TEACH YOURSELF BOOKS

INTRODUCING HI-FI

Hi-fi, in the author's opinion, is not an end in itself but rather the means to a fuller enjoyment of reproduced sound.

This book has been designed to act as a guide for the newcomer to the hi-fi jungle. It explains, clearly and precisely, the principles and standards of hi-fi and goes on to describe in intelligible, non-technical language the working of the various components of hi-fi systems, including tapes and cassettes.

Armed with the information in this book, the reader should be able to select the best hi-fi equipment appropriate to his needs and funds.

Leisure, Domestic and General

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Peter Turner first began listening to reproduced music on an Edison-cylinder machine belonging to a friend's father, and vividly recalls the days of the crystal-set and the moving-iron loudspeaker. From these beginnings he has developed a life-long interest in both music and hi-fi, and in recent years, tape recording. A regular contributor to the audio press on hi-fi and as a record reviewer, he is a passionate believer that technique is the servant of the art, seeing hi-fi as a means to an end, but as the means which must be understood in order to attain the end.

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Preface

High-fidelity equipment is a complex of electronic and mechanical components, the operation of which cannot be fully understood without considerable education in electronic and mechanical engineering. This book is designed for those without this specialist knowledge. The result is inevitably an over-simplification of many points but, it is hoped, without misleading inaccuracies. For those who wish to delve more deeply, there are many excellent books, besides research papers.

My thanks are due above all to the help of two friends: B. J. Webb and A. R. Evans who have, over many years, patiently educated me in the various aspects of a subject in which I share their enthusiasm, but not, alas, their learning. B.J.W. has been kind enough to read the manuscript and make a number of helpful suggestions; while A.R.E. has answered innumerable questions. With both, I have followed the progress of research projects, greatly to my enlightenment. Mike Carwithen, audio dealer, has also read the manuscript from the point of view of one who has consistently to introduce beginners to the art.

Acknowledgement is also due to those manufacturers who have kindly supplied photographs of their equipment. Mention or illustration of a product in this book do not imply the author's personal recommendation of it as against others, but every care has been taken to ensure that all such products are of international repute in their field.

P.D.T.

1

What Is Hi-Fi?

High-fidelity, conveniently if inelegantly shortened to hi-fi, is by no means easy to define, for the simple reason that it has no established meaning. As a label it can be, and is, tacked on to the most inferior products for reproducing sound, and nobody can do a thing about it. There exists a standard laid down by the Deutsche Industrie Norm (DIN) which defines certain limits to performance (what are usually called 'parameters') along lines which will be indicated in this book; but it is not a very exacting standard, and nobody is required to conform to it before describing their products as 'hi-fi'. A British Standard has long been contemplated; but the truth is that this is a field in which progress is so rapid that the true hi-fi of today will soon be the mid-fi of tomorrow.

It may therefore be better to avoid exact definitions, and to set up an ideal. Years ago, Mr Peter Walker, of the highly respected firm of Acoustical Manufacturing (known throughout the world for its brand name of 'Quad'), produced an advertising slogan: 'For the closest approach to the original sound'. Thereby he set—and not only for his own company—a standard which will never be attained but which gives an ideal towards which designers can constantly strive.

In other words, hi-fi is not a static standard at all: it is a constant search. The 'fidelity of reproduction' of the early Edison cylinders was regarded—quite rightly—as a revelation in its day. To hear one today, and compare it with a good modern reproducer, is to realise how far we have come

in that short time. Yet to attend a concert and immediately to return home and play a record reveals at once how far there is to go. Nevertheless, one's reaction is much more likely to be one of surprise at how close is the resemblance to the original sound—so close, indeed, that it is true to say that in the future perfection will be approached in ever-reducing increments, the acquisition of which, unfortunately, will be more and more expensive.

The 'closest approach to the original sound' will be found with small ensembles, individual instruments and singers. It recedes in proportion to the size of the orchestral resources deployed in the recording; and when we come to a full Mahlerian orchestra we realise that there is still far to go. This is due to the inevitable scaling-down required to accommodate the sound of a full orchestra in a domestic room, where it is nevertheless possible to enjoy thrilling orchestral experiences which enable one to relive actual performances —and in much greater comfort, very often.

All hi-fi enthusiasts should certainly refresh their ears by attending live performances, for it is all too easy to be deluded by 'chromium-plated' equipment into thinking that what is in fact false and indifferent reproduction is better than intrinsically more faithful sound. It is possible to write music specially for reproducing-equipment: it has been done, and may be done increasingly as hi-fi comes to be accepted as a normal part of the family home; yet the designer of equipment is seeking, above all, fidelity to the actual sound of music. That is the beginning and end of the hi-fi quest.

There exists the idea that there is some special quality of sound to which the label hi-fi can be attached: the author has heard certain recordings referred to as 'very hi-fi'. This appears to be a larger-than-life effect, as though it were possible for electronic equipment to improve in some way upon the sounds made by musical instruments. The trouble is that no two people are agreed on precisely what manipulations of sound they desire, and to which the authentic tag of

hi-fi can be properly applied. It is true that the resources available to the present-day recording engineer do indeed allow his emphasising certain aspects of the musical spectrum at the expense of others. This is usually done by reinforcing the higher frequencies, giving a characteristic 'swish' to the music; by reinforcing the middle frequencies to give greater 'presence' to the music; or by reinforcing the lower frequencies to produce a thundering bass quite out of proportion to anything one hears in the normal balance of an orchestra.

Some people seem to hope that hi-fi will give them an experience which is remote from reality by being 'better' than real music. This is a sad illusion, for all such effects are based upon different forms of distortion—the nature of which will be discussed later—which the true hi-fi designer is striving always to reduce. A word to be on your guard against is 'impressive'. Now, music *is* impressive, it *is* thrilling, but it is also soothing and moving in quite different ways; and when that word 'impressive' is used of hi-fi equipment it usually means larger than life, which is another way of saying that it falsifies the sound. Loudspeakers, in particular, are often said to be impressive. When you meet one which does seem so, watch it: you will nearly always find that the effect, after prolonged listening, becomes irritating in proportion to your realisation of its falsity.

One should also be watchful of the wiles of the professional salesman, who may well carefully select recordings which emphasise the better qualities of what he is trying to sell, while hiding its limitations. A very good hint here is to take with you a recording you know well, and ask the dealer to play that. Be careful, too, of a salesman who demonstrates first with an organ recording: nearly all equipment can be made to sound 'impressive' by an organ—unless, of course, the listener happens to be an organist or a dedicated student of that instrument.

You will find that in the long run you will be satisfied by the equipment which closely reproduces the sound of your

kind of music, as you hear it in performance. 'Impressive' equipment soon becomes tiring to listen to, and generates fatigue, so that you do not feel the urge to continue to listen. There is, of course, a limit to human concentration, and few of us would wish to listen all day and every day to music, even played by the greatest of artists. Music is recreation in the best sense—re-creation, and surfeit is possible even with the best of things. Nevertheless, enthusiasts flock to Bayreuth, Aldeburgh, Cheltenham, Edinburgh and all the other festivals of music, and live music for days on end, delighting. One should be able to do something like that with hi-fi, but you will not be able to with equipment which falsifies sound.

One also often hears it said of a reproducer that it has 'a beautiful tone', a 'mellow tone' or some such thing. A hi-fi reproducer should have NO tone in that sense, which describes either restricted or distorted sound.

The experience of sound

We experience sound as a result of vibrations set up in the air which are created by the source of the sound—be that a violin or a pneumatic drill. These vibrations impinge upon our eardrums, which are thus made to vibrate in sympathy with the original sound. A complex neuro-mechanical system transmits these vibrations to our brain, where that greatest of all computers recognises them as a sound signal. This process contains many obscurities, despite research; and as those obscurities are clarified the information will be of great utility to the hi-fi designer. Because we have two ears, not one only, each ear receives the sound in subtly different ways, both in position and time; apparently these minute differences allow us to locate the source of the sound. When this mechanism is masked—as it is, for example, when we are travelling in a car—we can be confused as to the source of a sound: we all know how difficult it can be to locate the source of irritating squeaks and vibrations in a car. It is this two-eared method of sound-location which

makes possible stereophonic reproduction—of which more anon.

Sound travels through the air—is 'propagated' in technical terms—in the form of waves, and the ear vibrates in response to those waves. A microphone can be regarded as a kind of mechanical ear, although it does not behave exactly like the human ear, and corresponding to the ear-drum there is a diaphragm which is set vibrating in response to the sound-waves. In doing so, it generates an electrical signal (we shall see later how) which can be reproduced on the television-like screen of an instrument known as an oscilloscope. Another instrument, known as a generator, can produce pure tones, whose wave-like structures can be clearly seen on the oscilloscope. The waveform of a pure tone is perfectly regular, as shown in Fig. 1. This waveform

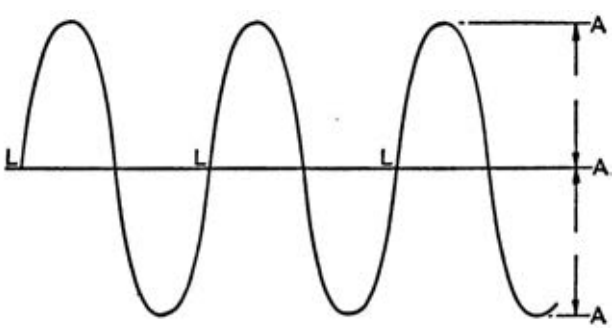


Fig. 1 Sine wave: L–L = wavelength; A–A = amplitude

can be examined in two ways: there is the distance between each undulation, and there is the size of the undulation. Pure tones thus displayed are known as sine waves, and they indicate two important things: wavelength and amplitude. It can be seen on the oscilloscope that when the loudness of the sound is increased, so is the amplitude of the wave; and when the note gets higher it increases in frequency. We thus have two rules: the higher the pitch of the

note, the greater the frequency; and the louder the note, the greater the amplitude.

