rose by 71%. Total deliveries of all machines fell in the first half of 1969, British made recorders by 24% and foreign models by 32%. Within this total, however, exports of British made recorders rose by 34%.

July production, at 11,283 machines, was 22% lower than in July 1968. Total deliveries of British made machines were 31% lower by value than in July 1968 but exports were 5% higher. Deliveries of imported machines fell by 18%. Stocks of British made recorders were 35% higher at the end of July than a year ago, but 2% lower than at the end of June. Stocks of factored machines feel by 3% over last year's figure.

NEXT MONTH

Keith Wicks pilots a new column devoted to individual recording studios, in the February Studio Sound & Tape Recorder, with a visit to Studio G. He also contributes the first of two articles describing the Dolby Noise Reduction System. David Kirk interviews John Alcock of Unitrack, and Robert Rowe outlines the construction of his attic studio.

Interview

David Kirk talks to Terence Long, consultant studio engineer.

D.K. *When did you first get involved in the tape recording business?*

T.L. About 1950. I bought a Grundig *700L*—we all have to start somewhere—½-track mono, 19 cm/s. I tried to improve it and so became involved in the mechanical side.

D.K. *Being a mechanical engineer?*

T.L. Yes.

D.K. *What machine did you progress to?*

T.L. Another Grundig, a little better, a *TK820*. I still get them occasionally to repair. My first decent recorder was an EMI *TR51*, followed by a stereo *RE301*. Since then I have had about five Philips, *Pro 20* and *Pro 35*.

D.K. *Is there much difference in quality between the valve Pro 20 and the transistor Pro 35?*

T.L. Well the transistorised one is much heavier! It's a bit of a nuisance as I have to get someone to help me carry it. The reason is they've taken much more trouble to screen the *Pro 35*, resulting in a better signal-to-noise ratio. The early transistor recorders were dreadful.

D.K. *When did you first start to make money out of tape recording?*

T.L. I made it straight away out of the engineering side. When the early Grundigs came out there was no real standard on track positions. The tape went from left to right but the heads scanned the bottom half. We transferred the heads to scan the top track and, when we advertised the service, were inundated with these recorders.

D.K. *Which was the first recorder to earn its keep?*

T.L. The *RE301*.

D.K. *What did you like about the EMI?*

T.L. Everything except the signal-to-noise, and the fact that it wows at the end of the reel. We made large-hub reels to get over this.

D.K. *What is your attitude to multi-channel—the sort of thing that's used for pop work at the moment?*

T.L. I don't like it. It's not realistic. I'm told by the studios I visit that unless they use this technique, they'll go out of business, because that's what the public wants. There are positive freaks of apparatus in some of the studios. It's unbelievable what they do because they can't afford to buy one of these multitrack machines. Many times I have had to rescue the most atrocious conversions.

D.K. *Convert them back?*

T.L. No, to try and make them work. They'll convert anything, so long as the capstan is big enough to take 12.5 mm tape. Four-channels appears to be the minimum they'll put up with.

D.K. *Do many classical recording people use multichannel?*

T.L. They're doing it now, I'm sorry to say.

D.K. *Have you yet come across any of these American 16-channel recorders?*

T.L. Yes. They remind me of mangles.

D.K. *Which mikes do you use?*

T.L. Nearly always capacitors, AKG *C24*, or STC *4038* ribbons.

D.K. *How consistent are studio microphones in performance?*

T.L. They're terribly individual. One is given a curve with most studio mikes and they might be identical, but I have yet to find two that sound the same.

D.K. *What is it that the curve doesn't show?*

T.L. I don't know. My favourite *C24*, the one I most use, sounds much smoother than any other microphones I have had.

D.K. *Does consistency vary between, say, AKG and Neumann?*

T.L. That's rather a leading question but, off the cuff, I think that Neumann have the greatest name for consistency. We once tested about eight of them here when we were selecting microphones for a certain purpose and I could definitely tell the difference between every one. Out of this eight I chose one for myself which I preferred to the rest.

D.K. *How do you go about testing a microphone? Would you rush it into a dead room and connect up to a B and K?*

T.L. No, I wouldn't dream of doing that. I like to do it by listening to something, preferably a percussive sort of sound. We use a piano for one test and a musical box for the other; they are very revealing.

D.K. *You use capacitors for everything?*

T.L. No. I like ribbons for stringed instruments. They always sound better. The STC *4038* is one of the best, or *the* best. Capacitors make a harpsichord sound tinny.

D.K. *You have had trouble with capacitor microphones going noisy, I gather?*

T.L. Once, but that was overcome by keeping it in a heated cupboard. I have had to cure damp capacitors for some studios, I've done quite a few; we put them in a dessicator and give them frequent changes of temperature in partial vacuum. This gradually extracts the moisture from behind the capsule.

D.K. *Is it true that you can extract moisture just by placing a microphone under a studio lamp, for example, or can this cause damage?*

T.L. I wouldn't like to do this, and doubt if it would be much of a cure.

D.K. *The advantage of a stereo pair is that it gives a recording of an event as it really was but the whole point about some of this pop stuff is that it never really was: the original performance was by a lot of people sitting in kapok cubicles in a basement somewhere. The 'original' is the mixture of performance and electronic effects on the master tape.*

T.L. That's true. An acceptable pop recording can only be made with multi-mike techniques, or multichannel with post balancing. That's where multichannel comes into its own. It's only the pop business that's done this.

D.K. *How much of your recording is done with a stereo pair?*

T.L. About 90%. I do use multiple mikes sometimes: they are only usually necessary if you have got one very loud instrument which cannot be quietened down. Then you have to put microphones on the weak ones to bring them up, at least I do.

D.K. *You can't send the loud chappie into the distance?*

T.L. You usually put him into a cubicle; it's nearly always the drummer or the pianist who drowns everybody. I have surrounded drums with mattresses before now.

D.K. *Do you find much variation between reels of professional tape, assuming the same brand?*

T.L. No, with a really good professional brand there is very little difference. But if you're making test tapes, you have not only to select the reel, you must also select pieces out of the reel.

D.K. *Both your Philips machines have ferrite heads?*

T.L. Yes, I have converted several recorders to take ferrites and had the most appalling difficulties getting rid of the top. At 19 cm/s I have had to get rid of something in the order of 12 dB at 15 kHz so the losses in metal heads must be enormous. I have spoken to one or two manufacturers of studio recorders in this country, asking why they don't use them. They all agree that ferrites are much better but there are difficulties in getting rid of the hum; you need extremely good screening on the replay head. They are also dearer.

D.K. *Is screening so difficult?*

T.L. Philips have got over it but Mullard have stopped supplying screening cans which makes life a little difficult. You can go straight to Eindhoven, however. Once you have fitted a ferrite head, you can forget it. They last longer than the life of a machine. You don't get the trouble of head characteristics changing which can be a bind when you do a lot of recording. On some machines the top response goes up as metal heads wear; on others it goes down.

D.K. *Ferrites obviously make searching much easier.*

T.L. Yes, but Raymond Cooke says its very bad for the speakers which object strongly to the high frequencies. He was most emphatic that more speakers are ruined this way than through any other cause.

D.K. *Now you're about fifty. Fifty-five?*

T.L. That's a great secret. Well?

D.K. *Have you noticed your hearing changing, for better or worse, as you've grown older?*

T.L. I haven't detected any deterioration. I can distinguish things that are 'wrong' much easier now than I could twenty years ago. I used to accept a loudspeaker because it was a loudspeaker. Now I expect it to sound a little bit like the original. If I walk into a room and hear a loudspeaker, I can tell immediately what is wrong with it. Every speaker has faults of one kind or another.

D.K. *Can you hear a 10 kHz television whistle?*

T.L. Yes. I can still hear around 15 kHz.

D.K. *You think your hearing is unusual in this respect?*

T.L. No, I think it is just that I am trying to make full use of my ears.

D.K. *I gather you do most of your monitoring on headphones.*

T.L. Yes, I used to use loudspeakers, most people do, but every room you set up in has a different acoustic and I don't know where I am. With earphones, I know they are always going to sound the same. A lot of engineers have great difficulty with earphones; they say the sound is at the back of their head, or the front of their head, but you get used to them if you employ them all the time. I always use the same pair, fairly cheap AKG *K50*; I have had them many years.

D.K. *Do you ever find yourself in a position so close to the subject that you need good sealing? The K50 doesn't give much.*

T.L. No, I always set up in a separate room and either use a talkback or work with a light. Talkback can be a nuisance if you are working in a very reverberant building because the talkback speaker may take several seconds to decay, during which you dare not start the tape.

D.K. *Yes. I've had this kind of trouble with the RE301 where the capstan starts up fairly slowly and people begin performing as the tape grinds up to speed. You can overcome this by waving somebody's thumb at the players.*

T.L. Most big machines start up within a fifth of a second because the capstans run continuously but all tapes jump a bit at the start. If a recorder is up to speed in a second, I think that's adequate.

D.K. *What is your attitude to servo-controlled capstan motors?*

T.L. I can tell a recording that is made on one. They introduce something not present in conventional recorders, a high frequency modulation which makes the sound edgy. Many engineers have told me they can hear the same thing.

D.K. *Do standards vary much between the larger studios?*

T.L. The general standard of studio maintenance isn't as high as it should be. As long as the wheels keep turning they don't seem to worry. There are exceptions but as a general rule its pretty grim.

D.K. *Where does the BBC fit into this? Are their standards above those of the average studio?*

T.L. The Radio backroom boys are excellent. Television sound standards are not quite so high. I have seen balancing engineers having difficulty with mixers because the studs were dislodged or dirty—they rattle the faders backwards and forwards to stop noise.

D.K. *What do you think of the EMI BTR2?*

T.L. The best machine EMI ever made. It gives very little trouble. The only thing I don't like about it, and we have converted a lot of them for studios, is the tape goes round a flywheel before it reaches the sound heads. It drives the counter mechanism and I presume was put there to remove flutter. If you remove it, your wow and flutter problems almost disappear. This also goes for the Ampex *300*. Until recently, designers never seemed to think about what happens to a left-hand flywheel; I think they put them there because their grandfathers did.

D.K. *Your most successful work ends up on disc. What do you think of this medium?*

T.L. I don't think much of the disc. I have a library of LPs made from my own masters and I have no means of playing them at all. I sometimes take them to friends' houses to play but I think the sounds are excruciating. There seems no point in keeping a turntable here. I feel sorry for those who have to rely on discs.

D.K. *What gets lost when a master is transferred to disc?*

T.L. Little gets lost but a lot gets added. A lot of mechanical noise. Rumble is added as well. High frequencies particularly get terribly distorted though this may be due to the pickups; I don't know anything about pickups. We have made one or two interesting experiments. When at a studio cutting a disc, one is often able to listen to the lacquer and compare it with the tape. Even at that stage there is quite a degradation and by the time it has been pressed, it is pretty grim. But it's a cheap way of copying. Quarter-track tapes can be horrible but there are some which are not too bad. I wouldn't like listening to them but I would prefer anything to a gramophone record. I think tape will completely overtake discs before very long. I know tape copying is a problem but I am sure it can be overcome.

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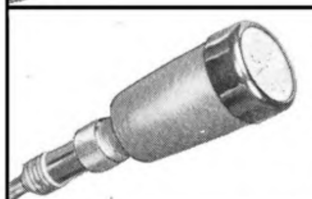

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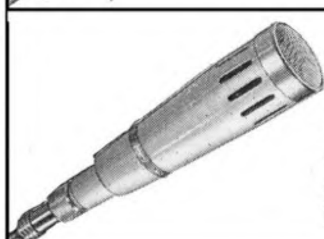

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RECORDING STUDIO TECHNIQUES

part one the early years

BY ANGUS McKENZIE*

IN this series of articles, after writing a resumé of recording techniques in the early years of tape recording and LP disc issues, I shall be discussing techniques in the recording studio as applied in the last few years. The articles will each month describe techniques in a particular field, and it is my intention to explain many of the somewhat baffling ways of professional engineers. I will include, for instance, an article dealing with professional recording tapes, mentioning the requirements, the different ways tape can be used and why, and an article dealing solely with professional microphones and their use.

To assist me keeping this series up to date I would be very pleased to hear about new professional studio equipment direct from manufacturers through the *Tape Recorder* office, and will also be pleased to assist any readers who care to contact me by phone during the day, although I am sure it will be understood that I will not be able to deal with lengthy correspondence.

It should be noted that the difference between the professional and the semi-professional is one of reliability, in that equipment can be used in a studio for perhaps 3,500 hours per year and during that time must perform consistently well. Whereas the semi-professional may well spend hours setting up his equipment for a recording session, the professional engineer has frequently to accept that the equipment is in perfect working order and concentrate on the sound itself without having to worry about, for instance, tape dropout, wow, or general faults in the equipment. The professional engineer should always have extra equipment available for any eventuality, and he should be able to match up the sound between tapes made at quite long intervals, in addition to tapes being recorded to a consistent peak level. It is also important to remember that a tape made in one studio should sound as good when played back in any other good recording studio. Also a stereo tape recording must be capable of being cut on to disc without the sound being tampered with to make possible the transfer to disc.

From the inception of electrical recording in the 1920's to the end of the second world war, recording techniques improved only slowly with relatively few large steps. It is true to say that 78 RPM discs recorded in this period were of much higher quality than was realised at the time, and present-day recreations on LP, often dubbed from the original metal parts or special vinyl pressings, show how remarkable some of these records were in their day. As is often the case, great improvements in all types of scientific techniques result from wars, and although there was little apparent improvement in gramophone records towards the end of the war the seeds of this improvement had been sown, not only by the realisation that the gramophone pickup could be vastly improved but, far more important, Germany had begun to develop the magnetic tape recorder, initially designed for war-time use. Some of the first Magnetophons, recording at 77 cm/s, were captured by the Americans who continued to experiment with tape, and later also by the British. It should be realised that at this time the difficulty was not so much the building of the tape machines as the almost total lack of magnetic tape on which to record.

Shortly after the war, in 1947, EMI at Hayes started on the development of a professional tape recorder for their own studios and also for military, post office and BBC use. With their inception of the *BTR1* tape recorder using 1 km reels of approximately 28 cm diameter, and at the same time making a tape to go with it, EMI started the biggest change in recording studio techniques known to the industry since the beginning of 78's—even greater than the change from acoustic to electrical recordings. It became possible for orchestras to perform complete works, or large pieces, and repeat as many times as necessary without the expense and trouble of continually putting new waxes or acetates on the cutting lathes. From 1948, therefore, many EMI recordings were done on tape as well as disc for a period, and then on tape only, and many of these early tapes, such as recordings by the late Sir Thomas Beecham, are now re-issued on LP. Other companies were quick to purchase tape recorders, and Ampex started manufacturing at about the same time.

In Vienna since the war, Dr. Rudolph Görike had been experimenting with capacitor microphones, and in the early 1950's he produced for AKG the *C12* which is still being used in studios today. Neumann in Berlin, and Hiller, also made capacitor microphones of excellent quality which far outclassed very early capacitor mikes which had been used back in the 1930's, but which in their earlier forms were rather noisy and unreliable, as well as being omni-directional. By today's standards the performances of the earlier tape recorders were very poor, and this was mainly due to the poor quality of the tape itself, particularly in hiss level. The earlier types of EMI tape for instance could not accept a level in excess of 32 mM/mm, and the replay gains of tape recorders used for playing back these tapes had therefore to be set at a high level. It should be realised that, since the dynamic range was limited by the performance of these early tapes, recording engineers had to balance the dynamic range between well defined limits, as they had also been having to do with 78's. Many of the early Decca LP recordings were dubbed from 78 metal discs, and the difference in quality between these and the first tape recordings was very marked. The earliest tapes were of course issued on 78's as well. Not very long after LP's had been established on the British market and after producing tape for several years, EMI brought out their first tape which could be considered as relatively good quality, namely *H77* giving approximately a 4 dB improvement in signal-to-noise ratio. In 1953 EMI brought out their *BTR2*, which in my opinion was one of the finest professional

(continued on page 40)

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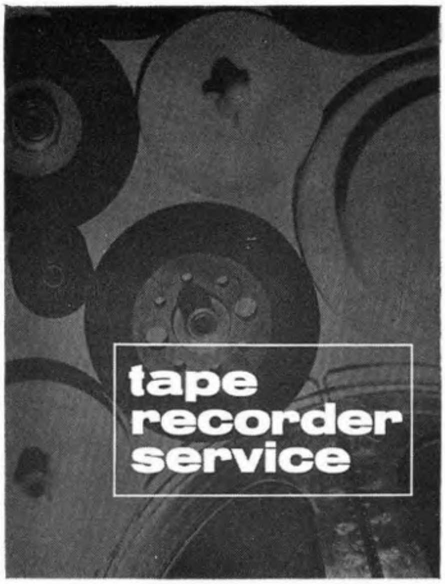


SONY TC250

BY H. W. HELLYER

HAVE you ever felt you were getting into a rut? I must confess that something of this feeling besets me when I see the new models that Sony (UK) are introducing, and my American friends assure me that they are even more blessed with Sony profundity. Having started a sub-series on the servicing of this very good equipment, I now find myself faced with an ever-growing list of possible machines to mention. In the current article we shall attempt to examine the *TC250*, lead on to its derivatives, and follow through a few of the development points that have now resulted in a tape unit of quite impressive performance in the *TC255*.

I hope we shall be able to show that these small improvements are aimed toward a better product in most cases, and not merely toward the target of a larger slice of the market—although Sony, being no novices in business, must have this target squarely in their sights.

First evidence comes from an inspection of the circuits given in **figs. 1, 2** and **3**. The basic shape is the same—a four-stage amplifier with a fairly heavily filtered power pack and a feedback oscillator of simple design. But we note that the *2SD24* input transistors of the *TC250* gave way to silicon planar types, *2SC401* by the time the early *TC250A* version had come along, with *2SC402* as voltage amplifier and a *2SC318*, with a more powerful rating to allow for the overload margin, fitted in place of the terminal *2SB382*.