Frequency is measured in cycles per second, the unit of which, in honour of a famous scientist, is the hertz (Hz). Thus the A above middle C, which is the standard tuning note we are familiar with at concerts, vibrates 440 times in a second and so has a frequency of 440 Hz. When the frequency reaches the thousands per second, it is measured in kilohertz (kHz); and when it reaches millions per second —as it does in VHF broadcasting—it is measured in megahertz (MHz).

Human hearing extends, in young and fit people, from about 20 Hz to about 20 kHz; but as we get older, acuity of hearing tends to fall off at both ends of the frequency band: an older person's hearing may not extend above 10 or 12 kHz. Many animals can hear sounds well above the range of human hearing. The high-pitched whistle which emanates from television sets is in the region of 10 kHz, so that if you can hear that clearly you will have an idea of your own range, which can be accurately measured by what is called an audiometric test.

The discussion so far has been concerned with pure tones; but no musical instrument—other than some 'electronic' ones—gives out pure tones: it gives out sounds which are made up of the basic, or fundamental, frequency and a mixture of 'overtones' or harmonics. These occur at multiples of the fundamental frequency, and are known as the first, second, third harmonic and so forth. They vary in intensity, and it is this variation which accounts for the very individual and characteristic timbre of each instrument. Although some of the harmonics produced may be above the range of human hearing (those produced by a cymbal clash, for example), there is experimental evidence that their presence does influence what we hear. In these experiments, the higher frequencies were filtered out, and the listeners were played both the full and the restricted range. Despite the fact that the filtering occurred beyond their normal range

of hearing, it was fully established, using 'blind' tests, that they could tell the difference. These experiments are important for hi-fi, as many people ask why all the bother to reproduce what cannot be heard. The answer, of course, is that these frequencies contribute to the sense of realism of reproduction, and are therefore essential and not just an expensive waste of money and effort.

The basic requirements of hi-fi

This highly simplified account of human hearing shows that a hi-fi reproducer must be able to play back the full range of sounds—fundamentals and harmonics—which constitute the original signal. A small radio set, or the kind of loudspeaker commonly incorporated in a television set, are incapable of doing this, which accounts—amongst other things—for the very inferior quality of television sound. In the case of television, one often gets the illusion of higher fidelity than one is in fact hearing, due to the ability of the imagination, supported by the visual image, to create an illusion of what is not there.

The ability to reproduce the full frequency spectrum is called the *frequency range* of the equipment, and is one of the most important things about it. A really good amplifier, for example, will have what is called a 'flat' frequency response from well below to well above the range of human hearing—i.e. from somewhere round 15 Hz up to 30 kHz or more. The word 'flat' derives from the possibility of plotting a curve of the frequency response of equipment. Ideally this response-curve should be a straight, or flat, line. In practice, there are always small deviations from the ideal, which do not matter provided that they do not exceed certain limits which we shall discuss later. The best amplifiers never do.

Perfection, however, does not exist: all parts of the reproducing chain do add something to the original, or take something away from it. Even the room in which the equipment is played can do that, and we all know that some

auditoria or churches are easier and pleasanter to listen in than others. Adding to, or subtracting from, the original signal is called *distortion*, a degree of which is present in all reproducing (and recording) equipment. In the best the error is so small as to be negligible, but it can be painfully obvious in inferior equipment—hence the horrible noises engendered by some transistor radios! Distortion can be of several different kinds, of which we shall say something later; it is measured as a percentage of the original signal. In a pickup or amplifier this should not amount to more than a fraction of 1%: so small, indeed, as to be normally quite inaudible. Designers are striving all the time to reduce it still further.

It will be obvious from all this that the standard required of hi-fi equipment is very high: components have to be of best manufacturing quality; manufacturing techniques, tolerances and inspection have to be strict and rigid. These things are not attained cheaply, which is why the best equipment is expensive—for in general one gets what one pays for, and cheap equipment simply cannot be as good as the more costly. Good equipment is also reliable, whereas the cheaper is not, and its makers are deeply concerned with the reputation of their products and go to great lengths to stand by them.

Thus, the basic requirements of a hi-fi system are a wide and smooth frequency response, and freedom from added distortion. These requirements are met by high-quality pick-ups, and very fully by good amplifiers. There is one other requirement which we now mention.

Imagine again a cymbal clash. The first minute fraction of that clash occurs with great intensity, and is very short indeed—it lasts only millionths of a second. Reproducing equipment has to have the power necessary to show that intensity, and the speed of response necessary to follow it. Both of these are essential every time the intensity of the sound changes, and the ability of the equipment to respond accurately to this is called its transient response.

It is perhaps here, more than in any other respect, that the transistor outperforms the valve. Hence all modern reproducers employ transistors (semiconductors) instead of valves, though it was some time before transistors could be made to match the performance of valves in terms of distortion. Poor transient response results in a dull and lifeless type of reproduction, even where the frequency response is adequate.

These basic requirements apply to all the elements of a hi-fi system: like every other chain, hi-fi is as strong as its weakest link. Hence a superb amplifier will faithfully reproduce the nasty noises made by a poor pickup; and by the same token the best pickup in the world—whichever that may be—cannot show its quality if the amplifier or loudspeaker with which it is associated cannot do justice to it. Moreover, a superb system will only—can only—faithfully reproduce any unpleasant noises on the disc it is reproducing. We can hear the best of which hi-fi is capable only when every item, from record to loudspeaker, is of the best. But since only the fortunate few are wealthy enough to start from the beginning with the equipment of their dreams, it is important to collect equipment in such a way as gradually to build up an ever-higher standard. In the next chapter we shall consider the order in which that should be done, the object being to start with good-quality sound in such a way that gradually, as funds become available, the good can be converted to the superb. And superb, happily, is the only way to describe the best of which hi-fi is capable.

Mono or stereo?

The first gramophones reproduced all the original sounds—or as many as they could of them—through one hole. This was coupled to a horn, in order to amplify (make louder) the sound, in much the same way as the cox of a racing eight uses a megaphone to this day. With the development of the loudspeaker—how this works we shall come to later—a

much more natural sound could be achieved; but even when electronic reproduction (the 'record player' or 'radiogram') took over there was still only one source of sound even though the loudspeaker might, and often did, make use of more than one unit. This type of reproduction is called 'monophonic', or 'single-voiced'. It could, and still can, make very fine sound and be the source of high musical enjoyment.

However, human beings have two ears; what we hear is always conditioned by that fact, be we in the street or in the concert hall. We saw earlier that sounds reach each ear in ways that are subtly different, which enables us to locate sounds in space. Although in later developments of the monophonic system two different loudspeaker systems, spaced apart, were used, the music came from only one source. In reality this happens only when a single instrument is playing, and even then it is playing in an environment which creates an 'ambience' to the sound: it is sound heard in a particular environment. Monophonic reproduction failed to give any sense of the location of sound, and it also coped badly with the problem of ambience. In the concert hall, one is well aware that the violins are usually situated to the left of the conductor, the basses to his right, the woodwind and percussion somewhere in between. With monophonic reproduction this could not be re-created: it had to be imagined. Powerful though the human imagination is, there are limits. Further, the sound-picture in monophonic reproduction was inevitably flat, even when two loudspeaker systems were used. In reality music has depth and spread.

Following earlier experiments in the field, an engineering genius called Blumlein—regrettably killed in an air-crash during the war—patented a system whereby the sound was both recorded and reproduced through two separate and different channels. The sounds emanating from the two channels could be made to differ in ways which more perfectly matched the way in which the two-eared system

of human hearing apprehends. Not only could the different instruments be heard spatially separated from each other, but the movement of a performer across the stage in drama or opera could also be followed. The effect was a much closer approach to the original sound, and the system was called 'stereophony', usually abbreviated to 'stereo'.

Even more importantly, much more of the depth and ambience of the original sound could be reproduced: the copy sounded more like the original. In the early days of stereophony movement and location in space were overemphasised, and early demonstration records were full of trains rushing through the room, table tennis being played and the like. The greater realism and ambience achieved by stereo is much more important. Today, stereo and hi-fi have become synonyms, and will be assumed so for the rest of this book.

Stereophonic reproduction calls for two separate channels right through the chain: a pickup tracing two separate channels on the record (or a tape being replayed on two separate heads at once), an amplifier with two separate channels and two loudspeakers, one connected to each channel. These two channels reproduce subtly different signals all the time. In recording, more than two channels are often employed, though they are reduced to two before the disc is cut. This is not an unmixed blessing, and has to be done with great restraint and responsibility if the recording is not to depart seriously from what one hears in the auditorium. There is still a lot to be said for the original Blumlein twin-microphone technique.

The two amplifiers can easily be accommodated in one box, and today always are, but the two loudspeakers cannot: they *must* be separated by at least 5 or 6 feet for best results. Attempts have been made to design long cabinets with speakers at each end, separated by a foot or so, but the result is never wholly satisfactory and the so-called 'stereogram' should be avoided. It is very difficult to design loudspeakers which are adequate and yet can be accommodated

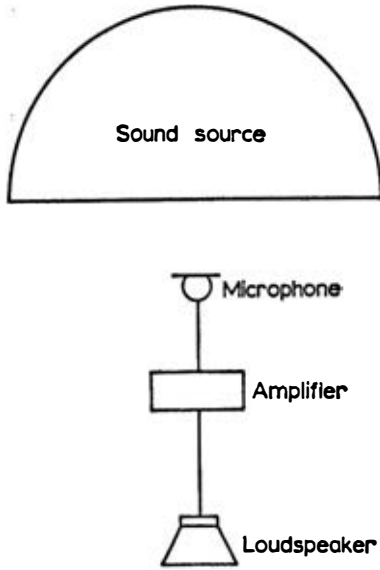


Fig. 2 Simplified mono reproducing system: one channel only

in a stereogram. What is often done is to have the speakers 'fire' outwards, thus bouncing the sound off adjacent walls. This destroys the stereo effect. We shall therefore warn readers off these devices and discuss them no more.

More recently, attempts have been made to reproduce still more faithfully the ambience of the concert hall by means of a four-channel system. In recording, two channels pick up the sound in front of the listener and two the sound behind him. The sound is re-created with four loudspeakers, two in front of and two behind the listener. This produces a greater depth and solidity to the sound, giving a better illusion of the ambience of the concert hall in the home. It may be that eventually this 'four-voiced' system will become the norm. It is usually referred to as 'quadraphony'—a bastard word which is much better rendered as

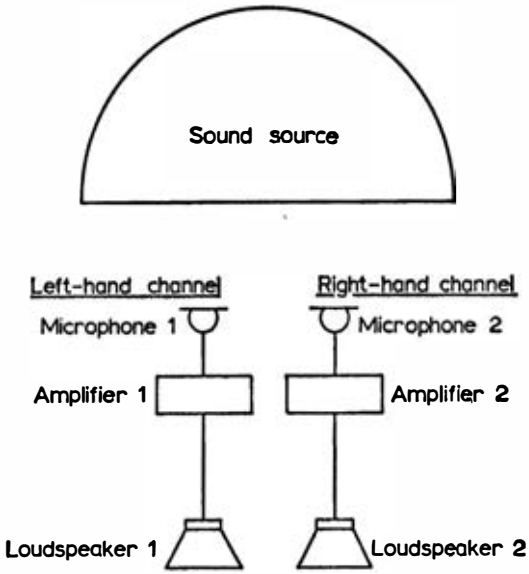


Fig. 3 Simplified stereo reproducing system: two separate channels

'tetraphony'. There are several competing systems to achieve this effect. All are complex, and will not be described here. The extra cost of equipment and the physical problem of accommodating two more loudspeakers in the domestic environment may well militate against wide acceptance of the system. Yet it may be that once a standard has been agreed, tetraphony will make progress. Already some amplifiers make provision for it, and records are being manufactured. The rear speakers need not be so large or so perfect as those in front, as they do not contribute nearly so much to the sound heard—they do little more than whisper. At the moment of writing it is unwise to recommend one particular system, as it might not be the one which will be adopted as universal. Tetraphony will therefore not be referred to

again, and the acquisition of 'normal' stereophonic equipment will be assumed.

It may, however, be worth remarking that a simulation of the tetraphonic effect can be achieved with stereo equipment by taking an out-of-phase signal (pp. 74, 90–91) and relaying it to a single loudspeaker placed behind the listener, with a small variable resistor connected to allow control of the volume of that speaker. Small 'black boxes' are available for the purpose, and the curious may care to try this.

Housing the equipment

Time was when a hi-fi system involved lots of trailing wires round the room giving the appearance of the flight-deck of an aircraft-carrier. All that is past: equipment can be housed in a variety of handsome cabinets, with only a connexion to a handy mains' point. The wires to the loudspeakers can be routed under the carpet or neatly round the walls or skirting-board. Alternatively, shelving can be used. Today, the styling of equipment is taken very seriously and, far from detracting from the appearance of a room, can become part of it. This is a question of taste and must be left to your own judgement and pocket. Just rid yourself of any idea that hi-fi looks ugly, gets in the way or hinders the lady of the house in her cleaning. If that were ever true, it no longer is: hi-fi looks as good as it sounds. (See pp. 84ff. for more about housing your equipment.)

2

Where To Start

Since you are interested enough in hi-fi to be reading this book, you will have recognised the limitations of the sound quality you obtain from your domestic radio or record player. You recognise this by reference, conscious or unconscious, to the true sound of the music you like—be it classical, pop, brass bands or cinema organs. Thus, the point at which to begin your quest for high-fidelity is to know thoroughly the sound which you intend to reproduce. All the best authorities on, and designers of, hi-fi equipment are sensitive and dedicated music-lovers before all else; and what they are seeking is music reproduced as much like the real thing as possible.

That, therefore, is your standard: the live performance. Beware of any reproducer which sounds larger than life, or which exaggerates either the upper or the lower end of the sound spectrum. Between the wars, as an advertising slogan one could often hear the exhortation, 'Listen to the bass!'. This arose partly from the invention of the moving-coil loudspeaker, which at last enabled the bass frequencies to be reproduced; but it pointed fatally to the deficiencies at other frequency levels. You must learn to listen to any unfamiliar equipment with detachment; to avoid being overimpressed by any one feature; and to keep as clearly as possible in your mind the memory of the real thing.

This implies that you have access to a variety of equipment. How does one achieve that? You may have friends who already have equipment; indeed it may be that hearing

it has inspired you to seek for your own. If you have not, you will be compelled to listen in the demonstration-rooms of hi-fi dealers. Here we come to our first decision.

Where to buy equipment

Since the abolition of re-sale price maintenance, dealers have been free to sell equipment at any price they choose. The result has been the emergence of the discount house, often operating by mail-order only, at which you can buy equipment for strikingly lower prices than at the high-street dealer. The temptation to save money by patronising one of these discount houses is very strong, but there are a few points to bear in mind.

Hi-fi equipment is complex, and consists of a large number of electronic and mechanical components, some of which are likely to go wrong in the course of time. Does your discount house offer after-sales service, and if so on what terms? Many have no service department at all, and can only send faulty equipment back to the manufacturer or importer, or tell you to send it yourself. This can be expensive; there is danger of further damage in transit; and you may have to wait a long time before you see your hi-fi again. The best manufacturers go to extreme lengths to satisfy their customers; but it is much easier to go back to the shop for servicing.

Servicing of hi-fi equipment is a skilled operation, and calls for qualified engineers, equipped with expensive test-gear. Has your proposed supplier either the staff or the gear? Both are expensive; and no dealer can offer both the maximum of discount and the maximum of service. The writer's dealer gives his personal guarantee on all equipment supplied by him, and for a term of *five years*. To do that, he cannot give large discounts; but he does sell peace of mind.

There is also the question of installation. Are you sure that you have the necessary knowledge to do this yourself? Installation is not the simplest of tasks, and it must be done

rightly if the equipment is to function at its best. The non-discount dealer may well undertake installation as part of his service; the discount dealer cannot afford to if his margins are already cut to the bone. Further, has he the necessary knowledge? A good dealer is not just a trader, but a dedicated enthusiast himself.

It is the same with advice. You need to be able to approach your dealer with the knowledge that his advice will be based upon more than the desire to sell. A mail-order house hundreds of miles away will supply you with the goods, but it will not enter into lengthy correspondence about your needs and aspirations.

Briefly, then, my advice is to seek out a good dealer, and to be prepared to pay more than the absolute minimum: you will find that in the end this is the cheapest course, as well as the best. When you become more experienced, you may feel able to do without dealer back-up; until that happens, you need it.

You can—and many people do—go to a local dealer and take advantage of his demonstration facilities and advice, and then order from a discount house. That seems to me grossly unfair; if you do it and find yourself in difficulties, do not expect a welcoming smile when you go back to the dealer for help.

These days the buyer of any goods is safeguarded by legislation—notably the Sale of Goods' Act, 1893, as amended by the Supply of Goods' (Implied Terms) Act, 1973. Like all laws, they are not simple; but they do mean that the buyer has a direct claim upon the seller, as well as the manufacturer, of anything he purchases. All goods must be of 'merchantable quality' and be suitable for the purpose for which they are sold. If they are not, or if they break down, the buyer has the right to repair, exchange, or his money back—even, in some cases, to compensation.

These rights may be exercised against any seller, be he a local trader or a discount house miles away. It is, however, easier to go back to a local shop with faulty goods than it is

to send them away. No so-called guarantee card can lead a buyer to abrogate any of his legal rights, as used often to be done, and those rights remain unaffected even if the guarantee card is not filled in. Always obtain a receipt or bill of sale to prove the date on which equipment was purchased; in the event of meeting trouble or obstruction from a seller, it is best to consult a solicitor—one letter from whom will usually bring an offender to a more pliant frame of mind. You can also obtain help and advice from the Citizens' Advice Bureau and from the consumer organisations.