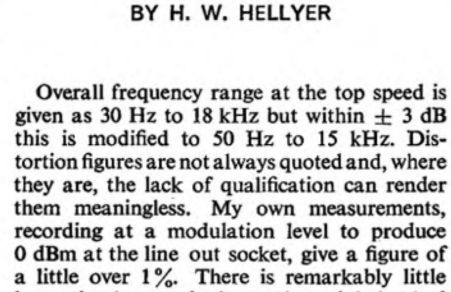
Of more importance, as an attempt to overcome the bogey of weak oscillator drive and noisy residual magnetism on tape, after erasure, the oscillator was first changed to an *n-p-n* pair, and later to a single high-power *2SD28*. This transistor, used extensively where power and fairly fast switching are required, can be troublesome if conditions inflict excessive heat on it. In the oscillator, it has to work pretty hard, even when the frequency is around 80 kHz (original germanium transistors were in a 50 kHz tuned circuit). It is interesting to note that the very slight changes in the *TC255* oscillator circuit, which we shall be looking at next month, have been made around the *2SD28* and the oscillator frequency has been raised to the praiseworthy heights of 160 kHz.

The *TC250* is a tape unit, having no power output stages or loudspeakers. It is fully stereo, record and play, but has only a single record button. This limits its facility somewhat, as we have observed before. Mono replay is possible by fitting the small modification shown in the diagrams accompanying the *TC250* article, (October 1969). In fact, separation of the channels can also be done by altering the switchlink arrangement, and I even came across one model to which a pair of draw-wires had been added, with auxiliary springs opposing the pull of the switch actuators.

Two-speed operation (19 and 9.5 cm/sec.), with single-motor drive via rubber-tyred idlers, from a two-step capstan. Maximum spool size is 18 cm, overlapping the deck. Rather cleverly, a simulated leather top cover which can be supplied has flapping sidepieces, so that one can transport the *250* and *250A* with spools left on. But there is no handle on the wooden plinth and the machine is quite obviously not intended to be carted around, despite its modest weight (7.7 kg).

Overall frequency range at the top speed is given as 30 Hz to 18 kHz but within $\pm$ 3 dB this is modified to 50 Hz to 15 kHz. Distortion figures are not always quoted and, where they are, the lack of qualification can render them meaningless. My own measurements, recording at a modulation level to produce 0 dBm at the line out socket, give a figure of a little over 1%. There is remarkably little hum, thanks, no doubt, to that triple-banked smoothing circuit and some very intelligent printed-circuit board layout.

Signal-to-noise ratio, again measured with a peak recording level signal that is injected, then removed, is better than 50 dB when a unit is up to scratch. In fact, the head wear situation, already mentioned, can aggravate this situation as well as cause a disturbing roll-off at the top of the response curve. Sony always provided head cleaning ribbons with their earlier machines. I had the curious experience of changing the record/play head on a *TC260* only this week and discovering these ribbons, still in their little plastic wallet, unused and tucked away in a corner of the socket panel, and the machine was two years old.



Wow and flutter figures are better than 0.19% at 19 cm/s. Two VU-meters are employed, illuminated on record. They are set for 0 dB when signal level is at 12 dB below saturation, so the practice, as before, is to put the signal on pretty hard. This seems common to many Japanese machines, and many a recording has been spoiled by hiss because an attempt was made to keep the swinging needle below the danger mark throughout the programme. In practice, it is better to risk the occasional, short-term burst of distortion than to lose passages in system noise on replay.

A lot depends on the tape which is used, and as the price was kept down by selling the TC250 without microphones or tape, many odd brands must have been used. My experiments have showed that the best recordings can be made with BASF *LGS35LH* or Zonatape, keeping to LP tape and not being tempted to DP or thinner. For really low-noise recordings, on this as on a number of other similar models Ampex *344* has proved ideal. Bias setting is, of course, important, and I have found that the recognised method of inserting a 1K resistor in the return lead of the record/play head (easily accessible on the rear and side of the head casing) and measuring across this with a valve voltmeter is not always as good as a trial and error assessment of the bias trimmer position, playing back the recorded tones and monitoring with an oscilloscope and valve voltmeter at the line out socket for minimum distortion compatible with best output, then rechecking the noise level. Measuring bias current alone: in this case we should get 1.2 V across the 1K resistor with the violet and black leads to the head removed and the test resistor taken to chassis from the head 'out' connection.

The two trimmers are 30 to 200 pF compression types, easily visible on the power supply and oscillator printed-circuit board. At the end of the board are the bias traps, and the adjustment for these is also quite simple. With the machine in the record mode, simply read off the bias breakthrough—plus any noise—at the line out socket with a valve voltmeter, then adjust each coil for a minimum reading.

It may bear repeating at this point that bias setting adjustment on this machine, and many others of all makes, should be done for best playback conditions. That is to say, an overall test should be made, although this takes a little longer. On a three-head machine with the usual A-B facilities, it is admittedly much more easy, but patience with a two-head machine will pay off in immensely improved recordings if the temptation to get a 'maximum bias' reading at all costs can be thrust behind you.

The *TC250* and the *250A* are both intended for use vertically or horizontally, with no change of mechanism. Rubber spool retainer caps are the norm with Sony equipment. In practice, I find that vertical operation, unless the machine is supported pretty firmly on a fairly high shelf, is a bit inconvenient. The wood plinth is only a little over 150 mm deep, and the single lever function control is fairly stiff, so the only practical way of using the machine is to support the top of the plinth with the free hand. Add to this the awkward-

(*continued overleaf*)

FIG. 1 SONY TC250 LEFT-CHANNEL, OSCILLATOR AND POWER SUPPLY

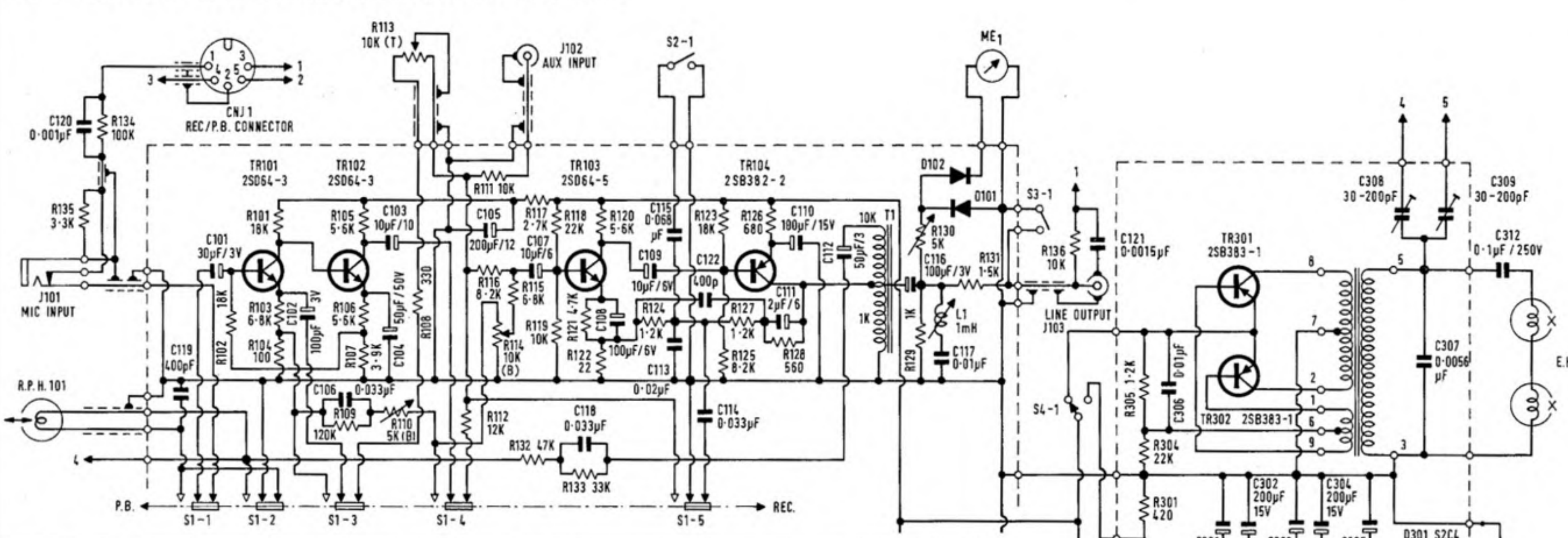
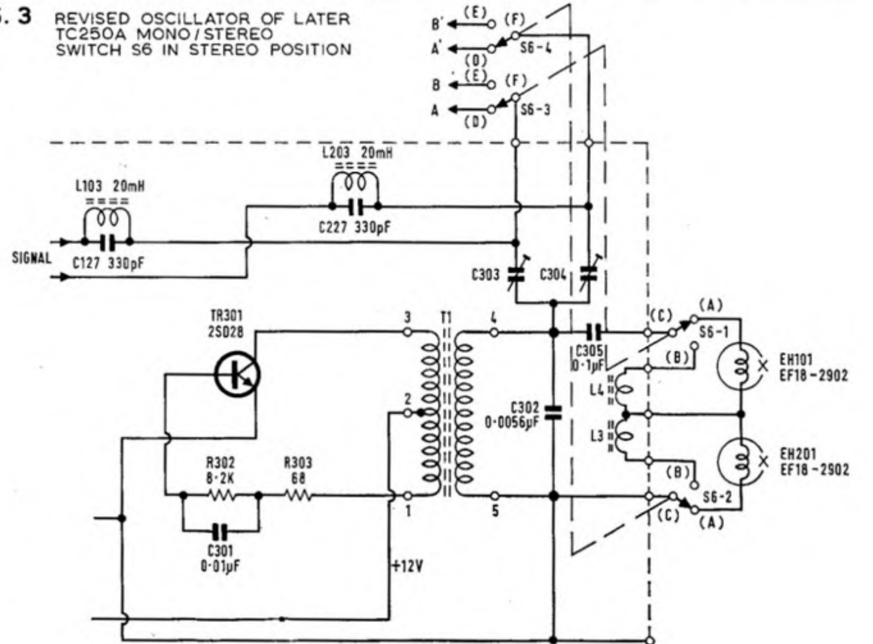


FIG. 3 REVISED OSCILLATOR OF LATER TC250A MONO/STEREO SWITCH S6 IN STEREO POSITION



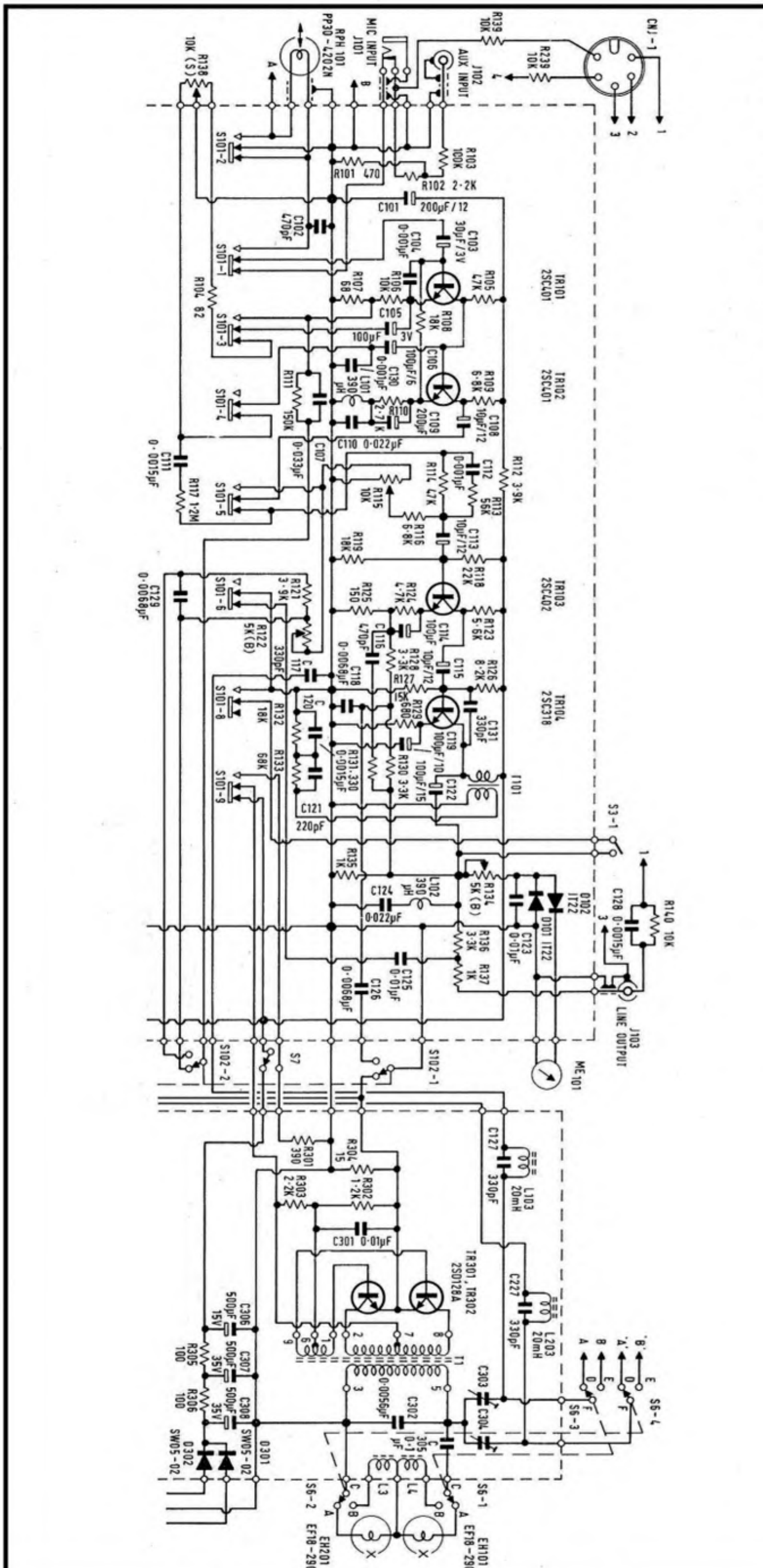


FIG. 2 EARLY TC250A LEFT CHANNEL AND OSCILLATOR

ness of twiddling the recording level controls beneath the flap at the left, and we have a good case for laying the machine down flat on the table. (Oh, those Oriental knobs! Japanese fingers must be more delicate than ours.)

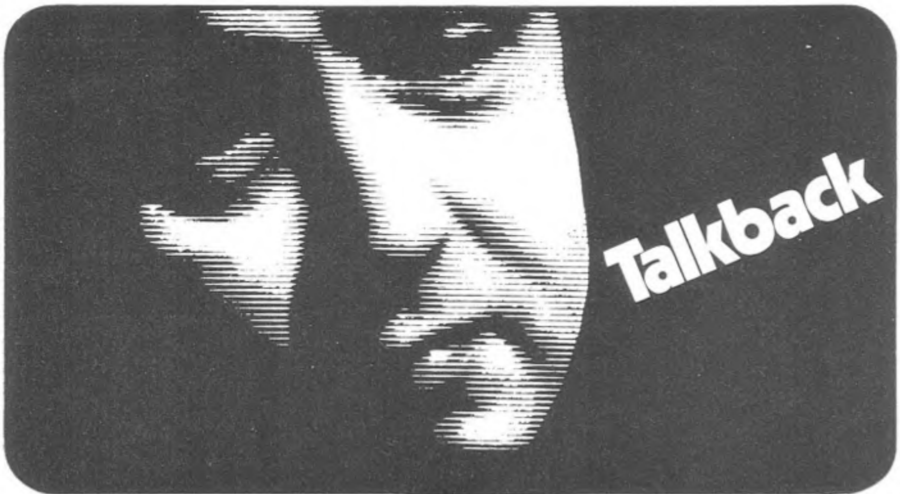
The snag with using the *TC250* in this way is the protruding ventilation 'cage' over the motor fan (a turbine style assembly which tends to gather dust in time). The cabinet should really be blocked up with taller feet so that the cage clears the table, both ensuring a free flow of air and preventing transmission of acoustic noise.

Inputs and outputs are listed on the brochures and the operating instructions that accompany the machines. However, these are the first victims in any spring-cleaning battle, and many an owner has nothing but the results of his experiments to go on. To make matters worse, some of the literature gives inadequate or misleading information. Sony are better than most at helping the user, but even they fall short of their own high standards now and again. An example is the tendency to state: 'Microphone impedance—low' and 'Auxiliary impedance—high', when these terms are as relative as a fisherman's idea of length.

The *TC250* and *TC250A* are designed to be used with a 600 ohm microphone. That may be low compared with a crystal job or a dynamic mike with an inbuilt step-up transformer, but in my language, 30 ohms or so is low, and the usual run of 30 ohm microphones will not do justice to these machines. Sensitivity is somewhere between —63 and —72 dB from zero level, depending on the microphone used, but in general one may expect 200 to 300 μV of signal across 0.5 to 2 K load to produce a fully modulated tape. The *TC250* was normally sold without a microphone, so some width of choice may be expected. If you are looking around for a matching microphone, the inexpensive Sony *F96* isn't bad. This unbalanced dynamic microphone comes in two impedance ranges, 600 ohms and 10 K. The 600 ohm *MTL* provides a -58 dBm signal, enough for either of these machines.

The auxiliary input is a bone of contention, because there have been numerous production changes, just as there have been with oscillator design. At first, the principle was to put the high impedance input into a high level point of the four-stage amplifier, as shown in our original circuit of the *250*. This makes it suitable for some of the high output tuners, but not much help to the chap with an insensitive ceramic cartridge. He has to put his trust in the dubbing socket, if it is fitted, where the input is to the first stage, via a series attenuator. Sensitivity can be around 100 mV and impedance is 100 K. The trouble here is that the ceramic cartridge needs to see a higher impedance and series matching can attenuate the signal too much.

This is not the place to go into matching problems; Anthony Eden has done so admirably in his two articles which appeared in the February and November 1969 issues of this magazine. I may say that those two articles, once I con the Editor into providing me with reprints, will be pinned on my workshop wall. I have never seen the subject more explicitly and authoritatively detailed.



by Peter Bastin

THE 1969 Audio Fair combined itself with the Photo-Cine Fair (and almost with the Dairy Show) which may have been a good idea. Or may not. Only the exhibitors would know about this. Anyway, it certainly resulted in a lot of people, most of them with bags over their shoulders and cameras round their necks, getting embroiled in the nicest possible way with the less-cluttered audiophiles. Personally, I found that the new venue, Olympia, left a lot to be desired. Missing was the friendly din and confusion of the Russell Hotel, missing were the cosy little exhibitors' rooms with bottles of sherry delightfully in evidence, missing was the general air of all-being-here-together. Olympia is a hard, cold battle-ground, punctuated by emergency-doors and iron roof trusses.