If you buy equipment, get it installed and find that it is not what you had hoped, you cannot then demand your money back. You must be fair to the seller as well as he to you, unless he misled you about what you bought. It all boils down to careful choice in the first place; and if you buy without consideration on the strength of some bright advertisement you have only yourself to blame, unless you can show that the advert falsified the actual nature of what you ordered. 'Let the buyer beware' is still a wise maxim.

Before buying, it is wise to read as widely and thoroughly as you can. Your local library will have a section dealing with hi-fi; start with simple introductions like this one, and progress to more technical monographs if you find that you can understand them. A basic knowledge of electricity helps! There are also periodicals, in which you can read articles about all aspects of hi-fi, as well as reviews of the latest equipment. In Britain, the most prestigious of these journals is *Hi-Fi News and Record Review*, published monthly. The high repute of this journal enables it to review equipment with total impartiality, and its contributors are all leaders in their field. The *Gramophone* is another journal of the highest repute, though it is primarily a review of the latest record issues, and insists upon strict standards of musicianship from its contributors.

Building from kits

Another possible path to hi-fi is to build it yourself. There are firms which supply kits of parts which you yourself assemble. This may sound impossibly difficult; but the manuals provided with the parts are so simple, and show you each step by means of clear diagrams, that the difficulty is not there: you are even taught how to solder. Since you do the work of assembly (some units do come pre-assembled if they are beyond the scope of the amateur) the kits are cheaper than factory-built models, but the best of them offer similar performance. There is quite a degree of satisfaction in doing it yourself; and this method is worth considering.

Second-hand equipment

Hi-fi devotees show a marked inclination to change equipment frequently. They do it by part-exchanging existing equipment for new—rightly or wrongly. As a result, dealers often have very good equipment for sale second-hand, and reputable ones will give a guarantee with it. Purchase of second-hand equipment from a good dealer need not be hazardous; but there is no need to underline the need for caution when approaching the private advertiser. Some journals—such as the *Gramophone*—offer a deposit system whereby your money does not reach the seller until you are satisfied with what you have paid for. The writer has himself bought second-hand equipment which has given perfect satisfaction, and also sold equipment about which he has received no complaint.

What item should begin your collection? The opinion of the writer is quite definite: the turntable.

3

Turntables

The choice of this article as the foundation of the system may seem curious. Not so: it is quite logical when we consider what the turntable does.

The requirements of a turntable are few and simple: it must rotate the record at a constant speed, and with no unwanted sounds added to the signal impressed on the record. Simple though these requirements are, they present formidable problems in engineering, as we shall see. But once a turntable has been acquired which fulfils them, it can be regarded as a more or less permanent servant. The writer has used a Thorens TD 124 (now obsolete) for at least ten years, and it is as good today as when it was first delivered. During that period, several amplifiers, pickups and pickup arms, to say nothing of loudspeakers, have been through his hands, but the turntable is still there, doing its quiet and unobtrusive duty. It is for this reason that I suggest you too begin here: whatever else you buy will be superseded; your turntable can still be there many years hence if you follow the servicing instructions given in the manufacturer's manual.

Faults

What are the snags with a turntable? They come under the headings of wow, flutter and rumble. These are descriptive terms: gramophone records, these days, are designed to rotate at either 33⅓ or 45 revolutions per minute. A turntable must rotate at precisely those speeds. If it deviate from them

notably, a change of pitch will be apparent: the pitch will go up if the turntable speed rises, or fall if it falls. No good machine varies speed greatly, but it may show small deviations, particularly due to fluctuations in mains' voltage.To cure these, all good machines are provided with a control which enables the speed to be minutely altered. Such checks should be made with the pickup tracking a record, as all pickups exert a small dragging force against the torque of the motor.

The test instrument is called a stroboscope, and it is supplied with the turntable either in the form of a disc which fits over the spindle which centres the record upon the platter or as a series of dots or stripes impressed on the rim of the turntable itself. The mains' voltage in Britain alternates at a speed of 50 Hz (and at 60 Hz in the USA); advantage is taken of this fact to space the dots or stripes on the stroboscope at such a distance from each other that when illuminated by an electric lamp (*not* daylight) the dots or stripes appear to stand still. If they drift gently in either direction, the fine tuner of the speed is adjusted to bring the marks to an apparent standstill. The turntable is then running to exact speed. Adjustments should always be made after the machine has been run at least ten minutes to bring it up to operating temperature.

The turntable is revolved by an electric motor, which has to be connected, or 'coupled', to the turntable platter. Usually the motor is first coupled to a pulley, which has a series of steps machined on it which give diameters to correspond to the range of speeds at which the machine is designed to work. The pulley has then to be coupled to the platter itself. This is normally done by means of an 'idler' pulley, which engages the stepped pulley on one side and the rim of the turntable on the other. A mechanical linkage imposes pressure on the idler pulley when the machine is in the 'run' position, so that the idler is made to rotate at a speed determined by the speed of the stepped pulley and the diameter of step with which it engages. Thus the 78 r.p.m.

speed, if fitted, will be achieved by the smallest diameter of the stepped pulley, and the 16 r.p.m. speed by the largest. In order to engage a particular step on the pulley, the idler has to be moved up and down in the vertical plane. This is also achieved by mechanical linkage.

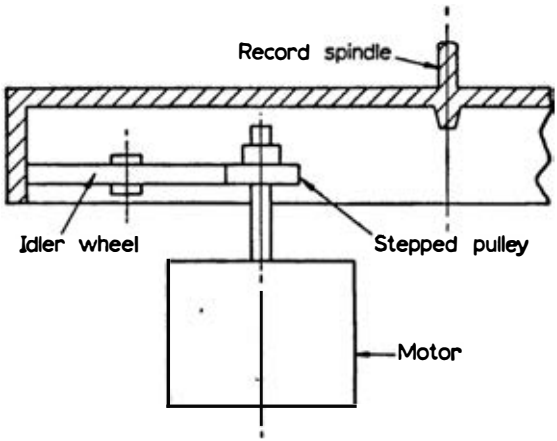


Fig. 4 Turntable transport: idler wheel and stepped pulley. In practice, the idler is provided with a sprung linkage to permit horizontal movement and accommodation to the different radii of the pulley steps.

An on–off switch starts the motor, and a selector switch engages the speed appropriate to the record to be played. A more recent design, now coming very much into favour, utilises a belt drive rather than the stepped pulley. This achieves a greater degree of mechanical de-coupling between the motor and the platter than can be achieved by the idler-wheel technique; and a little thought will make it obvious why that should be desirable:

Despite the greatest care in manufacture, the stepped pulley, the idler wheel and the platter itself cannot be perfectly concentric, and so there are variations—very small

indeed in the best machines—in the pressures exerted on each as they revolve. These variations in turn cause small variations in the speed of the platter, and with them variations in pitch. The platter is invariably a massive structure, so that it acts as a flywheel and tends to overcome small speed variations by its high inertia. Even so, a very small degree of eccentricity anywhere can produce audible results.

When the variations occur at low frequency, they produce an agonising effect known as 'wow', as the note heard wanders up and down around the nominal pitch. Some people are more sensitive to this effect than others; but quite a small amount of it is intolerable to most people. It is not usually apparent on staccato music or rapid passages, so that it should be tested by slow, sustained chords, but not confused with deliberate *vibrato* such as is commonly applied to violin, 'cello and other instruments. The ideal frequency for judging this phenomenon is about 3 kHz; but a good test record is one of the opening chords of Mendelssohn's *Incidental Music to 'A Midsummer Night's Dream'*, or slow, mid-range chords played on the piano. It is worth remarking that *recorded* wow is not so uncommon as it should be.

'Flutter' is the result of more rapid fluctuations in speed, and produces an overall roughness of reproduction, which in bad cases can be detected even on a recording of speech: a kind of gargling sound which is highly objectionable. No flutter should be audible from a good turntable.

Every table has to turn upon a bearing, and no bearing is entirely free from friction. Nor is any electric motor free from bearing friction, which must engender a degree of vibration. Any linkage, whether by belt or idler, operates through friction and thereby creates vibration. From this you will see that the problems involved in designing a turntable are very considerable. The motor is usually isolated by rubber mountings to reduce vibration; but the best guarantee is accuracy of manufacture.

This vibration is inevitably transmitted to the sensitive pickup, which reproduces it as an audible rumbling sound

through the loudspeakers. This rumble can, in a bad case, be audible throughout the music (and some of the BBC's turntables are that bad!); less bad cases become audible only in quieter passages. A good turntable should produce no audible rumble—though, as with wow and flutter, absolute perfection is not to be had.

A new generation of turntables is now coming into use, in which both idler and belt drive are eliminated, and their problems with them. In the new design, the spindle on which the record is centred is a continuation of the spindle of the motor itself. Speeds are varied by switching the number of poles in the motor, providing the necessary $33\frac{1}{3}$ or 45 r.p.m. speed, and fine adjustment by an electro-mechanical means. These turntables set a new standard in performance, and their wow, flutter and rumble is so low as to be virtually non-existent. At the moment, however, they tend to be expensive, and one should not suppose that a good-quality machine using idler or belt drive is out of date and useless.