About forty-nine out of every fifty visitors were men, which must prove something. And how earnest some of them looked. Dedicated types, *informing* the exhibitors, types in thick glasses looking at simply everything, and others with expensive cameras clicking away at the dolly-birds draped over veteran motor-cars on the photographic stands. Those poor, hard-eyed dolly-birds, baking in photofloods, smiling stonily and incessantly. Japanese jentlemen, Norwegians, the lot. Even Phillip Towell, looking disgustingly healthy in a bright blue suit; publisher Douglas Brown looking and sounding (still) like a prosperous west-country farmer, John Bradley of the Federation of British Tape Recordists and Clubs looking very worried. And to crown it all, the Editor's tie. The less said about that, the better.

The BATR Contest was very disappointing. It was held in the exhibitors' lounge behind totally inadequate screens. The noise from the relaxing exhibitors was quite sufficient to drown the best announcing efforts of Cyril Rex-Hassan and John Bradley and very nearly drowned some of the tapes. It occurred to me, whilst straining to hear the material, that it might be a good idea to dub all the entries on to a master tape, thus ironing out differences in level, excess bass and treble, and low quality. Not every machine is yet built to record to the same characteristic as the next one and replay on a totally different machine can play havoc with quality.

I asked Douglas Brown, who is a committee member of the Contest, whether he thought that the standard of entries had improved to any great extent over the last ten years. He thought not, but, on the other hand, he didn't say that it had declined. He felt, however, that there is a great lack of *imaginative* tapes; that the ground is becoming a little too well-trodden. David Kirk raised the question about Rule 5 of the Contest which expressly forbids the use of commercially-produced material. Two of the winning tapes apparently included music from disc or radio. Perhaps the Contest organisers can answer this one?

INCONSISTENCIES IN advertising. The Philips *Pro 12* machine is advertised in a current catalogue as 'a home studio stereo tape recorder'. In an American magazine, it is advertised as a 'professional tape recorder'. Which is it? There is a television commercial for petrol which shows two cars, location 'Europe'. One stops and the wolves move in; the other speeds happily by with the advertiser's petrol in its tank. In a German magazine, the story line is the same but the location is Sweden. I suppose that the idea is to keep the locale as far away from home territory as possible! In a German catalogue of audio equipment (recorders, record decks, amplifiers, microphones, speakers, etc.) there are appealing advertisements for hair-rollers, shavers and (excusably) cameras. This rather reminds me of the radio shops which suddenly spout washing machines and fridges.

A TAPE RECORDING enthusiast of great vintage once related to me the perils of gathering material for radio in the days of Daventry and Alvar Lidell. It seems that on one occasion, he suffered the indignity of forcible removal from the Savoy Hotel. A piece of fried-bread shot off his plate at breakfast time, hurtled at astronomic speed across the room, registering a direct hit on the back end of a Pekinese, causing it Grievous Harm. The Pekinese belonged to the wife of the Mongolian Ambassador. On another occasion, he was interviewing a society woman and getting along quite well. Suddenly she fell down. The doctor said it wasn't really surprising: she was chock-full of potato-crisps. Then there was the time he was talking to the First Lord of the Admiralty. His Lordship suddenly clouted our friend over the head with his telescope and had a terrible fit. It is instances like this upon which our noble art is founded and might well explain why so many recordists take to meths or become Quantity Surveyors.

STEREO REVIEW, 144 pages of which costs 60 cents (5s.) in the USA, contains one or two interesting items of equipment. There is the eight-track stereo cartridge player, manufactured by Lear Jet and costing about £25. Ampex have produced their smallest cassette recorder, measuring 170 x 100 x 50 mm, with all the usual additions, such as battery indicator, microphone and so on. About £40.

There is a large section devoted to record review and I must say that I like the précis method of presenting the records. Over the title of each review is Recording of Special Merit or nothing at all. Underneath the title is a brief summary of the record on the lines of Performance: bloated. Recording: good. Stereo quality: fair. This is splendid, for if the summary sounds pretty grotty, you don't read any further, saving a lot of time. I recommend this method to Britain's ponderous and frequently irritatingly-verbose record reviewers.

LOOKING THROUGH a recent *Tape Recorder* it was interesting to note the prices one can pay for an 18 cm reel of long-play tape (1800m feet or whatever it is in metre-things). Three firms offered it at 13s. and others at 27s., 28s 6d., 29s. 6d. 36s., 39s. and 41s. 6d. The same proprietary tape costing 51s. 7d. was offered variously by three firms at 36s., 39s. and 41s. 6d. Now I don't object to this. For too long we have had to put up with price-rigging and with the same motor-cars disguised by different radiators. Let's have competition and jolly good luck to firms like KJ Enterprises and others who can knock lumps off the so-called 'recommended prices'. In this context, one wonders about the vast profits made between manufacturers, wholesalers and dealers when a retailer can sell *Series 7* Ferrographs £20 below price and £223 Revox recorders at £201. My dealer complains bitterly that he cannot possibly afford to give me more than 5% discount. The cases above represent discounts of 10%. Since the benevolent retailer still has to eat, we might assume that his gross profit is around 15%. The manufacturer has to make a profit. This brings the cost price of a £200 recorder to just over £100 by the time tax has been added—deducted.

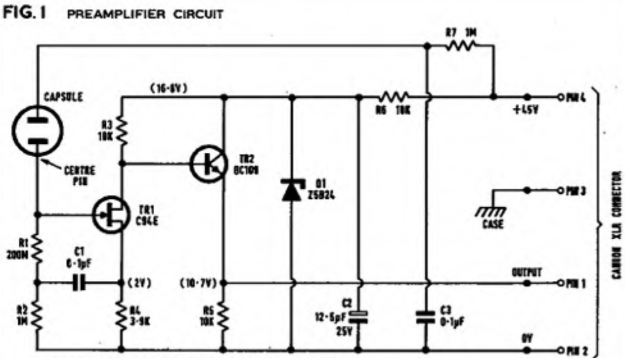
COMMENT FROM teenage son: 'I shall begin to feel *really* old when the Beatles start dying off'.

A HYPERCARDIOID CAPACITOR MICROPHONE

Part one/construction

BY TREVOR ATTEWELL

FIG. 1 PREAMPLIFIER CIRCUIT



FIGURES IN BRACKETS SHOW DC VOLTAGES WITH RESPECT TO PIN 2, MEASURED WITH A METER OF 20K/V SENSITIVITY

FIG. 2 MAIN ASSEMBLY

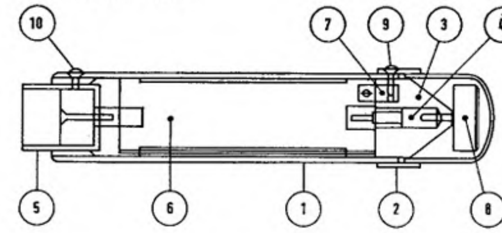


FIG. 5

FIG. 3

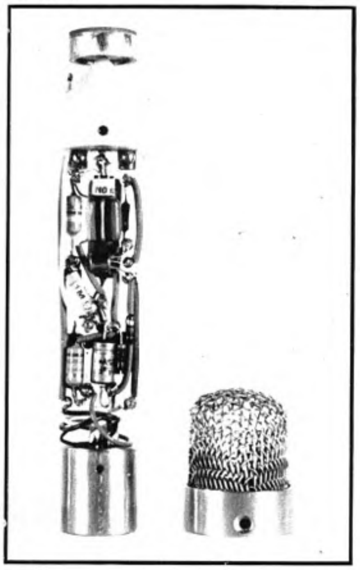
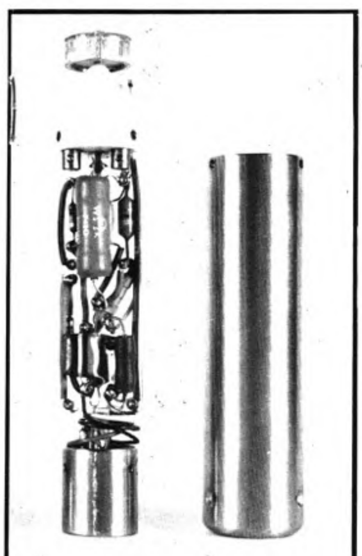


FIG. 4



A HYPERCARDIOID CAPACITOR MICROPHONE

THERE is little doubt that the capacitor microphone is capable of a superb all-round performance superior to all but the very best dynamic or ribbon types. Unfortunately the currently available commercial range, designed mainly for professional use, is expensive enough to be out of the reach of all but the wealthier amateurs. Readers may recall that a variable-pattern capacitor microphone for home construction was described in the September and October 1963 issues of *Hi-Fi News*. This was an excellent design and the author has a capsule of the type described, kindly given him by G. J. Cooper, doing valiant service. However, the making of this capsule required the use of the kind of toolroom facilities (and skills!) which are seldom available to most of us. In addition, the preamplifier was a valve type, with its attendant disadvantages, since suitable transistors were not then available.

When more microphones were needed, therefore, it was decided to base them, if possible, on commercial capsules, using a construction which would involve nothing more difficult than simple lathe work to nominal tolerances. The preamplifier would be transistorised, and the overall size would be small. Clearly, the capsule would have to form the basis of the design, and it would need to be reasonably priced. It was G.J.C. who first suggested trying STC capsules. These were developed for use in their *4126* microphones, and were used subsequently in the *4136*. Their design, construction and general properties have been described elsewhere.[1], [2], [3]. The *4136* microphone is finding increasing acceptance in professional studios, where it is liked not only for its excellent acoustic properties, but also because it is unobtrusive in front of cameras and employs a rational system of connections and power supplies enabling its use on booms wired for other microphones.

STC were therefore approached for a pair of capsules for development purposes, and they have now agreed, very generously, to make these available to *Tape Recorder* readers. Since this is not an item which is generally sold separately, no packing is available for it, and it will be appreciated that special packing would be costly to design and make. Intending purchasers are asked, therefore, to make arrangements to collect capsules, or to get someone to do this for them. Details of price and address are given under the parts list.

The remainder of the design falls into two parts, namely, the pre-amplifier circuit and the general method of construction. The circuit is considered first, since it partly determines the size of housing required. The circuit design must take a number of considerations into account.

First, the input impedance of the pre-amplifier must be very high. The capsule capacitance is of the order of 30 pF, so that the following stage must have an input impedance of 150 M if the frequency response is to be not more than 3 dB down at 20 Hz. However, it can be shown[4] that a much higher order of impedance than this is desirable in order to improve the noise performance, which it does by shifting the bulk of the Johnson noise to sub-audio frequencies, so that it is lost in normal inter-stage couplings.

This leads us, naturally, to consider the required noise performance itself. The capsule sensitivity is approximately 1 mV per dyne/cm^2, so that its output will be only of the order of 20 μV in, say, a concert hall during a performance pause, when musicians and audience are quite still and the sound level is about 40 dB unweighted. Taking this ambient noise level as an arbitrary reference of 'silence' (and you'd be surprised how hard it is to get a sound meter below this figure) the microphone noise should be at least 6 dB less. This gives a rough estimate of 10 μV as the maximum noise level referred to the capsule. To achieve even this fairly modest standard requires the greatest care. A very low-noise FET must be used, its operating conditions carefully chosen, and the following stage must also include a low-noise device working under optimum conditions. It has also been found that leakage in the insulator supporting the capsule and the FET must be held to a very low order, since this is an important source of noise. The insulation resistance required is of the order of 10^{14} ohms.

Finally, the output impedance of the preamplifier must be low, and it must be capable of driving the capacitance of the longest length of cable which may be needed between microphone and recorder. Ideally, this capability should extend to the highest audio frequencies at peak signal level, but some relaxation is reasonable on the grounds that this combination occurs only rarely. For this design it was assumed that up to 90 m (300 feet) of cable might be used, and the total capacitance of the signal core to earth in this length of the specified cable was measured as 16,050 pF. To ensure that noise generators in the main amplifier will not contribute significantly to the total noise, an amplification of at least 10 dB is needed in the preamplifier—this assumes that the main amplifier is not appreciably more noisy than the preamplifier. The output from the latter can therefore be as high as 1 V RMS. for a peak capability of 125 dB up to 20 kHz, necessitating a peak current output of 1.9 mA.

It was found that this conflicted with the circuit values required to optimise the noise performance. In practice, therefore, the output capability has been limited to acoustic levels up to about 117 dB at 20 kHz, rising to 120 dB at 14 kHz. This has proved more than adequate. It is worth noting that this limit is imposed by the available current output and not by the output impedance, which is about 50 ohms.

Before finalising the circuit a number of references were examined, [2],[4], [5], [6], [7], [8] and one or two arrangements were tested. The best results were obtained from a low-noise FET in a common source amplifier, followed by a *BC109* emitter-follower output stage. A 200 M input resistor is boot-strapped from the FET source to give an effective input impedance of over 1000 M. The complete circuit is shown in **fig. 1**. It should be noted that the zener diode (D1) is not used as a stabiliser—it is there to prevent damage to either of the transistors should one of several possible (though unlikely) circuit faults develop.

The mechanical construction of the complete microphone can be seen in **fig. 2**, the general assembly drawing, and in the photographs **figs. 3, 4** and **5**. The capsule **(8)** is supported on a conical insulator **(3)** by means of an insert **(4)** and is surrounded by a gauze shield **(2)**. This arrangement allows the sound access to the rear of the capsule. The shield terminates at its lower end in a ring through which it is secured by screws **(9)** passing through the body **(1)** into inserts **(7)** in the insulator. The circuit board **(6)** is secured at the top to the same inserts **(7)**, and the bottom has a cylindrical projection fixed to the connector **(5)**. The latter is secured to the body by three screws **(10)**. Drawings for all these parts are given in **figs. 6, 7** and **8**, but some additional notes on them and their assembly may be helpful.

The body is faced off at one end, the length being left about ⅛ inch oversize. A short length of ⅞ inch outer diameter tube is turned down to be an easy sliding fit in the body, and chamfered at the upper end. It is trimmed to length so that about ⅛ inch projects from the body when the chamfered end is correctly located, and the two tubes are then hard-soldered. The body can now be finished to length, cutting the radius with a shaped tool—or it can be finished square if preferred. The connector fixing holes should be drilled as accurately as possible to avoid the nuisance of a 'one way only' fit, but the upper holes for the shield should be left for the time being.

The ring **(2)** is made from a short length of 1⅛ inch outer diameter tube, machining the inside first so that it slides easily on the body. (Precision workers: allow 0.001 inch for plating!) Again, drill the holes as accurately as possible, preferably before machining, supporting the work on a mandrel. To shape the gauze it is necessary to make a simple wooden jig, as shown in **fig. 10**. To the mating faces of blocks **A** and **B** (which can be made up of two or more thicknesses if need be), glue or screw coverings of a smooth, thin material to act as low-friction surfaces. Off-cuts of Formica (or equivalent) are good, or smooth metal can be used. Screw blocks **A** and **B** together, using either wood or metal screws,

(continued overleaf)

but making sure that these fit the blocks so that the latter are positively located. Next, drill a pilot hole vertically through the middles of **A** and **B**. Separate them, and open up the pilot holes to the specified sizes. The die (**C**) is made from wooden dowel; you may find a broomstick just the right size. Now take a piece of 10 mesh by 25 SWG brass gauze having 36 wires in each direction of the weave, and carefully snip out eight of the wires as shown in **fig. 11**. Place the gauze on block **B** with its centre over the centre of the hole, and oil it well. Place the two spacers (**D**) alongside the gauze to prevent it being trapped too tightly between **A** and **B**, and screw **A** into place. Oil **C** and push it firmly through **A** until it emerges from the other side of **B**. No great force should be used; if you can't push it through by hand-pressure alone then either the gauze is locked between the blocks, or the exit hole is too small. Force will merely fracture the gauze.

The gauze is now trimmed to length by cutting round it with side cutters, the points of which can enter the slot in **C** provided for the purpose. Make certain that no wires are dislodged in the process; a temporary binding of wire may be found helpful. Do not try to push the ring on at this stage, as it may force some wires out of place. After trimming, the gauze can be removed from the die, and the ring slid over it. To locate the ring while it is soldered to the gauze, another very simple jig is useful, as shown in **fig. 12**. Soft solder is strong enough for this job.

The top of the shield should be solder-dipped to give it improved rigidity. The solder may be melted in a tin lid (¼ inch depth of solder) and the gauze dipped first into Baker's Fluid, then into the solder. After leaving it for a few seconds to heat through, the gauze is removed and *quickly* and vigorously flicked to shake surplus solder out of the holes in the mesh. Do watch carefully where and how you do this. The solder bath needs frequent scraping to remove oxide, and it's a good idea to practise on a bit of scrap gauze. Thoroughly wash the gauze to remove flux residues and leave it in a warm place to dry.

The conical insulator is straightforward, and the only thing to note is that the side hole must be drilled before the taper is turned, otherwise it will have to be jig-drilled. PTFE has been chosen for its outstanding insulating properties, and is strongly recommended. It is probable that Perspex would be a reasonable substitute if care is taken to keep it absolutely clean, and the microphone is stored in a dry place (always a wise precaution). The 8 BA fixing holes are left until final fitting. *When machining PTFE it is important to avoid excessive temperature rise, or toxic vapours may be formed.* Sharp tools and light cuts help, but it is also advisable to keep a trickle of coolant on the cutting edge of the tool.

Item **4** also needs little comment: care has to be taken in machining the final $\frac{1}{16}$ inch diameter, which should be done first, taking lighter cuts as the diameter reduces. The middle 'step' clears the insulator to maximise possible leakage path-lengths.

The cable clamp and rubber entry are removed from the Cannon connector, and the pin assembly is pushed out from the rear after taking out the side screw. The back end is sawn off, and the remainder faced to length, the raised lettering on the body being either turned or filed off. The hole in the insert is drilled and countersunk, and the insert temporarily replaced in the shell.

The cylindrical spacer on the circuit board can be cemented in place with Tensol cement or trichlorethylene. After drilling, the board can be fitted with any suitable commercial pin inserts, or pins can be cut from tinned copper wire. A printed circuit board can be substituted if facilities are available, the only vital point being that the connection between the capsule centre pin and the FET gate must be clear of the board to maintain good insulation. The circuit layout is shown in **fig. 9** and the photographs, **figs. 4** and **5**. The layout is not at all critical as long as leads in the input region are kept short. The FET gate must go directly to the capsule centre pin via the insert.