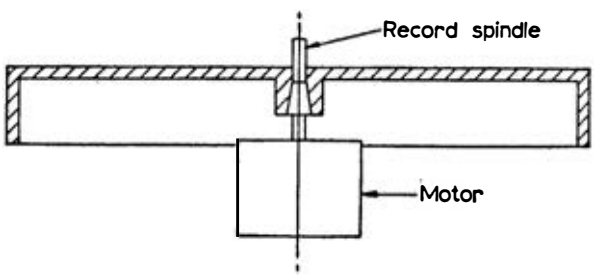


Fig. 5 Turntable transport. In the direct-drive system the record spindle is a continuation of the motor spindle. Rumble, wow and flutter are greatly reduced.

Rumble is much more than an annoying noise. Rumble has frequencies, and can generate harmonics which interfere with the sounds being reproduced at higher frequencies. This is a form of distortion, and the difference in overall

clarity on changing from a machine with an unacceptable degree of rumble to one without is a revelation.

There is a further factor: any instrument connected to the mains is liable to pick up the 50 Hz hum of the alternating current supplied by the mains. Again, this is not just an annoying sound, but a source of distortion. Not all turntable motors are free from it, nor are they sufficiently screened to prevent hum being induced into the pickup—and some types of pickup are more susceptible than others. Hum may be caused by faulty wiring or installation, which gives another good reason for employing a competent engineer to make the installation in the first place.

The amount of wow, flutter, rumble and hum generated by a turntable should be declared in the specification of the unit, and the way they are expressed leads us to define a concept which occurs frequently in audio literature.

Signal-to-noise ratio

All audio signals contain a wanted and an unwanted element: the wanted one is the sound being reproduced; the unwanted one any noise generated by the equipment itself. Special test apparatus can separate these two and measure them in relation to each other. The loudness of each can be expressed as a ratio of the other: the signal-to-noise (s/n) ratio. We are all familiar with the fact that a weak radio signal, as from a distant transmitter, is accompanied by a lot of hash and noise, and sometimes, as the signal strength fluctuates, the noise can rise and totally swamp the signal. With good audio equipment, nothing remotely approaching this condition should ever be experienced.

The loudness of both signal and noise is measured in a unit called the bel. As a whole bel is too large a unit for our purposes, it is divided into 10 decibels (dB); the amount by which the signal exceeds the noise is expressed in decibels, and the noise is quoted in decibels below the signal ($-x$ dB). 2 dB is the minimum deviation in sound level which can

normally be appreciated on test by the human ear, and the scale is logarithmic and not arithmetical (i.e. 4 dB is not twice 2 dB but 1·6 times); a good turntable, with a *s/n* noise ratio of —50 dB—a typical figure—represents a virtually silent background to listening, so far as the turntable is concerned.

Wow and flutter are measured as a percentage deviation from the norm. This percentage should be very small—0·1% or less. The ability of the individual to detect wow, in particular, varies greatly; but a percentage as high as 1% will be intolerable to most people. Again, a special test instrument compares the steady signal from a generator with that reproduced by the turntable.

It will be clear from the foregoing that the engineering standards required to produce a good turntable are exacting, and cannot be built in to a cheap machine. My advice, therefore, is to begin your hi-fi rig with a high-quality turntable. On that firm foundation you can build with assurance. How the turntable should be mounted will be discussed later (pp. 84ff).

Speeds

Many turntables still provide four speeds—16, 33⅓, 45 and 78 r.p.m. If you have a collection of old 78 r.p.m. records, you will of course need that speed; if not, don't seek it. 16 r.p.m. is useless, as only one record was ever issued at that speed, which was intended for speech recordings such as books for the blind. 45 r.p.m. records are common, now mainly or entirely in the pop field. The vast majority of records are 'thirty-threes'. Recently the 78 and 16 speeds have been dropped, leaving only 33 and 45. This is sound; and for many people 33 only would suffice. The reduction in number of speeds simplifies design and makes for higher standards in *s/n* ratio, and wow and flutter figures.

Auto-changers

The attentive reader may have noticed that no mention has been made of auto-change turntables. These are devices on which a small pile of records can be placed, which are automatically changed at the end of each—though only the upper side of each can be played in this mode. Most make provision for manual operation when a work is being played which extends over more than one side.

The method of operation is this: on the run-out grooves of the disc a linkage, usually mechanical, trips a mechanism which raises the arm off the record, returns it to the rest position, drops the next record down the extended spindle, returns the pickup to the run-in grooves of the next side, lowers it and plays the side.

This operation involves the dropping of a disc upon the still-rotating surface of the one underneath, which damages the playing surfaces of both: also the linkage with the pick-up arm is bound to exert a dragging force upon the arm as it traverses the record. Manufacturers warn one not to use the highest quality pickups with auto-changers, and some produce pickups specially designed to stand up to the extra wear and tear involved in use with these devices.

While there is a place for these things in installations used in restaurants, discotheques, dance halls and the like, they should not be regarded as hi-fi turntables, even when used in the manual mode. They are popular, for some reason, in the USA—though declinингly so—and despite the attraction of not needing to change records so frequently they should be avoided by the seeker after hi-fi of the highest quality.

A further point against them is that they do not permit cleaning of the record surface before playing; and that, as we shall see, is essential. The highly respected Swiss firm of Thorens did at one time produce a very expensive auto-change unit claimed to eliminate the disadvantages of these

toys; but it was not successful enough commercially, and has been discontinued.

You are therefore recommended to acquire a manual turntable of the highest quality you can afford, and leave auto-changers severely alone.

There are, however, high-quality auto-changers—the Dual range is an example—which provide for automatic operation but can be switched to manual operation at will, and operate manually in ways which obviate the technical snags mentioned above. The buyer must decide if it is worth spending the extra money for a facility which he may never need.

Idler-wheel drive

If the turntable you acquire has an idler-wheel drive (and you are recommended to acquire one of the more recent designs if you can afford to), you must make sure that after you have finished playing the idler is disconnected from the rim of the platter and stepped pulley. If these be left under pressure contact, a 'flat' may be created on the circumference of the idler. This is a potent source of wow, which can be cured only by replacing the idler. The disengagement is effected by a switch on the turntable, so make sure that you always operate that switch, and do not just turn off the mains. The mistake is made most easily if the turntable is powered from a switched outlet on the amplifier: turn off the amplifier, and the turntable will come to a stop. You must then remember to switch off the turntable with its own switch as well. It is a good habit to turn off the turntable first, then the amplifier.

4

Pickups

The groove and the pickup

Take up a gramophone record and examine it. It consists of a flat disc of plastic (if modern) or of shellac (if an old seventy-eight) which is cut with a single continuous groove from the outside circumference towards the centre. Round the outer edge there is a blank band, with no more than a 'run-in' groove on it, and in the centre there is another blank band, with a continuous groove cut in it so that when the side has been played the 'gramophone needle' remains in it. Inside that is the label, describing the programme on the record, and giving details of the manufacturer, serial number and the like.

In the days of the old, acoustic gramophone, the needle (in those days it was precisely that) traced the record groove, and was made to vibrate from side to side by the modulations impressed in it. This purely mechanical movement was transferred to an arm which connected at one end with the needle-holder and at the other with a diaphragm made of mica. This diaphragm was therefore set into vibrations corresponding more or less accurately to the movements of the needle. In doing so it moved air, and set that into sympathetic vibrations. In other words, it became a sound source of the kind we were discussing in the first chapter.

However, being small—perhaps 2 inches in diameter—and being moved over a very short distance, the diaphragm did not make very much noise: the sound needed amplification. This is received from a horn coupled to it; the 'sound

box' as it was accurately called, was held in the mouth of the horn by a bayonet fastening, and the sounds from the diaphragm were amplified by the horn. Originally this was a metal trumpet, but in time the design was improved to a folded wooden horn—folded, that is, within a cabinet.

The most advanced design of this kind was the EMG hand-made gramophone, invented by E. M. Ginn, which utilised a very large fibre horn of scientific design and produced a quality of sound which even today is remarkable. This machine remained the summit of hi-fi until electrical recordings came in, and with them the end of the sound box coupled directly to a horn.

But how does the groove get on to the record? By the exactly opposite process from replay: the sound source is made to activate a 'cutter', which therefore vibrates in sympathy with the sound source. Today, the sound source will be a series of microphones plugged into an amplifier; but in earlier days it was a directly coupled horn. The cutter, or cutting stylus, is made to traverse the record, cutting modulated grooves in accordance with a very accurate mechanism which ensures correct separation of the grooves, the number per centimetre and the like.

Thus, in the modern process, the original sound is converted into an electrical voltage by the action of the microphones, and that electrical input is amplified and made to drive the cutting stylus. In other words, sound vibrations are transferred from one form of energy to another; devices which do that are called 'transducers'. The amplifier, utilising electrical energy to produce mechanical movement of the cutting stylus, is a transducer.