Final fitting of parts can be carried out as

FIG. 6 BODY AND SHIELD DETAIL

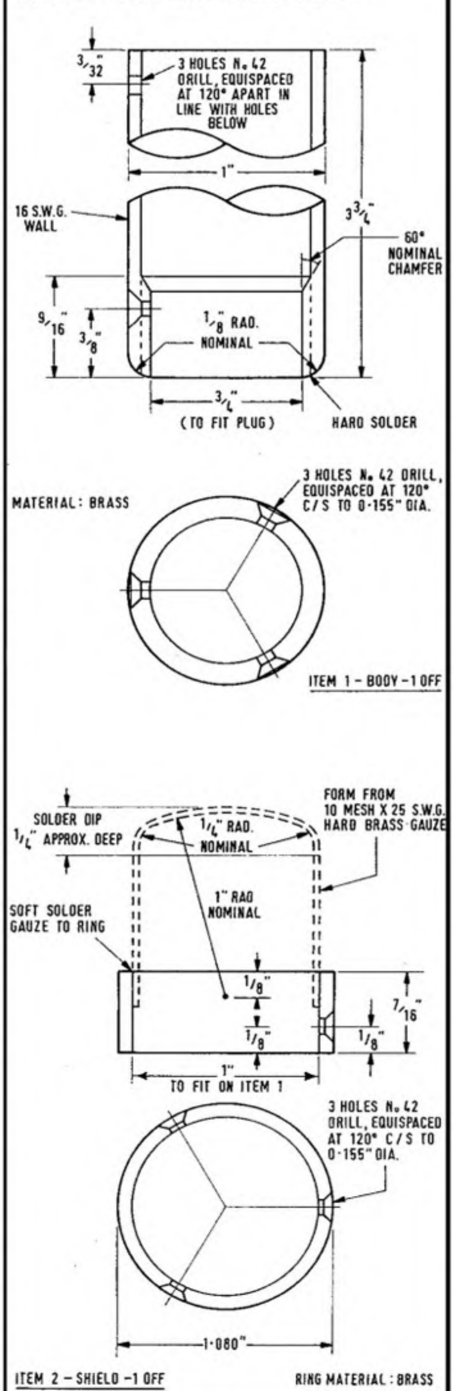
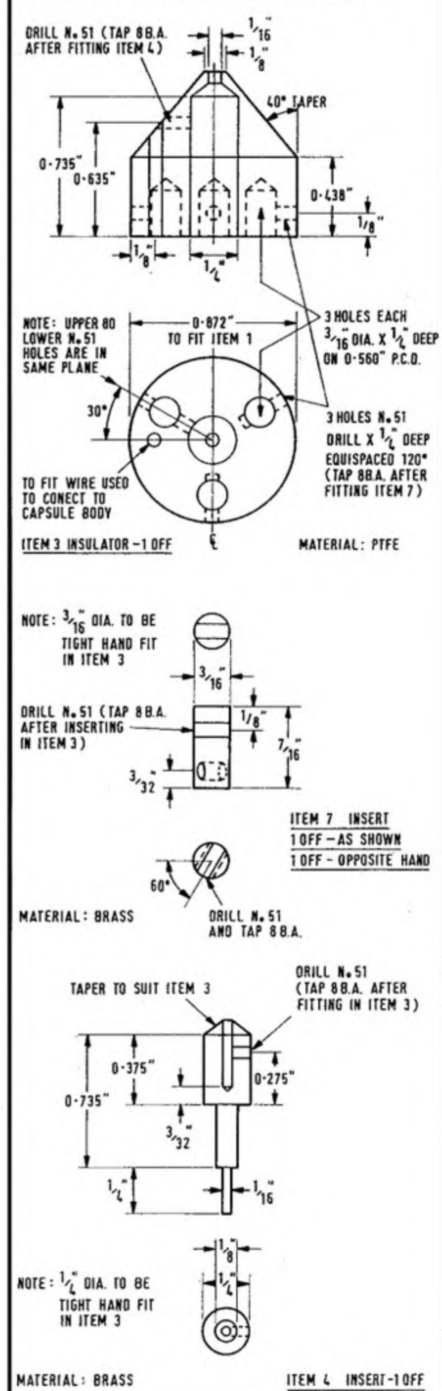


FIG. 7 INSULATOR AND INSERT DETAIL



follows: First, the shield is located over the body in its correct position. The upper fixing holes in the body are then drilled, using the shield holes as jigs. With the shield removed, the insulator is set in position, ensuring that the inserts are pushed well home with the circuit board holes correctly aligned. The three holes in the insulator and inserts are drilled, using the body as a jig. Next, the body, insulator, shield and circuit board are assembled, and the connector offered into position. The circuit board spacer is marked through the hole in the connector, and the connector fixing holes are marked through those in the body. The connector is removed, its insert taken out, and the three holes drilled and tapped. The board spacer is also drilled and tapped. Incidentally, the reason for using the spacer is not to support the board, but merely to allow the whole assembly, connector included, to be withdrawn as one unit, and it may be omitted at the expense of a slightly more fiddling assembly.

If a dividing head is available, all the holes can be accurately drilled in each item as it is made, and the jigging procedure described above can be dispensed with.

With the metalwork complete, the parts can be polished (this is worth doing very thoroughly) and sent for plating, along with the screws. Satin chrome is a common and practical choice, but this is a matter of personal preference.

The final assembly is simple. All components except R1 and Tr1 are fitted to the circuit board, which is then fitted to the insulator. R1 and Tr1 are added, followed by the connector, and the assembly slid into the body. The connector is secured, then the capsule is fitted, making sure that the centre pin is gently but firmly held by the grub screw. The flying lead is soldered to the wire passing through the conical insulator. When making this joint, take great care not to touch the capsule with the iron or to allow vapour from the operation to flow over it—laying the body on its side helps here. Finally, the shield is carefully lowered into place and secured. The completed microphone is shown in **fig. 3**.

A word of warning is necessary regarding the installation of the FET. It is possible to break down the gate insulation of these devices by the static charges which can sometimes build up on your body, or by capacitive currents from certain types of soldering iron, particularly those which are not earthed. The safe way to avoid this is to pick up the device carefully by the body and wrap a piece of thin tinned copper wire around the lead-out wires so as to short-circuit them all together as near the body as possible. After soldering the FET into the circuit, the wire is removed. For similar reasons, do not touch the capsule centre pin while installing it, and tighten the grub screw with a screwdriver the shank of which is temporarily connected by a loose lead to the O V line (Pin 2 of the connector).

The power supply is straightforward and can, with advantage, be nothing more complicated than a battery capable of supplying about 2 mA, e.g. five Ever-Ready *PP3* cells. If mains operation is preferred, a circuit such as that shown in **fig. 13** is suitable. No construction is given, since this will depend on individual preference; there is nothing critical about it. Care with earthing is an obvious requirement, and a single-point earth at the recorder input is advisable. Good screening is also needed for the signal lead where it passes through the power supply on its way from the microphone cable to the recorder signal input lead. In some cases it may be possible to extract a suitable supply from the tape recorder, but this should be very well decoupled—considerable extra smoothing is almost certain to be needed.

The total cost of the microphone as described is about £12 10s, but it is possible to reduce this to not much more than half by making certain economies. One is to omit the rather expensive Cannon connectors and use either cheaper ones of a different type, or even none at all, bringing out a lead directly from the microphone. This can be rather inconvenient in use, since microphone and cable cannot be separated, and may require modifications to mountings, etc. If this is done, the connector in the base of the microphone should be replaced by a cable gland.

Next, the plating can be dispensed with, and the brass case either polished (which doesn't look at all bad in an olde-worlde sort of way) or painted. Finally, you can cross your fingers and sling out the zener diode D1! It is also possible to buy much cheaper components than those specified, but this is almost certain to worsen the noise performance to a completely unpredictable extent, especially in the case of the FET, and no information on alternative components is available.

Another query likely to arise is the necessity for the particular type of wire gauze specified for the shield. This has been carefully chosen as an effective compromise between conflicting factors. On the one hand, the mesh should be open, with a thin wire gauge, in order to give good acoustic properties and to make the forming process easy. On the other hand, a closer mesh, with a thicker wire gauge, gives better electrical screening with improved mechanical rigidity. The gauze used was selected on both theoretical and experimental grounds, and no significant change should be made without due consideration of the possible difficulties.

Having built the microphone, what results can be expected? **Fig. 14**, reproduced by courtesy of STC, shows typical frequency response curves, traced from a B & K analyser under anechoic conditions. Clearly, this response is adequately flat for all practical purposes. Even the small irregularities at about 10 kHz can be smoothed out, either by mechanical additions to the microphone, or

(*continued overleaf*)

FIG. 8 CIRCUIT BOARD AND CONNECTOR DETAIL

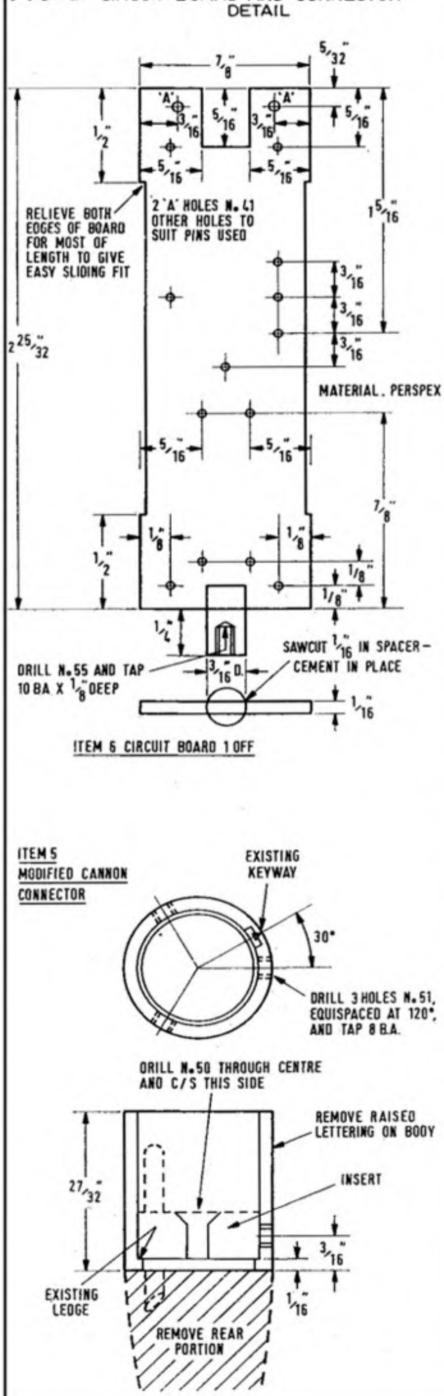
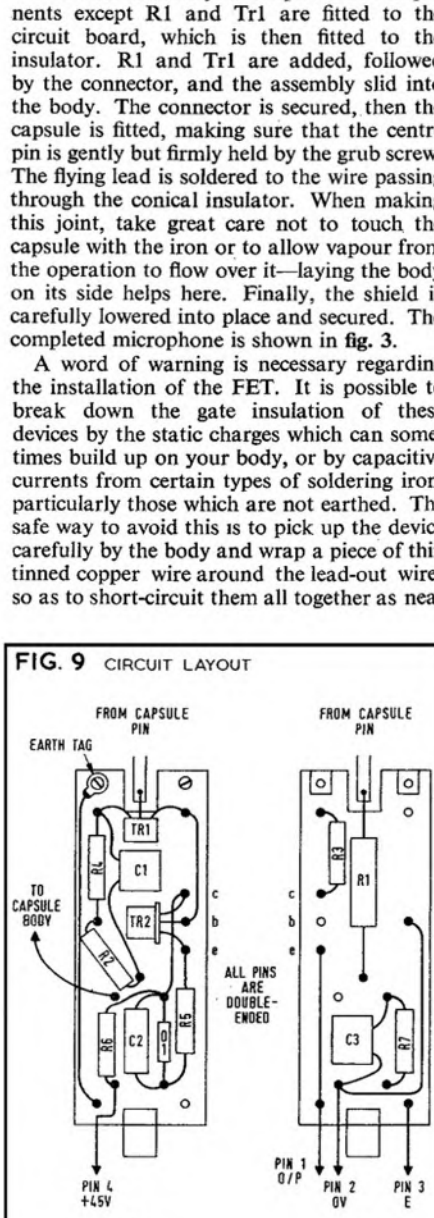


FIG. 9 CIRCUIT LAYOUT



electronically in the following amplifier, but to do either of these modifications would add a good deal of difficulty for the home constructor, and, in any case, these small peaks and troughs are negligible compared with those which occur in ordinary rooms as a result of the formation of standing waves. It will also be noticed that the curves of **fig. 14** are not continued below about 100 Hz—the reason is that anechoic conditions are extremely difficult to attain at these low frequencies, and there are further complications due to source proximity, which gives an (apparently) rising response as the frequency falls. Practical tests in ordinary rooms confirm that the frequency response is sensibly flat at least down to 20 Hz, so there is nothing to worry about. In fact, the mere appearance of these curves is a good indication of the extreme difficulties of this measurement.

Fig. 15 gives the polar diagram, measured at 1 kHz in the open air. The pattern is hypercardioid, having a fairly flat minimum at about 140° on each side of the forward axis. There is a small rear lobe, while the frontal response is slightly sharpened compared with a cardioid. This pattern is very useful for stereo work, where the slight increase in forward directivity improves source location, while the microphone positions are generally such that each has a minimum pointing in the direction of the audience (and the echo from the back of the room). For monophonic work the difference in directivity is scarcely noticeable, and the directional efficiency, defined as the output due to simultaneous sounds from all directions expressed as a fraction of the output from an omni-directional microphone of the same axial sensitivity exposed to the same sounds, is practically identical to that of a cardioid pattern, namely one third.

The 'inherent deafness' of the microphone, defined as the sound level required to give an output equal to the random noise output in the absence of any sound, has been estimated at about 30 dB. Suffice it to say that it was most difficult to find a spot quiet enough to allow a measurement! At these levels the smallest trace of hum pick-up is upsetting, and battery supplies are essential, together with extreme care in shielding and earthing arrangements. Large piles of blankets are also required, even in the middle of the night, to muffle the car and aircraft noises with which we are now constantly assailed. When the capsule was replaced by a mica capacitor it was found that even the capacitor leads were surprisingly microphonic, and, in any case, the answer obtained by this method is not truly representative. The figure of 30 dB has proved adequate in practice—to reduce it further would involve component selection, (which allows the best professional microphones to achieve about 20 dB), but is obviously laborious and costly and would only be appropriate for use in exceedingly quiet studios.

After the measurements, what about the subjective results? Needless to add, these were sampled long before any measurements were attempted, and all the characteristics normally associated with capacitor microphones were apparent—the effortless bass right down to the lowest pedal notes of the organ (naturally the first concern!), the crisp top, with no sign of 'tizz', and the clean, transparent middle range, with voices sounding particularly natural. A stereo pair was found to give excellent image stability.

All test recordings were made using the normal 500 kΩ microphone input of a Revox *736/HS* machine, the available sensitivity, (≃3 mV), being rather more than sufficient — in fact, for most recordings the 50 mV 'radio' input would be perfectly satisfactory. It should be noted that any circuits following this microphone should be capable of handling peak signal levels of up to at least 0.5 V referred to the microphone output.