With modern records, the cutting of the first record is only part of the process: from the original plastic disc is made a 'stamper', which is then used to stamp out numerous copies of the original. Careful control is exercised to make sure that the stamper is changed for a new one before it shows signs of wear and begins to produce inferior copies. The production records are usually made of vinyl, which

can reproduce the extremely tiny and complex movements of the cutting stylus to near-perfection. Research is constantly carried out by the major companies to seek ever-improved materials.

Monophonic records naturally carried only one channel of information; and the tracing of this information required only that the stylus should move in the horizontal plane. The mono pickup, that is, had horizontal 'compliance' only. For stereo we need two channels of information, and the second channel is ingeniously contrived by having both cutting and reproducing styli move also in the vertical plane, necessitating a vertical as well as a horizontal compliance of the stylus. This is one of the most important parameters of a stylus, and is the reason why a stereo record must not be played, even once, with a mono stylus. If it is, the record will be irreparably damaged in its delicate grooves. There exist mono pickups which are described as 'compatible' because they are provided with a degree of vertical compliance, and enable a stereo record to be played on a mono machine. These devices, however—mostly of the ceramic type—do not come within the scope of hi-fi and will be ignored.

The pickup therefore 'tracks'—that is, follows—the modulations in the record grooves, and in doing so makes extremely rapid and complex movements in the vertical and horizontal planes at the same time. This purely mechanical movement is transduced into electrical energy. This is performed in one of two basic ways. Certain substances, such as Rochelle salts and some types of ceramic material, when cut into a plate shape, generate a minute voltage when flexed. The cheaper types of pickup use this principle and are called 'crystal' or 'ceramic' types. To the slip of crystal is attached a cantilever arm, on the end of which is fixed a jewel point. This arm-and-jewel assembly is referred to as the 'stylus'; and it is the stylus which makes contact with the record grooves. The modulations of the grooves move the stylus, which flexes the slip of crystal to which it is

attached, and thereby generates a small alternating voltage corresponding to the modulation of the record grooves: it is, that is to say, a transducer of mechanical into electrical energy. The voltage is transmitted by tiny wires to a series of pins which emerge from the back of the pickup-housing, and thence to the input of the amplifier. Stylus, crystal generator, wires and pins are housed in a covering, usually of plastic, which is mounted in the tone arm.

Crystal pickups, however, do not come into the hi-fi category: the need to flex the crystal generator makes the movements of the stylus too stiff: the movement of the stylus, referred to as its 'compliance', is not high enough or free enough for the best quality, nor are such devices, generally speaking, too kind to expensive records. The Decca 'Deram', which employs a 'decoupled' stylus assembly, represents the highest development of crystal design, but cannot—as its makers would readily admit—compete with the better magnetic types. In order that a crystal pickup may track the modulations of the record, it has to press rather heavily on the record surface, and this causes rapid wear: stereo records are delicate things.

We shall therefore say no more about crystal or ceramic pickups, and pass to the realm of true hi-fi with a description of the magnetic types. To understand these, it is necessary to recall some elementary physics. You will remember that if a wire is coiled round a core of iron and an alternating current passed through the wire, the iron core becomes magnetised: it is an electro-magnet, in fact. Conversely, if a magnet is passed to and fro within a coil of wire, an alternating current is generated ('induced' is the technical term) in the coil of wire. This simple device is the basis of the turbo-alternators which generate our mains supply.

These are also the elements from which those marvels of precision—the magnetic pickups—are created. They have styli very like the ceramic types: a cantilever arm with a jewelled point. But then the stylus produces movements either of a coil within a magnetic field (the 'moving coil'

types) or of a magnet within a coil (the 'moving magnet' types). There are other variants, such as the so-called 'variable reluctance' types; but they all reduce to the same principles. Naturally, the voltage generated by such instruments is tiny—an average of perhaps 2 millivolts; the amplifier steps up the voltage to a useful amount for driving a loudspeaker.

It will be seen that in principle a pickup is a simple idea; but the research required to produce the highest possible results, and the delicacy and precision required for the mass production of them, are prodigious; and that is why pickups are expensive. Let us look a little more closely at the requirements of a good pickup.

Pickup requirements and faults

As with all hi-fi components, a pickup must have a wide and smooth frequency response. Typically this will be from 20 Hz to 20 kHz without any deviation exceeding 2 dB. In other words, from well below to well above the range of human hearing, the pickup will reproduce every frequency at a steady level. It will faithfully follow the complex modulations of the record groove. This requires that it have a high compliance in both horizontal and vertical directions. It must also press upon the record as little as possible: the best pickups track at a pressure of not more than 2 grams (gm), and some will, in a suitable arm, track at a fraction above 1 gm. This should be compared with a pressure of several *ounces* for the old acoustic sound boxes and 'radiogram' pickups.

None of these features should cause the pickup to lose contact with the walls of the record grooves. Should it do so, the result is audible distortion and break-up of the signal, besides damage to the record as the pickup flies uncontrollably about the grooves, which in bad cases it may even jump. This ability to track has been called 'trackability', and this is now used as a measure of the performance of the pickup

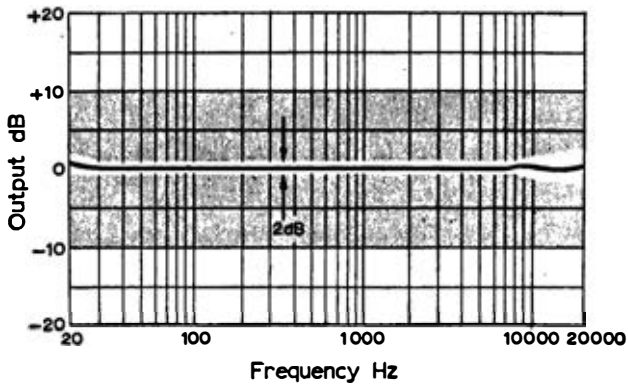


Fig. 6 Shure V-15 Type III pickup cartridge frequency response. This graphic representation of the audible spectrum illustrates the flat response curve that fits within the narrow limits of the response 'output envelope' (the unshaded area above) before it is shipped. The curve shown was made by a typical Type III, mounted in an SME arm, and tracking the STR100 test record.

(*Shure Electronics Limited, Maidstone, Kent*)

in this respect. Here a word of warning is in place: your records will be harmed far more by tracking at too light a pressure than doing so at slightly above the possible limit. Your pickup will be accompanied by a data sheet from the manufacturer which will tell you the limits within which the pressure should be set (how it is set we shall come to under 'pickup arms'). Always tend toward the higher end: one of the leading experts on pickup design, B. J. Webb, has given it as his opinion that there is at the moment no pickup which will, in *any* arm, track *every* record at a pressure of less than 1 gm. These limits will be surpassed; but at the present time, a pressure of between 1 and 1¼ gm is safest even with the best pickups and arms.

A good pickup should also have a very low distortion figure. Since a stereo pickup has to provide two channels of

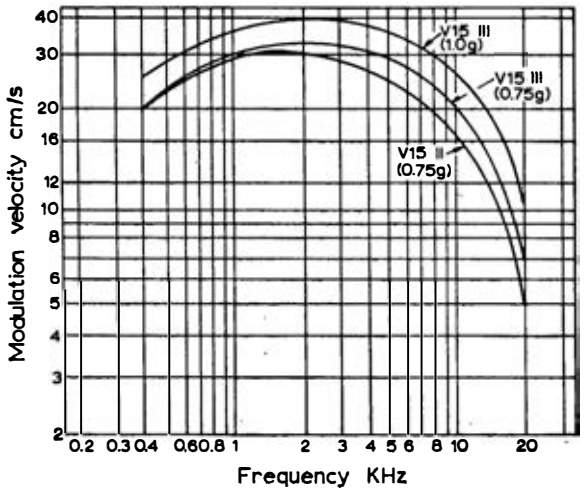


Fig. 7 Shure V-15 Type III. The chart above shows the Type III cartridge in the single, most important measure of overall cartridge performance—trackability.

Trackability measures the ability of the stylus to stay in contact with the groove modulation at a specified tracking force and across the total frequency spectrum found on records.

Here the new Type III cartridge is compared with its predecessor the V-15 Type II Improved. Modulation velocities are shown up the left edge of the chart: frequency range is registered across the bottom. The smoother the curve and the higher it is up the modulation scale at all frequencies, the greater the trackability.

Note that the Type III shows significantly greater trackability than the Type II Improved.

(*Shure Electronics Limited, Maidstone, Kent*)

information to the amplifier, these channels have to be kept separate. Absolute separation is impossible with existing designs: one signal always appears to a small degree in the other channel, a phenomenon known as 'cross-talk'. The cross-talk figure is again expressed in decibels, and varies

with frequency. The figures claimed for one of the leading pickups is better than 25 dB at 1000 Hz, and better than 15 dB from 500 to 10 000 Hz. Good stereo without good cross-talk performance is impossible.

The jewel point of the pickup is another very important part of the design. This is, in all good pickups, a tiny diamond, and no other type should ever be used: sapphires are still sold for ceramic types, but they wear readily and unpredictably, and should never be used. A diamond should last for many hundreds of sides, but it should be examined under a microscope every year, to make sure that there are no signs of breakup or wear. Good record shops provide this facility. Should there be wear, the stylus assembly should be renewed: a new stylus is much cheaper than a pile of damaged l.p's. The diamond is ground and polished to an extreme degree of accuracy, and centred precisely upright on the stylus arm. These are operations which call for almost unimaginable precision in manufacture, which is why styli are expensive—not because they are diamonds.