FIG. 11 GAUZE TRIMMING

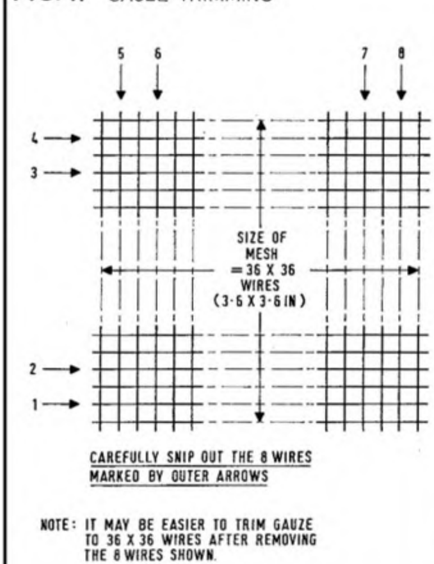


FIG. 12 GAUZE SOLDERING JIG

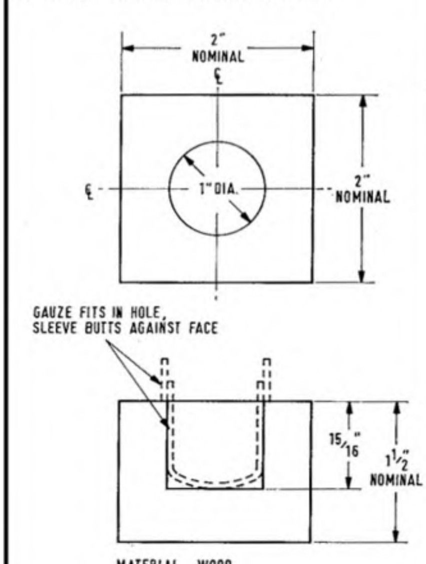


FIG. 10 GAUZE SHAPING JIG

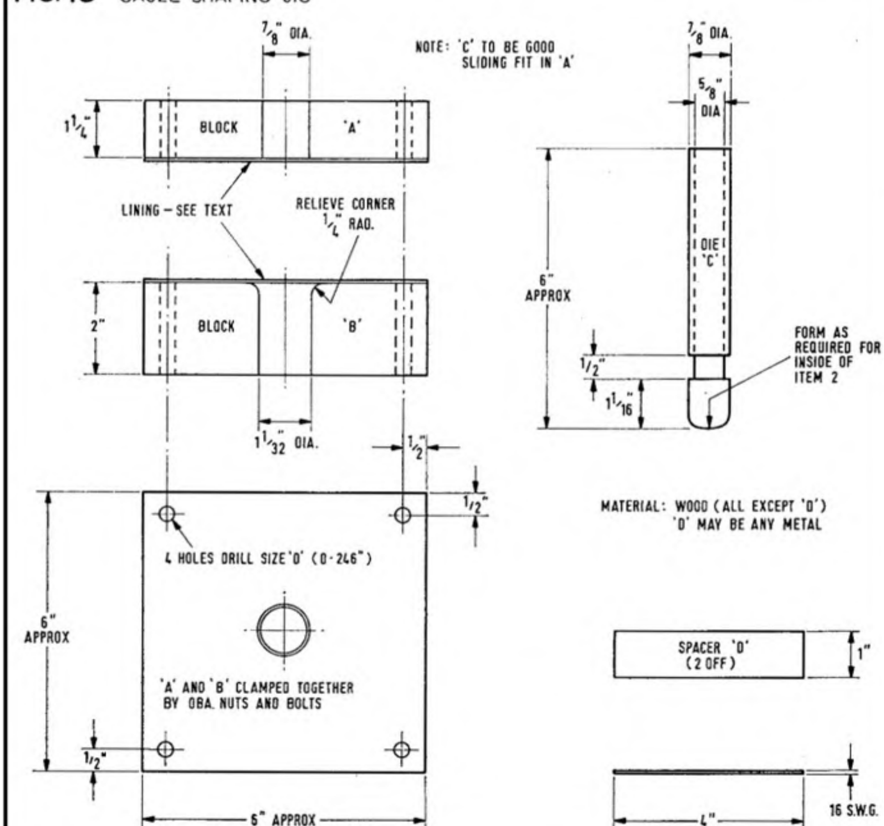


FIG. 13 TYPICAL MAINS POWER SUPPLY

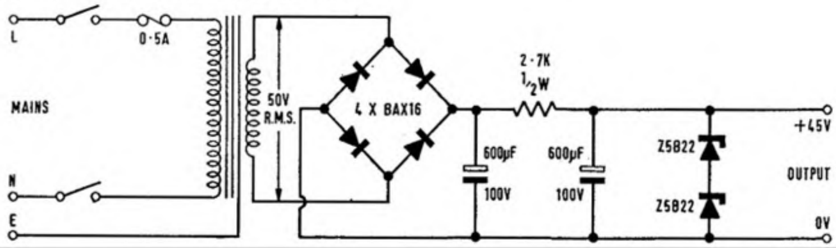


FIG. 14 TYPICAL FREQUENCY RESPONSE

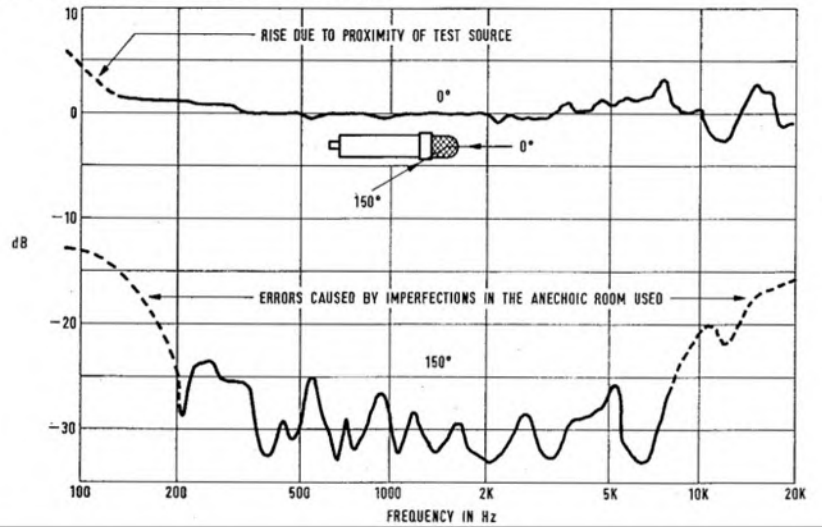
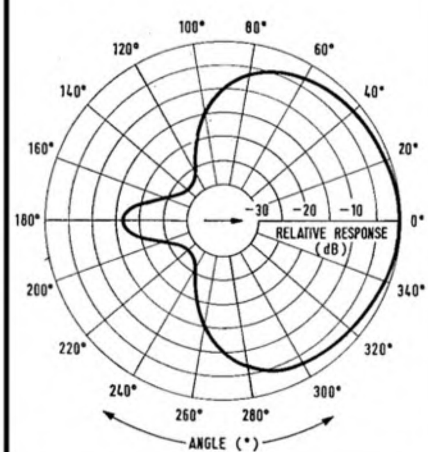


FIG. 15 POLAR DIAGRAM



A second article, to be published next month, deals with some subjective aspects of microphone placement, with particular reference to stereo recording, and includes some ideas on microphone mountings, cable suspensions, and windgags.

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7. *Silicon Epitaxial FET's*—Part 3 FET AC Amplifiers Carl D. Todd Electronics Components March 1966, page 249
8. *Design of Low-Noise Transistor Input Circuits* W. A. Rheinfelder (Iliffe Books Ltd). A general account only.

PARTS LIST

Quantities given are for one microphone. Where appropriate, an arbitrary allowance of approximately one inch has been made for machining.

MATERIAL	QUANTITY
BRASS TUBE	
1" O/D x 16 S.W.G.	5 inches
$1\frac{1}{8}$" O/D x 16 S.W.G.	$1\frac{1}{4}$ inches
$\frac{7}{8}$" O/D x 16 S.W.G.	$1\frac{1}{4}$ inches
BRASS ROD (ROUND)	
$\frac{3}{16}$" dia.	2 inches
$\frac{1}{4}$" dia.	4 inches
PTFE ROD (ROUND)	
$\frac{7}{8}$" dia. $1\frac{1}{2}$ inches (approx. $\frac{1}{2}$ inch for machining)	
PERSPEX ROD (ROUND)	
$\frac{3}{16}$" dia.	1 inch
PERSPEX SHEET—CLEAR	
3" x $\frac{7}{8}$" approx.	1 off
GAUZE—BRASS, HARD	
10 mesh x 25 S.W.G. .. allow	4 inch x 4 inch
SCREWS	
Item 9. 8 B.A. x $\frac{5}{16}$ inch C/S or I/H, steel or brass	3 off
Item 10. 8 B.A. x $\frac{3}{16}$ inch I/H, steel ..	3 off
(For circuit board spacer—10 B.A x $\frac{3}{8}$" inch C/S brass 1 off)	
WOOD, FORMICA etc. (for jigs)—off-cuts only required. See text.	

COMPONENTS

CAPSULE
TYPE *65R-DPOO-742633* (see below).
CONNECTORS
Microphone: CANNON *XLR 4 12 C*
Cable end: CANNON *XLR 4 11 C*
FIELD-EFFECT-TRANSISTOR (Tr1)
Semitron Type *C94E*
HIGH VALUE RESISTOR (R1)
Welwyn Ltd. *Type H11*
Note: The photograph of the prototypes shows a Welwyn *F43D* resistor in this position. This was used experimentally—it is larger and more expensive than the *H11* and gives only a marginal overall noise improvement. The circuit board allows space for either.

GENERAL CIRCUIT COMPONENTS

RESISTORS (except R1) All 5%, high stability, insulated type, commercial rating $\frac{1}{4}$W. Any reputable make.
CAPACITORS
C1 and C3: Mullard P.C. Type.
C2: Mullard sub-min. electrolytic.
CABLE
Radiospares standard 4-way screened.
NOTE: Prices given are subject to change, and should be checked when ordering.

SPECIALIST SUPPLIERS

PTFE
G. H. Bloore Ltd., 480 Honeypot Lane, Stanmore, Middlesex. ($\frac{7}{8}$ inch rod 22s. 9d. per foot. Minimum charge 10s.)
CAPSULE
Please WRITE, in the first instance, to:
Mr. R. H. Fisher,
Standard Telephones and Cables Ltd., West Road, Harlow, Essex. (Price is currently £5 4s.)
CONNECTORS
Electroniques,
Standard Telephones and Cables Ltd., Edinburgh Way, Harlow, Essex.
FET and D1
Semitron Ltd., Cricklade, Wiltshire, through their agents, or direct if in difficulty.
Price approx. *C94E* 25s.; *Z5B24* 3s. 6d.

the synthesis of musical instrument tone

PART FOUR
BY R. M. YOUNGSON

FIG. 40 ELECTRON-COUPLED HARTLEY OSCILLATOR SHOWING CR NETWORK ARRANGED SO AS TO DELAY RATE OF TURN-ON IN ACCORDANCE WITH THE TIME-CONSTANT CR

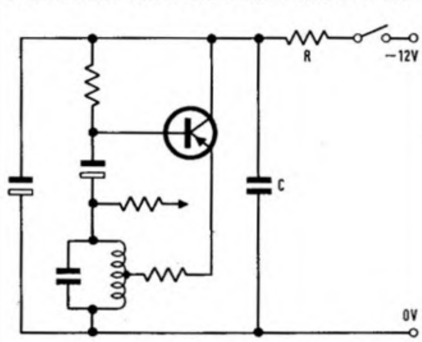


FIG. 41 METHOD OF IMPROVING LINEARITY OF SAWTOOTH OSCILLATOR BY PROVIDING A HIGH CHARGING VOLTAGE

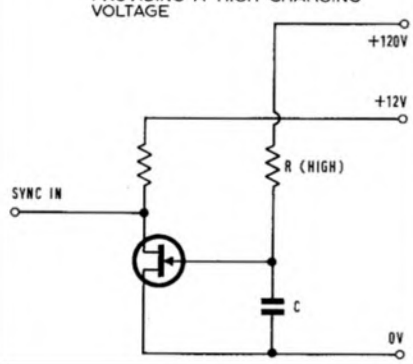


FIG. 42 (a) UNIJUNCTION SAWTOOTH OSCILLATOR OF IMPROVED LINEARITY. THE CAPACITOR CHARGES THROUGH THE TRANSISTOR TR1

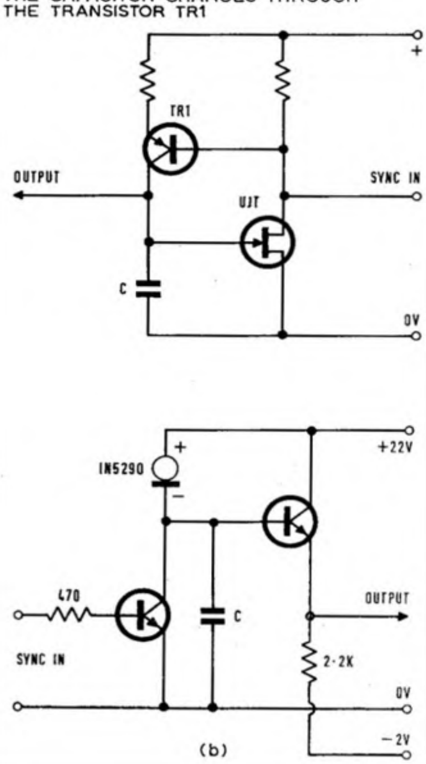


FIG. 43 METHOD OF COUPLING A UNIJUNCTION OSCILLATOR TO A LOAD

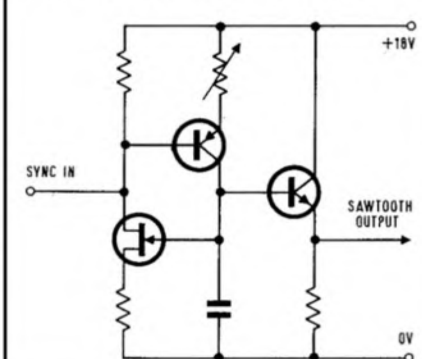
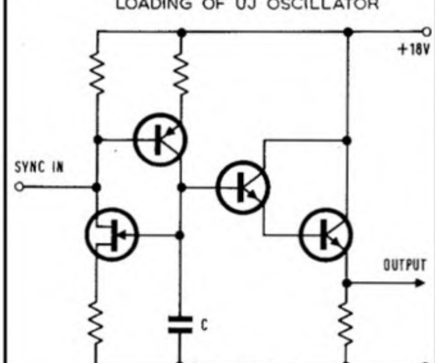


FIG. 44 DARLINGTON PAIR EMITTER-FOLLOWER FOR MINIMAL LOADING OF UJ OSCILLATOR



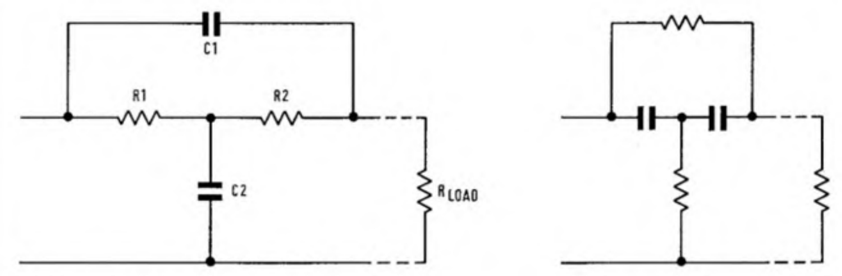
THE usual method of switching the master oscillator is to apply the supply current via the note switches, in conjunction with a shunt RC time-constant for each oscillator as in **fig. 40.** This arrangement permits adjustment of the rate of attack by varying the time taken for the supply voltage to the oscillator to reach the full figure (the common-base Hartley is so insensitive to variations in supply voltage that it will remain in tune with voltage reduced to about 25% of the normal working value).

If, however, we apply the full voltage to the sawtooth oscillator at the instant of switch-on, we run the risk of the latter operating momentarily at its natural, lower, frequency before falling into sync with the master. We cannot get round this difficulty by increasing the time-constant determining the rate of switch-on of the sawtooth oscillator, as this would again alter the frequency of the latter. Probably the easiest solution is simply to omit the time-constant network from the Hartley, provide a common supply line to both oscillators and rely on a variable-rate gating circuit as described in the section on 'attack'.

The simple unijunction synchronised oscillator can produce a very reasonable approximation to a linear sawtooth, certainly much better than that given by the blocking oscillators used as tone generators in the past, but, bearing in mind that harmonics as high as the thirtieth may be required for good synthesis, we should try to achieve the best possible linearity compatible with reasonable simplicity. Probably the easiest approach is to make use of the fact that the time taken for a capacitor to charge through a resistor is a function of the applied voltage (CR=time taken in seconds, to charge to 63% *of applied voltage*). Since the charge on the capacitor is an exponential function of time, by making the supply voltage high relative to the triggering voltage of the unijunction we can obtain a considerable improvement in linearity. This method, however, calls for an additional stabilised high voltage supply. The triggering voltage of the unijunction is determined by the interbase voltage and the intrinsic stand-off ratio, so the supply voltage to the device itself should be kept reasonably low but need not necessarily be stabilised (**fig. 41**).

Another approach to linearisation is to use the high output impedance of a transistor in the common base mode to achieve 'constant' charging current. The method is shown in **fig. 42 (a).** Even simpler is to employ one of the new 'constant current' diodes as shown in **fig. 42 (b).** *(continued overleaf)*

FIG. 47 BRIDGED – T FILTERS



(a) LOW – PASS (b) HIGH – PASS

FIG. 48 (a) PASSIVE TWIN – T RESPONSE

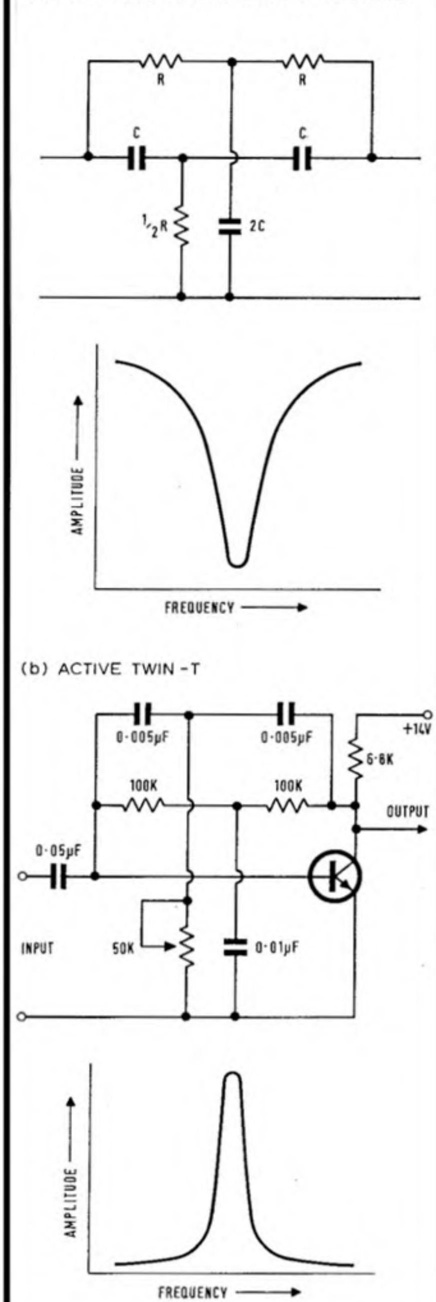


Table 4

Capacitive and inductive reactances. For capacitors use frequency column on the left. For inductors use that on the right.

CAPACITANCE

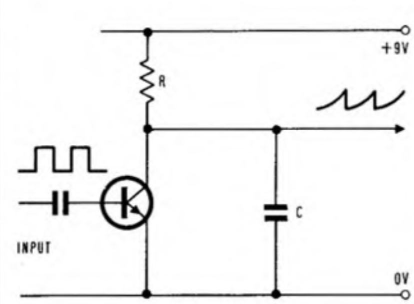
μF	2.5	1.0	0.5	0.25	0.1	0.05	0.025	0.01	.005	0.0025	0.001	
Hz 30	2K	5K	10K	20K	50K	100K	200K	500K	1 meg	2 meg	5 meg	30 kHz
100	600	1.6K	3.2K	6K	16K	32K	60K	160K	320K	600K	1.6 meg	10k
300	200	500	1K	2K	5K	10K	20K	50K	100K	200K	500K	3k
1,000	60	160	320	600	1.6K	3.2K	6K	16K	32K	60K	160K	1k
3,000	20	50	100	200	500	1K	2K	5K	10K	20K	50K	300 Hz
10,000	6	16	32	60	160	320	600	1.6K	3.2K	6K	16K	100
30,000	2	5	10	20	50	100	200	500	1K	2K	5K	30
	10mH	26mH	55mH	100 mH	260 mH	550 mH	1H	2.6H	5.5H	10H	2.6H	

INDUCTANCE

Synchronisation of unijunction sawtooth oscillators can be effected either by a positive-going pulse at the emitter or by a negative-going pulse at base two. Since the sawtooth output can be taken only from the emitter, it is best to apply the synchronising signal to base two. This means that we must either use an *n-p-n* transistor for the Hartley or turn it 'upside-down'. Note that the amplitude of the sawtooth is reduced by the amount of the amplitude of the synchronising signal so the latter should be kept reasonably small. If you wish to attenuate it, use a diode clipper or a coupling capacitor of low value.