Originally the stylus was conical in shape; and those designed for playing mono records still are. However, it has been discovered that an elliptical, or 'biradial', stylus is better, and gives improved tracking and separation. The stylus thus lies *across* the grooves, the side in contact with the grooves being usually about 0·0002 inch and the broader plane 0·0007 inch. Imagine the precision required to produce a piece like that! The biradial stylus more closely follows the modulations on the record, as records are cut with a chisel-shaped stylus, and it also reduces what is called 'tracking error'.

To understand this last term, consider that the record revolves with a constant radius on the platter. The stylus which tracks it is attached to an arm, which also moves on a constant radius, but about a *different centre*, so that the arm is strictly tangential to the record at one point only, whereas the cutting stylus is driven strictly tangentially across the

disc it is cutting. The result of this is inevitably distortion. Provided, however, that the arm is correctly designed and fitted (pp. 45ff), the tracking error is extremely small and can be ignored, as it is undetectable by ear, though it can be shown by instruments.

It is important to consider in greater detail what happens to the stylus point when it is tracing the microgroove on the record. The movements involved in the reproduction of high frequencies are rapid and tiny—as rapid as 20 000 a second; those made in reproducing the lower frequencies are larger and less frequent. However, a 40-Hz note, though low, requires that the stylus trace forty times a second, which is still quite rapid! When the volume of the note rises, the amplitude of the waveform to be traced gets larger—though all these terms are relative to the very small size of the groove itself.

It will be apparent from this that first of all the movement of the stylus, both horizontally and vertically, must be as free as possible. This is referred to as 'high compliance' and, as we saw earlier, is one of the performance parameters in which crystal pickups are inferior to magnetic. Clearly, this compliance is connected with minimising the effective mass of the stylus tip; and this is one of the most important things about a stylus. As an example, the effective tip-mass of the Shure V15 Type III pickup is specified as 0·33 mg, which should be compared with 2·2 mg in the case of the less expensive—though still excellent—Shure MD3.

Now, in order that the full potential performance of the pickup shall be realised, it must be fitted to an arm which does not degrade its performance. Should the movements of the arm be stiff, or should it have a resonant frequency which interferes with the action of the pickup, even a superlative instrument like the V15/III cannot give of its best. Hence the pickup and arm should be regarded as a single unit, and no attempt should be made to use a high-quality pickup in a poor arm, though a good arm will always allow even an inferior pickup to do all it can.

In order to stay in the groove, a pickup must press upon the record. In the days when stiletto heels were fashionable on women's shoes, we all noticed the damage they inflicted upon, say, wood block floors. Indeed, it was calculated that a 7-stone woman putting her whole weight upon one stiletto heel was acting rather like a baby elephant! Much the same effect occurs when a tiny diamond traces a record with a pressure of a little more than 1 gm. A good deal of heat is engendered by the friction, and pressure and heat are the two things most calculated to damage a plastic surface of great delicacy. Therefore we need to have as small a pressure upon the stylus as is compatible with perfect performance. The arm plays an important part in this, too.

We must not forget that when the music reaches great climaxes the movements of the stylus, although on a tiny scale, become very large and fast. A poor pickup, indeed, cannot cope with them: it starts to get out of control, and to make very nasty noises resulting from 'mis-tracking'. As the art and science of recording have improved, greater and greater recorded velocities have been impressed on records, and pickup designers have striven to keep pace with these advances. There is a point of view which holds that the dynamic range of some recordings has got too wide: that is to say, the difference in volume between the quietest and the loudest passages on the records is too great. Indeed, there are recordings which are such that if the volume control be set at a comfortable level for the quiet passages, the climaxes become uncomfortably loud. Yet this range is considerably less than that which one hears at a symphony concert, which of course takes place in an auditorium much larger than a domestic room, however large that may be. This is a matter of opinion; and 'too wide' a range seems preferable to 'compressing' the recorded levels to some arbitrary limit.

The controlled behaviour of the stylus in the groove is greatly assisted by 'damping'—about which more will be said when we come to discuss the pickup arm. Damping

does two things: it permits the movements which are required, while restraining those which are not; and it allows of the removal of unwanted resonances.

The pickup has to be held down into the groove even on the loudest passages; but the pressure required to do that has to be as small as possible. The ability of a pickup to track at high velocities without misbehaving is called its 'trackability'; and that quality has improved enormously over the past few years. The tracking pressure should always be set for the loudest passages. Several pickups will track a great deal of music at pressures of a fraction of a gram; but it is important to remember that when a pickup mistracks, it is flying about uncontrollably in the groove instead of tracing it accurately. This process does far more harm to the record and the stylus than a pressure which will enable the pickup to do its work properly.

Choosing a pickup

As with all hi-fi products, choice is to some extent governed by taste. All pickups sound subtly different, and none is perfect. It is therefore perfectly legitimate to prefer the sound of one to that of another; and what one likes can only be determined by experience. Back once more to the dealer's demonstration room! It is, however, unreasonable to expect a pickup costing, say, £10 to sound as well as one costing £30 or more. Nevertheless, price is not the only criterion: your ear is the final arbiter. From what has been said above, you should preferably choose a pickup which will track at less than 2 gm, has a wide frequency response and good cross-talk figures.

Reviews in the better audio journals will inform you how a pickup shows up when rigorously and impartially tested by independent experts. Should the test sample fall noticeably below its claimed specification, mistrust it: the best audio products are conservatively rated so that they continue to meet their specification as they age. It is, however,

impossible to convey in words the *sound* of a pickup, and how that sound compares with that of others. Words like 'smooth', 'sweet', 'clinical', 'analytical' are often used but convey little. There is, however, a useful criterion: ease. If a pickup never suggests that it is about to make a nasty noise on climaxes of orchestral sound, or on *fortissimo* notes of the human voice, especially in choral music; if it can distinguish between the sound of oboe and clarinet, violin and viola; if it can stand up to perhaps the supreme test of making a piano sound like a piano, and does all these things *with ease*, so that one never needs to worry about its performance, then it is a good pickup.

Performance at this level is attained by the leading models in several ranges, any and all of which will give lasting musical pleasure. We all have our preferences, and I have mine; but it would do no good to tell you which I happen to prefer after listening carefully and for long periods to most of the best in the world. My judgement is no better than yours; my musical taste may be different from yours; my hearing will certainly be different from yours; the room in which I listen will be different from yours. Therefore, within the limits specified above, choose the one to which you like to listen, which never fatigues you (listening fatigue is one of the surest guarantees of the presence of distortion of some kind) and which presents the music as you like to hear it. You can then be confident that for some years you will be happy with it. One day you will come across a pickup—as happened to me some time ago—which is so much better than the one you are using that you must have it. That is the time to think of making a change, and not before.

Caring for your pickup

The stylus is one of the few parts of your gramophone which needs regular attention. It is a costly and delicate instrument, and deserves to be looked after. Should you fail to do

so, the result will be impaired and increasingly distorted reproduction. There is very little involved: it is a matter of keeping it clean. Later we shall discuss how to keep records in good condition, and doing that is the best guarantee of a sound stylus; but with the best will in the world not all dust can be kept from the record surface. This dust can build up on the stylus and form a hardening mass which impedes the proper contact of stylus with record.

You will be recommended to put nothing whatsoever on the record which leaves any deposit upon it. If you do, you can create a gooey substance in the grooves which can foul up a stylus in a very short time, and be very difficult to get rid of, as *a stylus must be touched only with the slightest possible force.* Regularly—and that means after any lengthy playing session—the stylus should be cleaned with a special brush (which will probably come with your pickup). I prefer a velvet stylus-cleaner such as that designed by the late Cecil Watts, who was the greatest authority in the world on the care of record surfaces. With the brush or velvet, *gently* stroke the stylus tip from behind forwards a few times: nothing more. Never be tempted to brush from the front of the pick-up backwards, or from side to side: if you do, you run a strong chance of damaging your expensive stylus. At most, brush at an angle of not more than 20°, again from behind forwards *only*. Make a habit of this simple precaution, and you will prevent the build-up of deposits; and that is a great deal better than trying to remove them afterwards. A bad case should be returned to the maker or importer for attention.

A magnifying glass of about X12 is useful for examining the stylus point for dust and the like (the stylus assembly can be easily and safely removed from the body of the pickup), but it is useless for determining the state of wear of the stylus: that requires a microscope. Today, with very light tracking pressures, styli wear only very slowly, and once a year your stylus should be examined by an expert. Good record shops and audio dealers have special microscopes for

this purpose; but if there be neither in your immediate district, deprive yourself of the stylus for a few days and return it to the manufacturer, who can do the job better than anybody else. Remember that a worn stylus damages the grooves of your records long before you actually hear any noise or distortion: I once, without knowing it, used a chipped stylus and ruined a record with one playing. Should you, by mischance, drop your stylus on a record or any part of the gramophone, have it examined before you use it again: it may be all right, but you cannot know, and the risk is not worth taking.

As a very occasional measure, you can lightly moisten your brush or pad with isopropyl alcohol, which can be obtained through a pharmacist. This should not be done as a routine, but only when your examination of the stylus point shows a tendency to clogging—which should not happen if you care for your records properly and regularly clean the stylus after use.