Any load on the emitter of a unijunction must affect the frequency of oscillation and should therefore be as high and as constant as possible. A satisfactory solution to this difficulty is to connect the emitter directly to the base of an *n-p-n* emitter-follower stage as in **fig. 43.** The charging capacitor is now shunted by a resistance equal to R_L times the gain of the transistor and, to minimise the effect on frequency, R_L must be made large. In fact, it must be large enough for the product to exceed the value of the charging resistor by a factor which is greater than the triggering voltage, otherwise the oscillator will not function. You must therefore select transistors

FIG. 45 INTEGRATOR CIRCUIT FOR SQUARE TO SAWTOOTH CONVERSION. C MUST BE CHOSEN SO THAT RC IS EQUAL TO SEVERAL TIMES THE PERIOD OF THE INPUT FREQUENCY



of high H_{fe} and use an appropriately high value of R_L. A useful alternative is to employ a 'Darlington pair' as in **fig. 44.** With this arrangement, the gain is roughly equal to the product of the gains of the two transistors and thus a very high input resistance is achieved.

You should adjust the free-running frequency of the unijunction oscillator so that it is just below the desired tone frequency. The negative-going synchronising signal on base two will then reduce the peak point so that the rising voltage on the emitter will drive the device into conduction at the right moment.

As an alternative to synchronised sawtooth oscillators, passive devices for conversion of sine-waves can be used. These include leaky rectifiers, diode squarers, frequency multipliers and various clamp circuits. None of these will provide a sufficient range of harmonics for our purposes. *(continued overleaf)*

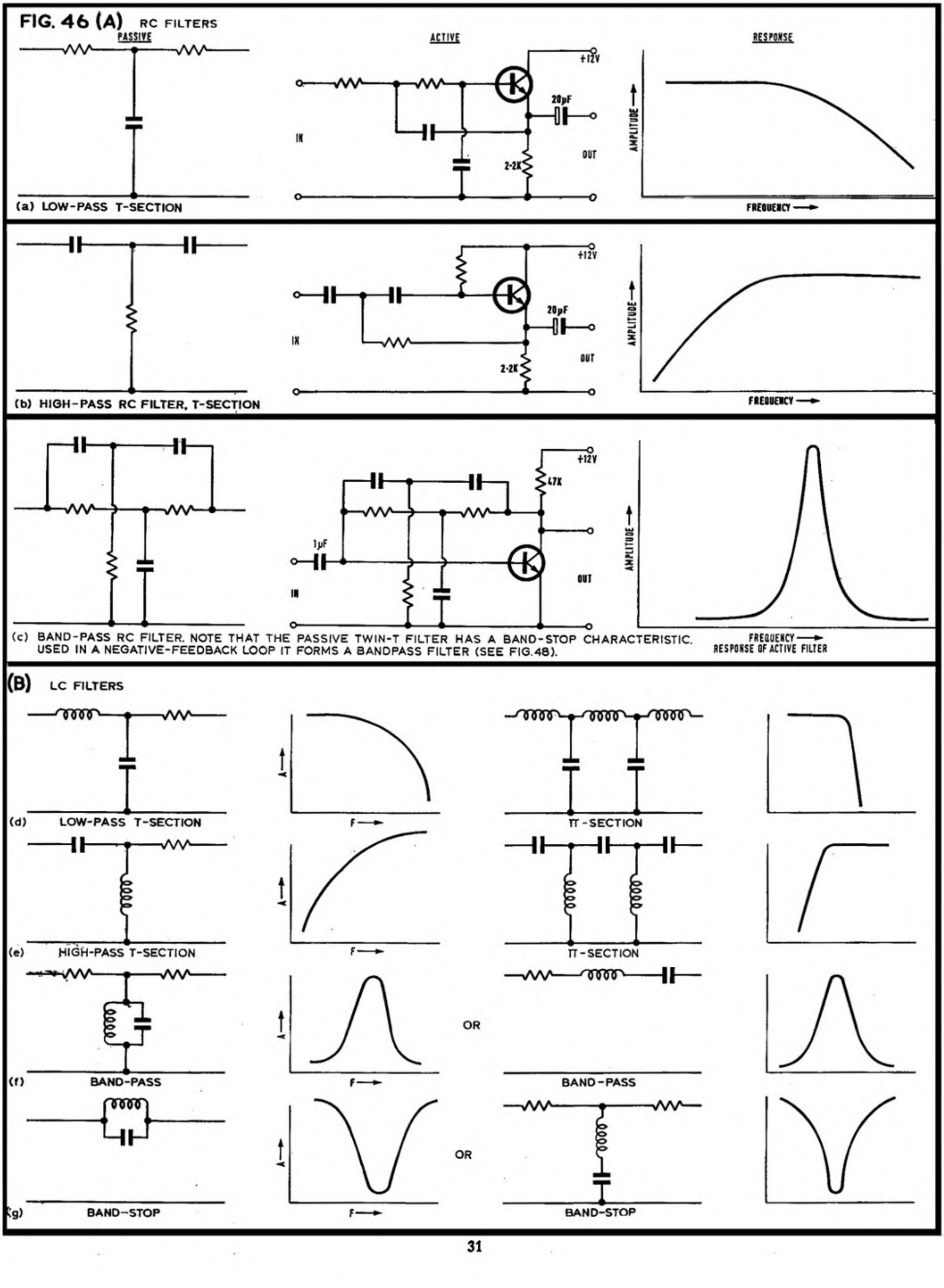


FIG. 46 (A) RC FILTERS
PASSIVE
ACTIVE
RESPONSE
+12V
20µF
IN
OUT
2·2K
AMPLITUDE
FREQUENCY
(a) LOW-PASS T-SECTION
(b) HIGH-PASS RC FILTER, T-SECTION
47K
1µF
(c) BAND-PASS RC FILTER. NOTE THAT THE PASSIVE TWIN-T FILTER HAS A BAND-STOP CHARACTERISTIC.
USED IN A NEGATIVE-FEEDBACK LOOP IT FORMS A BANDPASS FILTER (SEE FIG.48).
FREQUENCY
RESPONSE OF ACTIVE FILTER
(B) LC FILTERS
A
F
(d) LOW-PASS T-SECTION
π-SECTION
(e) HIGH-PASS T-SECTION
π-SECTION
OR
(f) BAND-PASS
BAND-PASS
(g) BAND-STOP
BAND-STOP

Another active device worth mentioning is the square-wave to sawtooth integrator circuit of **fig. 45.** With a negative, or with no signal, at the base, the transistor is cut off and the emitter is at the full supply voltage. Capacitor C therefore charges through R_L and the voltage at the output rises. This continues until the input signal swings positive, at which point the transistor is turned hard on and C discharges through it. For a reasonably good sawtooth output a good square wave input is needed and the time constant CR_L must be several times larger than the period of the input signal. Linearity can be improved in much the same ways as mentioned for the unijunction relaxation oscillator. The integrator has the advantage of giving no output with no input signal.

So much for sawtooth generators. Now we must consider how the sawtooth waveform is modified to produce the desired tone colours.

The three basic passive filters, low-pass, high-pass and resonant, may be used individually or in combination to provide a considerable degree of control. The elements, with their effect on the waveform in terms of frequency against amplitude, are shown in **fig. 46.** In all such filters the rate of change of attenuation with frequency is increased by increasing the number of sections and in the case of the resonant filters the bandwidth reduces and the gain increases in Q. Q can be reduced by shunting resonant circuits with resistance and increased by using inductors of maximal inductance and minimal resistance.

Table 4, which gives capacitative and inductive reactances, and the resonance nomogram in **Table 2,** will enable you to determine the effect of RC filters and find appropriate values for resonant filters at any desired frequency. Ensure that the terminating impedance is high enough in relation to the reactances of the filter elements. It is excellent practice to terminate filters in an emitter-follower stage.

Active filters, using the same elements in negative feedback loops around a stage of amplification can give greater flexibility and range of control. Some of these are shown in **fig. 46.** Check that you are clear about the difference between a filter feeding a negative feedback amplifier and a filter in the feedback loop.

The bridged-T circuits of **fig. 47 (a)** and **(b)** and the combination of a low-pass and a high-pass filter into the twin-T (band-pass) circuit of **fig. 48** are especially useful. The twin T network is not, so far, as much used in tone-forming circuits as are LC circuits, but it is often found as a feedback element in oscillators, and, as already shown, can be usefully employed in musical instruments. The bridged networks can, of course, also be used in active, negative-feedback tone circuits.

Harmonic analysis of musical tones is done by means of band-pass filters having a band-width narrow enough to exclude all but the harmonic under examination. If the filters are tuned to the fundamental, and then to frequencies equal to whole number multiples of the fundamental, the relative amplitudes of the various harmonics can be determined. The spectrum can then be scanned for enharmonic partials. The analysis is repeated for a range of fundamentals and the formant or formants checked. Such work is unlikely to be undertaken except by the most enthusiastic amateur and a good deal must be taken on trust from published results.

Wave forms are also susceptible to analysis, within the limits of the delicacy and accuracy of the recording process, and they also provide a useful starting-point for the development of tone-forming circuits, since direct comparison can be made with oscilloscope tracings. The basis of procedure, however, is a knowledge of the relative amplitude of the various partials and the selection and adjustment of filters to give the correct frequency/amplitude response. This is by no means the most difficult parameter to get right and there is no reason why steady tone synthesis should not be extremely satisfactory. In the last analysis the results must involve aesthetic judgements and there will always be an element of the empirical in filter design. It is salutary to remember that, in aesthetic terms, the tone quality of different individual instruments of the same species (or even of the same instrument played by different people) can vary within wide limits. This is especially true of the bowed string instruments, in which the range of differences in tone quality (variations in the quality of the player apart) is legendary.

To be continued

VTR CIRCUITRY PART 5

BY HENRY MAXWELL

AFTER our digression, back to work with a vengeance, for this month we shall be taking a look at a part of the video tape recorder that differs greatly from the audio recorder: the head amplifier.

In ordinary sound recording, the constant-current technique is employed. Recording heads have a very low resistance winding and their inductance is kept as low as possible. Where the recording head performs only this function, inductance can be as low as 5 mH and, in practical cases, may go up to 100 mH or so. Even when compromise has demanded the use of a combined record/replay head, the inductance of this device will be kept down to a Henry or less.

Despite this reduction of inductance, the head winding must, by its nature, have a frequency-dependent effect. The physical nature of its windings must also impose a limit on the current they can carry. There is, therefore, an upper limit of recording current. (In fact, this upper limit has to be defined earlier than the danger line, because distortion is the first problem we would meet—but that is quite another story.) The recording current will depend on the inductance of the recording head. For audio equipment, a head power of about 1 mW would be typical. This is in addition to the HF bias power, which can be as great as 200 mW at the recording head.

Because of the frequency-dependent nature of an audio head, a series resistor is generally fitted. The recording current flows through this resistor and, if its value is large compared with the head impedance, the current will be determined by the resistor and not the head. Constant-current recording is the result. The head impedance rises with frequency, and with a constant voltage signal to the head, as it would be without the series resistor, the head current would fall with increasing frequency.

The FM system can be used to record any frequency from about 20% of the carrier limit down to zero, (DC). Although tape speed still defines the upper limit, the extension in practice can still encompass all that we need for TV reproduction, where the signal itself has certain bandwidth limitations imposed by the medium.

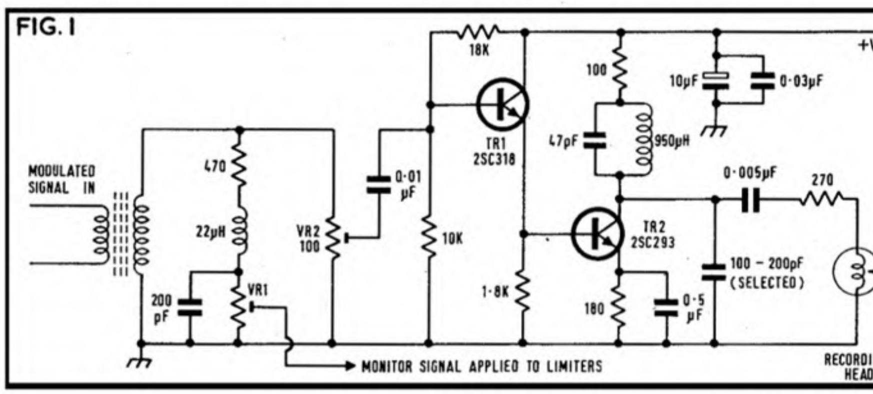
As a result of all this, saturation recording is employed, and the head driving circuits may look a little unfamiliar to us. The directly-coupled pair of transistors in **fig. 1,** for example, from the Sony *CV 2000B* 405-line VTR), is more of an impedance correction device than an amplifying circuit. The low-impedance recording head is energised by saturation current: there is no HF bias. Recording current is controlled by **VR2,** which simply regulates the base input of Tr1. The frequency characteristic of the recording amplifier is fixed in design and compensates for the magnetic transfer from head to tape, which, as we have seen, must itself be non-linear.

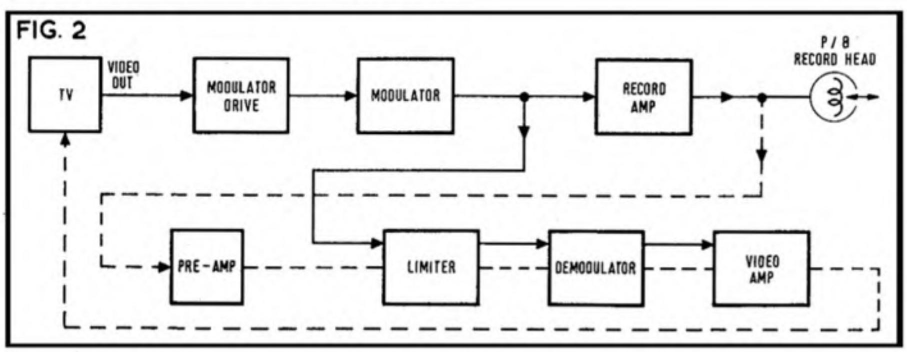
The other preset in this circuit, **VR1,** is just a take-off device, feeding the required level of modulating signal to the limiter.

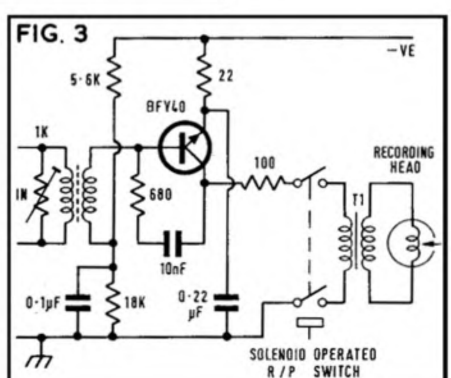
One critic said that the big drawback was the lack of a before-after facility on the average VTR. By this he meant he wanted to be able to compare the incoming signal with the recorded signal, as when we switch from 'source' to 'tape' on an audio machine. But a moment's reflection will show us that the incoming signal is the off-air or from-camera television picture. The first can be switched to show on the screen of the television receiver directly, before-mode, and is then fed to the recording head as we have seen. By taking off the same information at **VR1** and feeding it via limiters, which process the frequency-modulated signal then pass it to a demodulator stage and the extensive video amplifier section, just as the pre-amplified playback signal is handled, we have an 'after' signal all but the link of tape and heads. In practice, I can assure my critic that the system, outlined in block form in **fig. 2,** works very well, and requires the minimum of setting up.

Again as an example, take the setting of the recording level control VR2, shown in **fig. 1.** Note that this is used to set recording current, not signal level, which has already been set by the modulator drive controls, including the manual control, (see fig. 3, Part 2). The easiest way of setting this, using the minimum of

(*continued overleaf*)







instruments, is to make a series of adjustments, recording the steps aurally as the alterations are made, noting the output from the recording amplifier as each adjustment of VR2 (in **fig. 1**) is made. To do this properly, without loading the circuit unnecessarily and obtaining a false indication, a good oscilloscope is necessary, connecting this directly across the output from the recording amplifier to the recording head, i.e. after the 270 ohm resistor. If the timebase is set to 3 mS/cm and the vertical gain to 0.1 V/cm, the waveform will show as a band with a vertical pulse narrowly on it, and under correct conditions should be 2.2 V p-p. But correct conditions are subjectively judged in practice by replaying the off-air recordings, noting which is best, checking against the 'log' what voltage setting corresponded to this setting, then resetting VR2 to the position which gives this reading. It takes less time to do than to tell!

From this optimum setting, one can now deviate slightly to suit incoming signals. To get an absolutely accurate result, one can make the initial test as before, adjusting VR2 in steps, then replay this and measure the voltage at the output of the replay preamp board (details of which follow), then reset to the position of VR2 which gave the maximum voltage. With this method, a VVM can be employed. An oscilloscope will give a 600 mV p-p indication. The trace can be affected by discrepancies between the two heads, both of which are in action during replay. We shall return to this point.

A different method of achieving the same end is seen in **fig. 3** which is a detail from the circuit of the Loewe-Opta *600* VTR. This machine has a 'rotating transformer', shown as T1. The fixed winding is connected to record or replay amplifiers by a solenoid-operated switch. The head is connected across the 'floating' winding.

In the record mode, the fixed winding of T1 is in the collector circuit of the record amplifier output stage, via the interconnections and switching. It can make servicing a bit touchy. Similarly, adjustment of the resistor across the input to the coupling transformer in the base circuit of the *BFY40* can be critical. The balanced FM is applied across this winding and it needs little in the way of leakage or self-capacity to upset matters. A scope is again the ideal test instrument. With it, monitoring at the collector of this transistor, we can check in one go the 3.3 MHz oscillator frequency, the symmetry of the waveform—which is vital, and set the amplitude by the 1 K preset.

The circuit of **fig. 4** should be familiar to regular readers and is, of course, the recording amplifier (output section) of the 625-line Sony *CV2100CE*. The catch about this is that it is one of a pair. In this machine the head amplifiers are duplicated, getting rid of the awkward switching problem that limited the facilities of the older machines and enabling such necessary functions as a still picture and editing to be added to the later versions. It is of especial interest when compared with the two-stage circuit of **fig. 1.** This is a much more precise circuit, with more exact yet gentle frequency correction, and is extremely stable in operation. The operating voltages are higher, and ratings of the components that much closer. The 33-ohm resistor in the emitter of the *2SC756* output stage, for example, has to be a 1 W component.

Which brings us (as the pundits say when usually it does not) to the circuit of the Sony *DKV 2400B* battery portable video recorder. To put things in context, this machine is purely a recorder, the intention being to replay its tapes on the larger machine. Although the version we are dealing with is a 405-line machine, there is another version now on the market with 625-line facilities, plus some very special features that need not concern us yet. It again uses FM for video recording, helical scanning, a servo-controlled system, and 12.5 mm tape.

The circuit of **fig. 5** is almost a scaled-down version of the previous one, operating at a lower voltage and with less obvious frequency correction. The purpose of the first stage in this kind of circuit is to act as a buffer, preventing the necessarily hard-working head driver stage from loading the modulator. Another (not so apparent) factor about this circuit is the way the 9 V supply is derived. This little circuit, the FM modulator, and a control amplifier with one transistor, have the same 9 V positive rail voltage as the rest of the amplifiers, but is fed by a triple-transistor switch circuit, shown in **fig. 6.**

When the record switch closes, a small current flows in the base circuit of the first transistor, turning it on. This does the old 'domino' trick, turning 'off' the second stage and turning 'on' the third. The collector of this stage is fed from the main 9 V positive line and the supply to the critical stages is taken from its emitter, across a 20 K resistor.

To be continued

FIG. 4

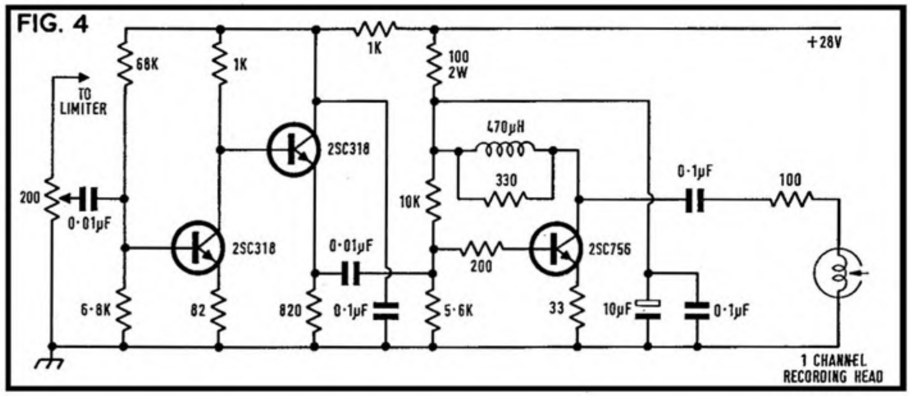


FIG. 5

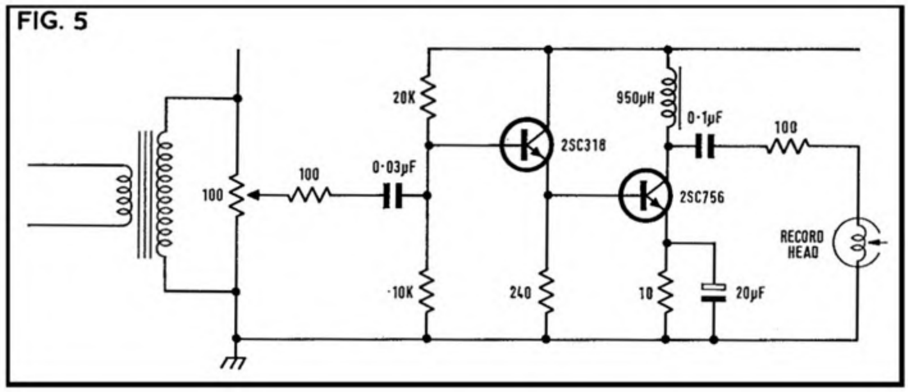
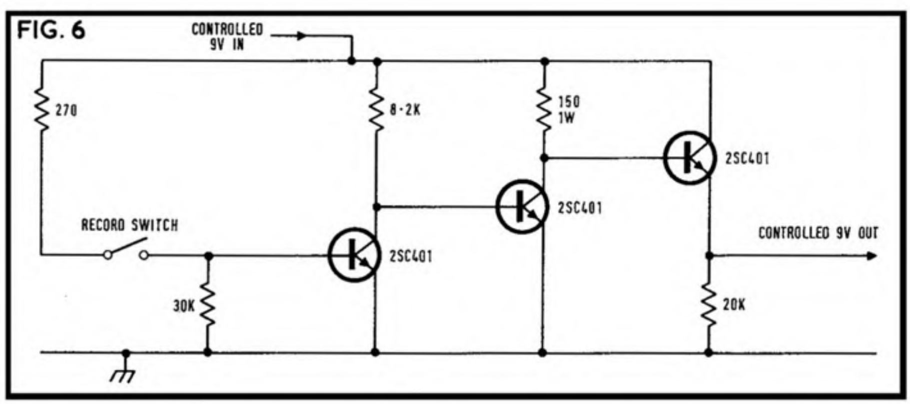
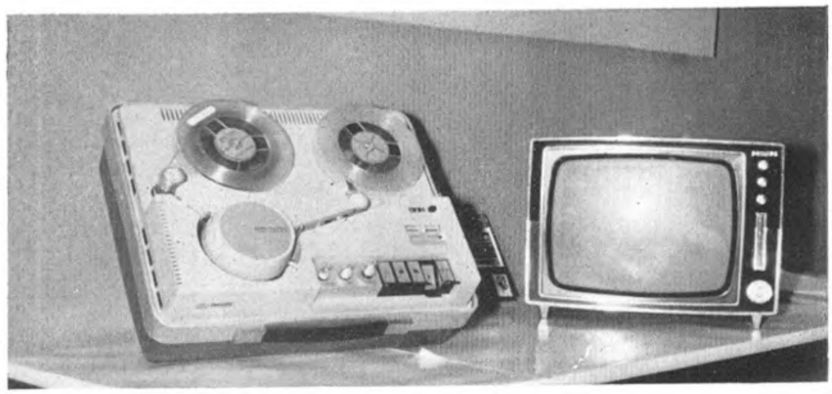


FIG. 6



FIRATO '69

F. C. Judd reports on recording equipment at the Amsterdam audio/visual exhibition



Above: Philips *LDL 1000* domestic VTR.
Far left: Dokorder *8010* stereo copier.
Lower left: Akai 6.25 mm audio/video tape recorder.

THE bi-annual Firato festival held at the R.A.I. Exhibition Centre in Amsterdam in September 1969 attracted over a quarter of a million visitors. This combined 'electronics' show covers radio, television, hi-fi, tape recorders, electronics, musical instruments and domestic electrical appliances.

There was plenty for tape recording enthusiasts and the Dutch N.V.G. (Netherlands Sound and Photography Society) made a special feature of video recording with the help of the new Philips *LDL 1000* domestic video tape recorder. This is being sold in Holland for approximately £350 complete with TV receiver, video camera with a zoom lens, and microphone. The video tape head system is helical scan using 12.5 mm tape at a head to tape speed of 808 cm/s. The nominal running speed of the tape is 16.8 cm/s and the recorder will accommodate a 480 m reel of tape which provides a total running time of 46 minutes. The twin rotating tape head scans at 1500 rpm and the total length of the diagonal tracks is 16 cm.

The width of the sound track is 0.7 mm and sound is of course recorded in synchronism with the video signals. The horizontal bandwidth for video is 2.2 MHz and the picture signal-to-noise ratio better than 40 dB. Pictures recorded from the camera and replayed off tape showed definition comparable with that of average broadcast TV reception.

Akai were showing their new combined helical scan video and ¼-track stereo tape recorder which uses standard 6.25 mm tape for video as well as for sound recording. Accessories such as a standard TV receiver/monitor and a video camera are available but the Dutch distributors had no idea of the actual selling price of the complete outfit. It is estimated however, that this would be less than £300 in Holland. The recorder was in operation on the distributor's stand and pictures from tape were of very good definition. Tape speed is 28.6 cm/s, resolution more than 200 lines, signal-to-noise ratio better than 40 dB. The drum assembly uses twin rotating video heads. The audio bandwidth of sound tracks associated with video recording is 100 Hz to 10 kHz.

Most of the audio tape recorders on show were those we are already familiar with in this country. One or two firms were showing new models and one, which although not completely new as far as the idea is concerned, is of Japanese manufacture and has a built-in tape copying facility. This recorder, the *8010*, is a ¼-track stereo two-speed domestic machine featuring what the makers call 'Automatic continuous reverse' and the Dub-a-Tape system which enables it to do the work of two conventional recorders. The system employs a single capstan to pull both tapes through the head block. The copy tape spools have their own rewind and take-up motor which is synchronised to the normal spool motors. The master tape is played via the normal replay head block and dubbed via its own record/erase head block which is situated to the left of the normal record/replay block. The capstan drive is central to both blocks and tapes can be run in either direction. The reverse record/replay system obviates turning the spools over at the end of a tape. Would two tape recorders work out cheaper?

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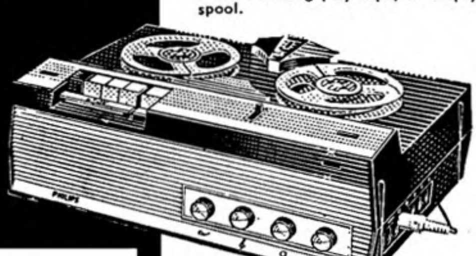

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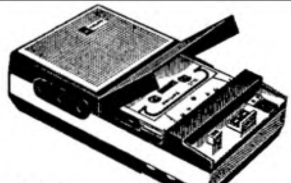

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5"	600'	6/-	17/6	5"	900'	8/-	23/6	5"	1200'	12/6	37/-	5"	1/9
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equipment reviews

THE Magnetophon *250* is for the home audio enthusiast who wants a tape unit to feed external power amplifiers and speakers, with facilities for echo, multiplay, track-to-track transfer, on and off tape monitoring, headphone outlets, etc., in a compact unit with a logical control layout.

All the push key controls are grouped around the head cover. To the left we have rewind, playback, forward and record with the stop bar behind. Below the heads are: 'echo-multiplay', 'monitor source', 'monitor tape' and the mains on/off switch. To the right are the pause key, the four-digit revolution counter and microphone, radio and phono input selectors.

On a vertical panel to the right of the deck there are the two slider type record level controls with the pre-set 'trick' level controls for echo, and track-to-track transfer directly above the sliders. Half way up the panel we find the two record level meters and above them the tape speed control.

The main function switch for mono, stereo, track-to-track, and double-mono, is on the head cover, and the various DIN and stereo headset sockets are on the panel at the rear of the deck.

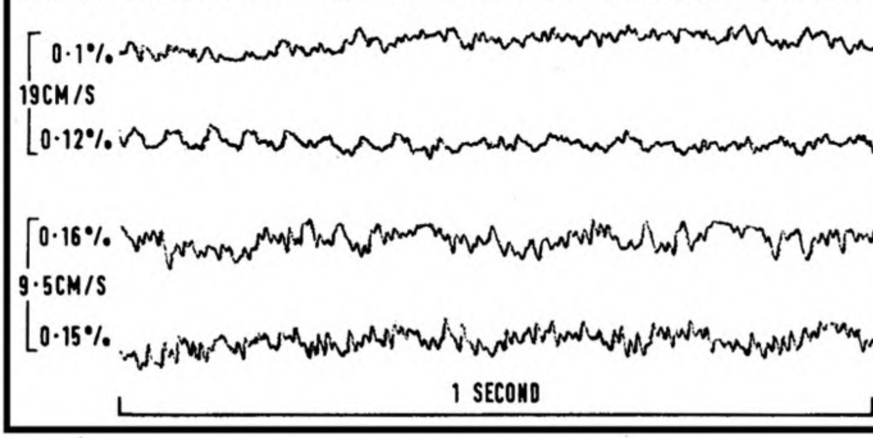
Long term tape speeds were well within 1% of the nominal 19 and 9.5 cm/s.

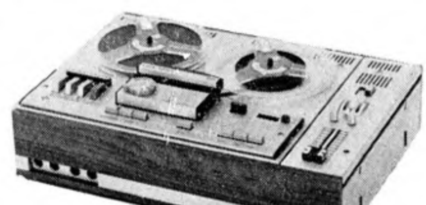
Short term speed imperfections were mainly due to the 25 Hz motor rotation frequency at 19 cm/s and a slight 5 Hz capstan wow with brief bursts of 25 Hz motor flutter at 9.5 cm/s. RMS readings ranged from 0.1% to 0.12% at 19 cm/s and from 0.15% to 0.16% at 9.5 cm/s. These readings cannot be directly compared with the specification, which quotes weighted peak readings to the DIN standards, but they are adequate without being sensationally good.

The play-only responses of **fig. 2** were obtained by playing standard NAB 19 and 9.5 cm/s test tapes and plotting the levels at the line output. Despite the NAB 3180 μS bass rise the 19 cm/s response falls below 200 Hz. The dip at 60 Hz and recovery at lower frequencies shows that this is a wavelength effect and is due to the small pole face length of the play head. At high frequencies the equalisation is within ±1 dB up to 15 kHz.

System noise was 58 dB below reference tape level (32 mM/mm, 1 kHz, 19 cm/s) unweighted, and -66 dB when weighted to the IEC 'A' curve. Bulk-erased tape noise was -64 dB when measured under the same conditions, and

FIG. 1 TELEFUNKEN M250 RECORD-PLAY WOW AND FLUTTER

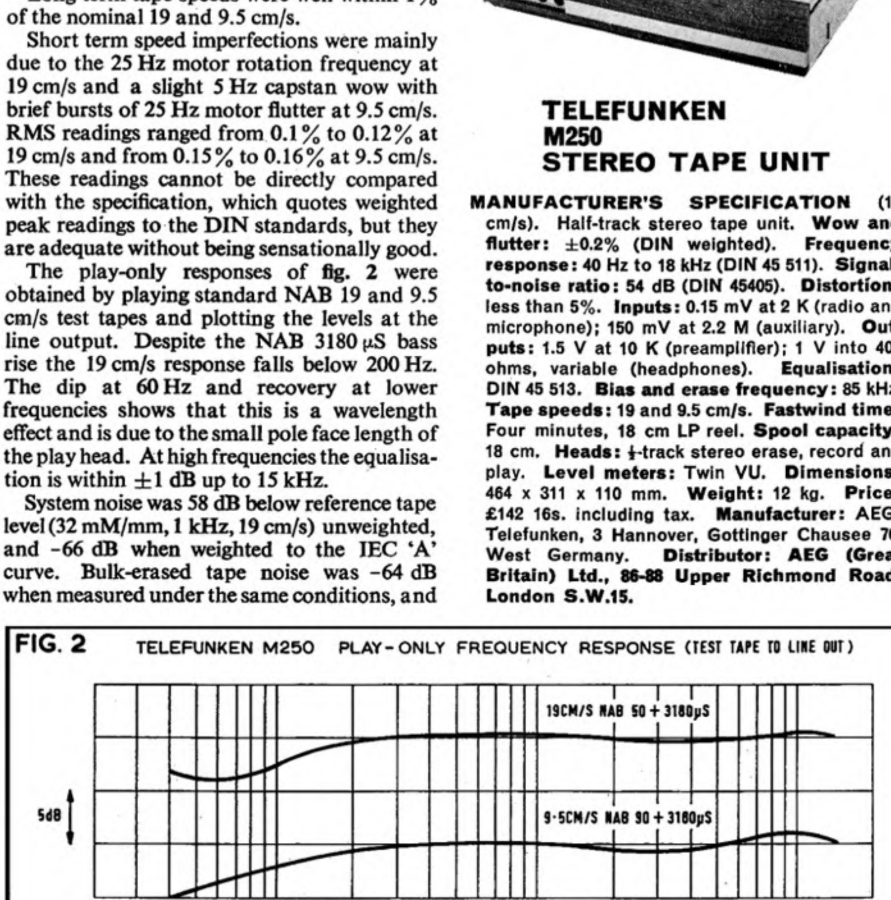




TELEFUNKEN M250 STEREO TAPE UNIT

MANUFACTURER'S SPECIFICATION (19 cm/s). Half-track stereo tape unit. **Wow and flutter:** ±0.2% (DIN weighted). **Frequency response:** 40 Hz to 18 kHz (DIN 45 511). **Signal-to-noise ratio:** 54 dB (DIN 45405). **Distortion:** less than 5%. **Inputs:** 0.15 mV at 2 K (radio and microphone); 150 mV at 2.2 M (auxiliary). **Outputs:** 1.5 V at 10 K (preamplifier); 1 V into 400 ohms, variable (headphones). **Equalisation:** DIN 45 513. **Bias and erase frequency:** 85 kHz. **Tape speeds:** 19 and 9.5 cm/s. **Fastwind time:** Four minutes, 18 cm LP reel. **Spool capacity:** 18 cm. **Heads:** ¼-track stereo erase, record and play. **Level meters:** Twin VU. **Dimensions:** 464 x 311 x 110 mm. **Weight:** 12 kg. **Price:** £142 16s. including tax. **Manufacturer:** AEG-Telefunken, 3 Hannover, Gottinger Chausee 76, West Germany. **Distributor: AEG (Great Britain) Ltd., 86-88 Upper Richmond Road, London S.W.15.**

FIG. 2 TELEFUNKEN M250 PLAY-ONLY FREQUENCY RESPONSE (TEST TAPE TO LINE OUT)



BASF *LGS35* tape recorded at peak recording level and erased on the machine was -62 dB. This is a most impressive signal-to-noise ratio as it means that the tape hiss and remnant signal level is better than 1,000-to-1 down on peak recording level.

On recent testing of semi-professional recorders with equally good signal-to-noise ratio, and wow and flutter below 0.03%, I have been able to measure pretty accurately the distortion actually recorded on the BASF *19S* reference level tape at 1 kHz, 32 mM/mm, 19 cm/s. This distortion is 0.075%. A distortion reading from this reference tape of 0.8% was obtained on the *M250*. This is very interesting as it shows that 0.1% wow and flutter does not wobble the test signal out of the rejection band of my harmonic distortion meter.

Equally impressive was the fact that 1 kHz 32 mM/mm level could be recorded on BASF *LGS35* tape at only 0.9% distortion! This is the only domestic recorder that has broken the 1% distortion barrier.

Such a low distortion at reference level means of course that about 2 to 4 dB more level can be recorded on the tape without exceeding the normal 3% limit. Thus 3 dB can be added to the already more than adequate 62 dB dynamic range mentioned earlier.

Record/play responses from line input to line output are shown in **fig. 3**. The falling play-only responses at low frequencies have been compensated by extra bass pre-emphasis during recording so that the 3 dB down points are now 30 Hz at 19 cm/s and 40 Hz at 9.5 cm/s. The HF response at 19 cm/s extends beyond 20 kHz and reaches 15 kHz at the lower speed of 9.5 cm/s.

COMMENT

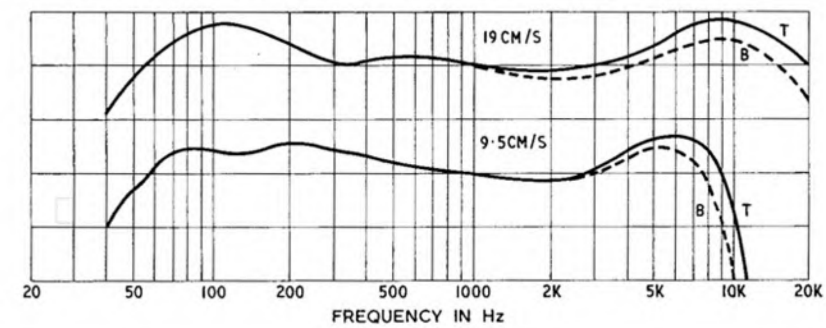
I think the best tribute to this tape unit is to say that it is almost completely neutral. If you connect a good quality FM tuner to the input, set the tape moving at 19 cm/s, and press the centre key below the function switch, you will hear the programme direct, exactly as it would sound if the recorder were not inserted between

(continued overleaf)

the tuner and your main power amplifier. If you now press the off-tape button there is a momentary hesitation, or time jump, equal to the time it takes for any given spot on the tape to move from the record head to the play head, and then you hear the programme exactly as before: no better, no worse, no brighter or cleaner; just the same! If the same experiment is tried at 9.5 cm/s there is a just perceptible difference in hiss or in absolute cleanness on certain complex programme material such as choral works, but for speech or light music you may again hear no difference at all. This is an acid test which only the best recorders can pass. The *M250* joins the select few machines on which it dare be tried.

A. Tutchings

FIG. 3 EAGLE TC450 RECORD / PLAY RESPONSE (LINE IN TO LINE OUTPUT)



PHILIPS 4307

MANUFACTURER'S SPECIFICATION (9.5 cm/s). Single-speed domestic ¼-track mono recorder. **Frequency response:** 60 Hz to 14 kHz within 6 dB. **Wow and flutter:** 0.25% (DIN weighted). **Spool capacity:** 18 cm. **Microphone input:** 0.2 mV at 2 K. **Auxiliary input:** 100 mV at 1 M via EL3768/03 lead. **Auxiliary output:** 750 mV at 20 K. **Loudspeaker output:** 2 W at 4 or 8 ohms. **Weight:** 7.5 kg. **Dimensions:** 420 x 300 x 140 mm. **Price:** £48 11s. 11d. **Distributor: Philips Electrical Ltd., Century House, Shaftesbury Avenue, London W.C.2.**

THE Philips *4307* does not pretend to be anything more than a good-quality domestic recorder. Nevertheless the frequency response is smooth over a wide range and the signal-to-noise ratio excellent due to the use of modern low-noise transistors. The high frequency flutter on my pen recording looks a bit alarming, but in fact the ear is not sensitive to such flutter as a change of pitch, the subjective effect is of a slight roughness on a sustained high frequency tone.

I like the independent record and play gain controls which allow monitoring at any level during recording, or muting of the speaker when using the microphone to avoid acoustic howl back.

A two way switch at the rear of the recorder offers optimum matching for a 4 or 8 ohm speaker.

The control keys are marked with the now familiar symbols reading (from left to right) record, fast rewind, play, fast forward wind and pause. The stop bar is placed in front of the keys.

To the right, the three knobs are record gain, play gain and play tone respectively. The track selector switch is directly above the record control and the record level meter is above the play control.

A three-digit revolution counter with push button reset is at the rear of the deck plate between the tape spools.

The fluttergram of **fig. 1** shows a high frequency flutter of approximately 1% peak-to-peak or 0.35% RMS. As mentioned above, this looks worse than it sounds, but it should be noted as it affects the accurate measurement of distortion later.

The play-only response of **fig. 2** shows a response level within 3 dB limits from 100 Hz to 8 kHz when playing the standard NAB 9.5 cm/s test tape. System noise, with no tape passing the heads, was 56 dB below 32 mM/mm reference level tape, unweighted. Weighted to the IEC 'A' curve, the ratio improved to −62 dB. Bulk-erased tape gave a weighted reading of −58 dB and peakrecording level erased on the machine was −54 dB below peak recording level.

Peak recording level equal to the reference tape was obtained with the record level meter needle just entering the red sector of the scale at reading 6. Harmonic distortion at this level read 3.8% but this reading was suspect as some of the flutter frequency harmonics showed in a CRO examination of the residual distortion products.

A band pass filter was used to isolate the true third harmonic tape distortion and this was estimated to be in the order of 2.5%.

Recording tests at 20 dB below peak reference level gave the line in to line out response of **fig. 3.** Bass response is similar to that of the

FIG. 1 PHILIPS 4307 RECORD–PLAY WOW AND FLUTTER

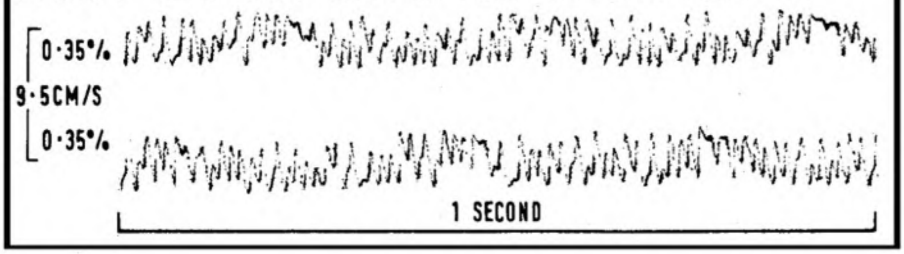


FIG. 2 PHILIPS 4307 PLAY–ONLY RESPONSE (NAB 90+3180µS TEST TAPE TO LINE OUT)

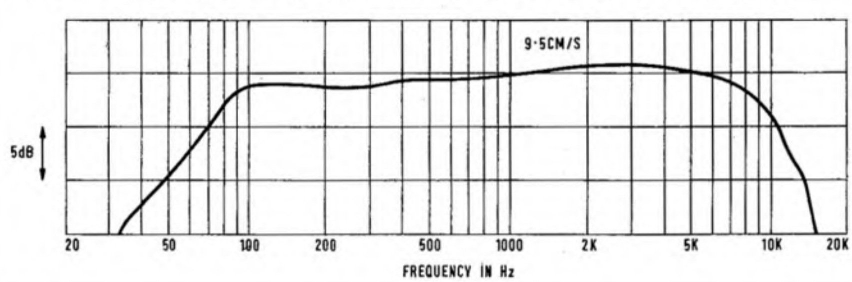


FIG. 3 PHILIPS 4307 RECORD–PLAY RESPONSE (LINE IN, BASF LGS 35, LINE OUT)

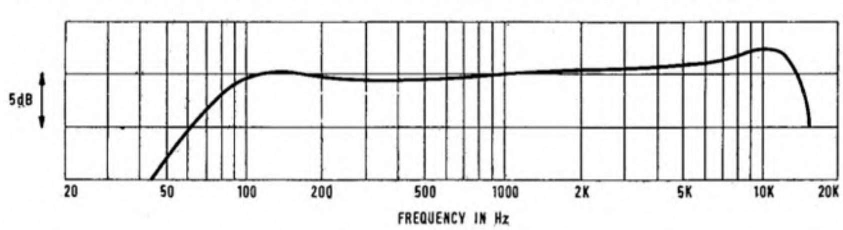


FIG. 4 PHILIPS 4307 ACOUSTIC RESPONSE (WHITE NOISE TAPE ON SPEAKER AXIS)

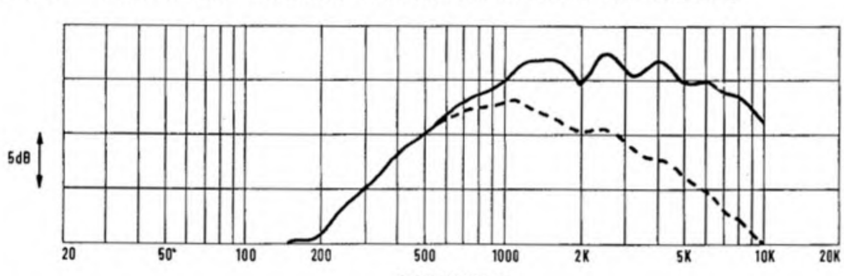
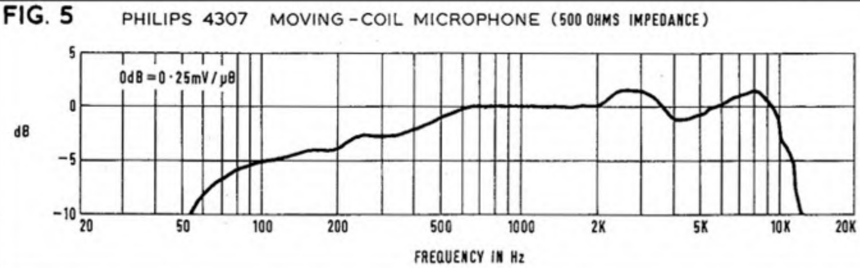


FIG. 5 PHILIPS 4307 MOVING–COIL MICROPHONE (500 OHMS IMPEDANCE)



4307 REVIEW CONTINUED

NAB test tape, but extra high note pre-emphasis has extended the treble response to 14 kHz.

Twenty-five one-third-octave bands of filtered white noise were recorded and the sound output measured on the speaker axis during replay. The resultant overall electro-acoustic response at the two extremes of the tone control are shown in **fig. 4.** It will be seen that the bass response falls by 6 dB per octave below about 700 Hz to a virtual cut-off below the speaker cone resonance of 150 Hz. For speech reproduction this response is adequate and the full top response can be used, but for music reproduction most listeners will prefer a more balanced response with the tone control cutting the top response towards the dotted curve of **fig. 4.** On a good quality external speaker with adequate bass response, the full treble response can be used.

The *EL 1980* moving coil stick microphone provided with the recorder was also tested in a white noise sound field to give the response of **fig. 5.** This is a very smooth performer indeed and recordings made on this microphone and recorded on the *4307* recorder will stand comparison with much more expensive equipment when played into wide range reproducers.

A. Tutchings.

RECORDING STUDIO TECHNIQUES
CONTINUED

tape recorders that has ever been designed, especially considering the state of the art at the time. The machine was first made available with switched speeds and equalisation for 76 and 38 cm/s, and shortly afterwards a model was made for 38 and 19 cm/s. Some ten years ago with a colleague of mine I went to great lengths to see how good a performance the machine could be made to give. It may surprise readers to learn that with careful adjustment of the playback head Mumetal screens and changes of valves in the replay amplifier, replay noise figures of 71 dB below 32 mM/mm were achieved, and on full-track recording an overall figure of -66 dB was achieved with a response ± 1 dB from 40 Hz to 15 kHz. Several hundred of these machines are still in use today by the BBC although they are only rarely used in their original form by the recording companies since they were basically mono.

A typical recording studio in the 1950's would have had its mixing desk working at a level of $+8$ dBm (i.e. approximately 2 V at 600 ohms) and the outputs of mikes in the studio were amplified up to levels suitable for the desk in racks of mike amps with auxiliary equipment. Equalisers and limiters were almost always working at the same line in and line out levels and were connected with patch cords, making many studio control rooms behind the scenes rather like spaghetti factories! At this time, of course, all electrical equipment used valves, and the amount of heat generated in many control rooms was phenomenal; an immense amount of ventilation was therefore necessary. Even in these circumstances mono recordings made in the early 1950's were of very fine quality, and many still sound good by today's standards.

The majority of recording studios used a large number of mikes to obtain a good perspective in the recording. As the listener was only listening to one channel, with the absence of stereo definition, the engineer had to achieve a definition by controlling the reverberation on each section of the orchestra, at the same time as making every instrument clear without being unduly forward in balance.

Considerably less care was taken in the acoustic design of the studio, and in general engineers preferred controlled artificial reverberation from echo chambers and artificial reverberation machines, to very expensive acoustic treatment. Many excellent recordings were made in town halls and concert halls in this period, however, and this involved the transport of very heavy mobile equipment which took many hours to set up.

Returning once again to the days of 78's, it is interesting to consider the types of mike that were then available and which were in current use by both recording companies and the BBC. Both the Marconi *AXBT* ribbon and the EMI ribbon were considered as being high quality. Their response extended from 60 Hz in the bass to 8 kHz in the treble but, above this frequency, treble loss was very apparent. For recording pianos EMI often used an STC *4017* moving-coil mike which was the forerunner of the famous 'ball and biscuit' *4021*. The *4017* had an omnidirectional characteristic in the lower and mid-frequency range, but a more directional characteristic in its high frequency range. The *4021*, which was also omnidirectional, has a considerably improved HF response in all directions, and was frequently used for the recording of musicians grouped round it. Although designed before the beginning of the war, the STC *4021* was considered the best British moving-coil mike for two decades, and the only reason that it became relegated to talkback use was that its omnidirectional characteristic made it totally unsuitable for stereo. The early EMI stereo recordings, made mainly by Sir Thomas Beecham and Sir Malcolm Sargent, included Handel's *Solomon*, Schubert's *6th Symphony* and Gay's *Beggars' Opera*, none of which were released in stereo disc form until a decade after their original recording. These were made using a crossed-pair of ribbon mikes, a technique which was first formulated by Blumlein in the early 1930's. It is interesting that this basic technique now still gives, in my opinion, the closest approximation to the original sound when a stereo capacitor mike is used, and when the reproduction equipment is of very high calibre.

Since the early days of LP record cutting there have also been some significant developments. The earliest LP's had rather a poor top response, partly due to the limitations of early tape, and partly to the imperfections of the old type LP cutter heads. Many early LP's also had rather a high rumble caused by the apparatus which moved the cutter in towards the centre as the disc cutting progressed.

At the beginning there was also mass confusion throughout the world on recording characteristics, and it was not until many years had elapsed that the characteristics now known as RIAA was adopted by practically all companies. I well remember gramophone preamplifiers on the market with six or more different replay characteristics giving different bass and treble turnover points. American Columbia LP's for instance had far more treble pre-emphasis applied on the recording than early Decca LP's, which were recorded to a very similar curve to that of American post-war 78's. It is for this reason that many early LP's on the Nixa and Vox labels rarely sounded satisfactory since the average listener played them back with the characteristic adopted by Decca before the change-over, and thus they sounded very shrill. I know for a fact that some companies obtained the recording equalisation by the use of a disc preamplifier in the chain set to maximum treble boost with a high degree of bass cut giving only an arbitrary equalisation curve. Many early LP cutters also lacked negative feedback applied from an extra winding in the cutterhead to an early stage in the cutter amplifier.

It is interesting that stereo prerecorded tapes were produced at least a year before the first stereo discs, and were certainly of better quality than the equivalent stereo discs, although having rather a high hiss level.

Shortly after EMI's early stereo tapes, Arnold Sugden of Connoisseur offered to produce a stereo cutter and it is most unfortunate that the idea of a 45°/45° cut had not been thought of by him at that time. After nearly two years of very hard work Sugden produced a good stereo cutter having the left and right channels as lateral and vertical recording respectively and pressings made from his acetates were then played back with a stereo pickup which he also designed. Sugden's system worked well but was, of course, not compatible in that the records when played back on a mono system gave only one channel. In addition to this, many turntables produced rumble on only one channel, and this tended to sound very distracting. More distortion was also apparent in the vertical channel than the lateral one.

Shortly after this system had been produced, the Westrex Company of America produced a 45°/45° system which was adopted immediately throughout the world.

The first stereo LP's issued in Great Britain were made by Pye, and although we now know that the LP's themselves were of fairly good quality, early stereo cartridges used were not particularly good, causing many people to be put off stereo for many years. I think it is unfortunate that the first stereo records were issued too early, and in my opinion the manufacturers should have established the availability of high quality stereo cartridges before launching the records. Most of these Pye stereo recordings appeared to have soloists wandering from side to side, and an early record of Larry Adler for example appeared to produce a 3 m wide harmonica! They sound better on modern equipment.

To a lesser degree the same remarks also apply to stereo discs made by the other companies, although by the time they were released, a number of better pickup cartridges were available.

It appears that over the decades record production has always been better than reproduction, and I cannot help feeling that, as this has occurred so often, a great attempt must be made by manufacturers to improve reproduction equipment before any further advances are made.

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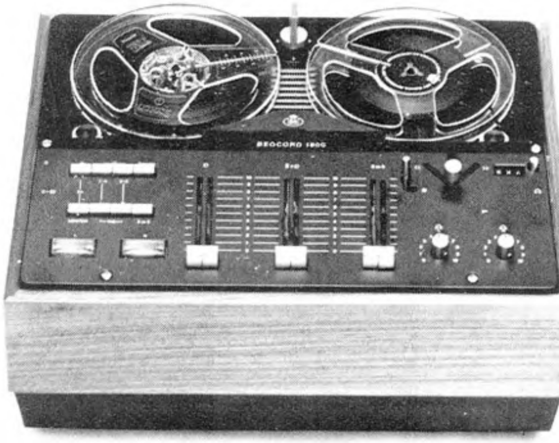

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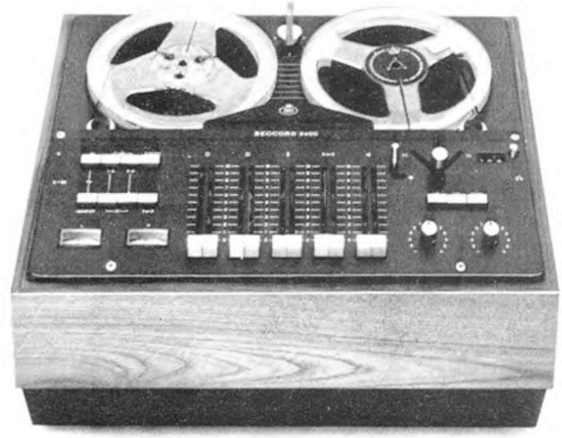

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