5

Pickup Arms

In the days of the old acoustic gramophone, the arm which carried the sound box was known as the 'tone arm', a description which had point, as the arm did indeed form part of the horn which amplified the sound from the sound box, and contributed significantly to its 'tone'. Today, the arm which carries the pickup does no such thing, so that 'pickup arm' is a better term for it.

Pickup arm requirements and faults

As in the case of the turntable, the requirements of the arm can be quite simply stated, but the engineering problems involved in achieving the purpose of the instrument are considerable. The arm holds the pickup in such a way that the pickup can track the record as accurately as possible, and with minimum interference.

That means, firstly, that the arm must exert as little force as possible upon the pickup, in any direction. Take, for example, the inevitable friction as the arm turns on its pivot. There is no such thing as a frictionless bearing, but we need as little friction as possible. These days the most frequent design is what is known as the 'unipivot': the arm itself rests upon a single point on a standard or mounting-arm, so that it moves upon only one, tiny, friction bearing. The bearing is designed from metals or a jewel which offer the freest possible movement; but such a bearing is a delicate and somewhat fragile thing, so that a degree of damp-

ing is exerted upon its movement, usually by means of a viscous fluid such as silicone grease of a very light type. A damping agent such as this offers virtually no resistance to slow movements, but acts with great speed should the movement be swift—as when the arm is lifted from the record, or knocked in some way. Thus the arm is highly frictionless when tracking, but is stable enough for the limited range of movements which it is required to perform. Other ways round the friction problem are minute ball-races, or a gimbal joint in which the arm is mounted in a circular ring bearing at two points only, and the ring bearing is attached to a standard by only one bearing. This gives lateral and vertical movement without torsional movement, whereas in the unipivot design torsional movement is limited by sleeves. Fig. 8 shows the differences. All

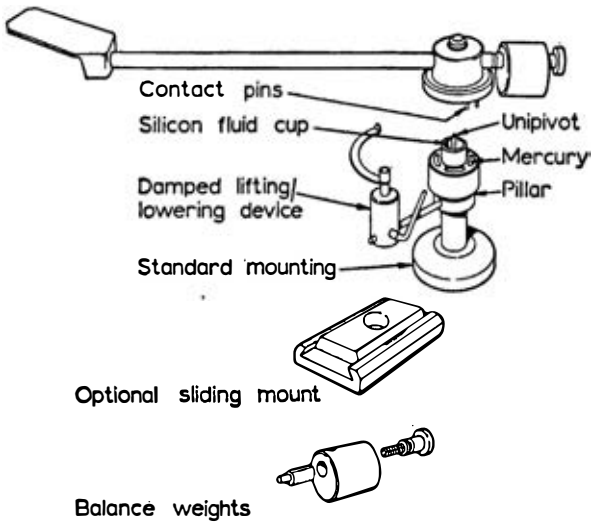


Fig. 8 Structure of a pickup arm: the KMAL M9AB Mk II, a unipivot design utilising mercury baths for contact between pickup and leads-out

(Keith Monks Audio Ltd, Fleet, Hampshire)

arm bearings are self-lubricating, and on no account should any ordinary oil be applied to them; servicing an arm is a delicate operation which should be entrusted only to the manufacturer or his authorised agent.

We have seen that tiny wires carry the output voltage of the pickup to the amplifier. These wires terminate in small pins on the back of the pickup; these connect to similar wires through the tube of the arm. In turn these are led through the bottom of the standard of the arm and thence to the input of the amplifier. However delicate these wires may be, they are bound to flex as the arm traverses the record. Though tiny, this force does add to the drag exerted by the arm against the movement of the pickup; and the best designs go to great lengths to ensure that the type of wire used and its routing minimise drag. In one design (by Keith Monks Audio) the wires are terminated by small pins which project downwards from the arm, where they are immersed in four baths of mercury. This produces very low friction indeed; but of course it does mean that whenever the arm is to be removed from its mounting the mercury must first be drawn off, or it will spill away. The arm is therefore unsuitable for any mobile use without special precautions being taken.

We now have an arm which moves as freely as possible across the record as the groove draws the pickup towards the centre. But this movement is itself the source of our next problem. As we saw (p. 36), the record and the pickup arm do not revolve about the same centres. Hence, if the arm is set up so that it is strictly tangential to the record at the first groove, the stylus point will move further and further away from that optimum position as it gets nearer to the centre of the record. It thus becomes progressively more difficult for the stylus to trace the modulations in the groove accurately, particularly as the cutting stylus is driven across the original master on an arm which ensures that it remains tangential throughout. One has to remember here that this cutter is *creating* the modulations, and is therefore *driven* across,

unlike a replay pickup, which is led as gently as possible by a pre-existing groove. The two operations are totally different.

The result of the twin-centre operation is that we get what is called tracking or tracing error, which is a source of distortion, especially towards the end of the recording where, unfortunately, we often get climaxes of sound. This error has to be minimised; the commonest way is to offset the end of the arm which carries the pickup. These days most arms are made of an alloy tube; either it is curved into an elongated S-shape (as on the famous SME arm) or it is straight for the greater part of its length, but the end which carries the pickup is angled in towards the centre of the record (as in the KMAL arm with the ingenious mercury-bath contacts). If this be done scientifically (and the calculations are very exact in the best arms) and the arm be mounted in the precise position for minimum tracing error, that error is reduced to the point where the distortion created is of such a small order as to be inaudible even at the end of the record. The mounting of the arm in relation to the platter is therefore of crucial importance.

How is this done? The arm is inserted through a hole drilled in the board which is to support it. This is either the same mounting-board as the turntable, or second smaller one in the same plane. The position of this hole is important, and you will find that the maker of your turntable will supply a template which indicates not only the exact shape of hole necessary to take the turntable itself, but also the position of the hole required for mounting the arm. This aperture may be a circular hole, or an elongated slot, according to the design of the arm. It is as well to make this hole slightly oversize, so as to allow small adjustments. When positioned, the arm is held down firmly either by screws or some form of keyed clamp—as in the case of the Decca Universal arm. So mounted, the arm will be close to the position for optimum tracking. However, all arms designed to accommodate more than one make of pickup

make provision for the fact that models differ in physical size and in their relation to the exact position of the stylus point—the thing which does the actual work of tracing the groove.

All arms, therefore, incorporate adjustments to cope with these slight variations. The standard on which the arm is mounted allows it to be slid to and fro over a small distance, and then locked in the correct place. This critical—and it is really critical—point is found by means of a simple protractor which is supplied by the maker of the arm. This, made of card or thin plastic, is a strip which has at one end a hole to fit over the spindle of the turntable, thus mimicking the placing of a record. It is ruled with parallel lines; on one of these is a tiny hole, into which the pickup point is lowered (do this on top of a record so as to avoid contact between the stylus point and the mat on the turntable). The 'shell' which carries the pickup is then observed from directly above, and the sliding adjustment is used to bring the edges of the shell into position parallel with two of the lines on the protractor. The stylus point is then in the optimum position, and the adjustment is carefully locked, and a check made to see that the optimum position has not been lost. Tracing error is then at the minimum, and should produce no audible distortion. Once made, this adjustment should hold permanently and can be forgotten.

Various attempts have been made to design an arm which would remain tangential to the record throughout the length of the groove. Some had quite a vogue in the days of mono and heavier pickups, but all involved some form of articulation which was bound to add friction through the additional pivot(s) and most of them have disappeared. Two, however, remain: the Garrard 'Zero' arm, and one by Bang and Olufsen which travels on an arm very similar in conception to that used for cutting, i.e. a straight arm behind the turntable, with the pickup literally floating across the record. This design is a piece of exquisite engineering, and consequently very costly. Further, at the moment of

writing, it will carry only pickups designed by the same firm and is therefore not truly 'universal' in application.

Adjustments

The adjustment we have just discussed is not the only one needed: setting up the pickup is undoubtedly the most tricky part of installing hi-fi. The pickup must track the record in such a way that it is precisely parallel to it. This is necessary because pickup designers follow agreed standards of tracking angle, and serious departures from that angle will cause distortion (how often we have to mention that word!). You will be told in the literature accompanying your pickup which of the surfaces—top or bottom as seen from the side—should be the basis of this adjustment. You then place a record on the platter, since it is the playing position which matters, and use the height-adjustment provided on the pickup standard to raise or lower the arm until the exactly parallel position is achieved. The arm is then again locked into position. It helps here if one positions a piece of white card or paper behind the pickup. All these adjustments require good light from the side such as that provided by a lamp of the Anglepoise type.

The stylus must also be strictly upright in the vertical plane. If it is tilted in either direction, the all-important contact between groove and stylus will be incorrect, and again introduce our old enemy distortion. Pickups provide a means whereby the part which holds the pickup shell (or sometimes the whole tube) can be swivelled. To achieve the optimum position, it is best to place a small mirror on the platter in place of a record, and lower the stylus point on to it—which will cause no harm if done gently. One can then see the front of the pickup and the stylus assembly, together with an upside-down image of them in the mirror. Comparison of the two images shows at once if they are not parallel, and also which way to adjust. In the correct position, the mirror-image is identical to the actual pickup.

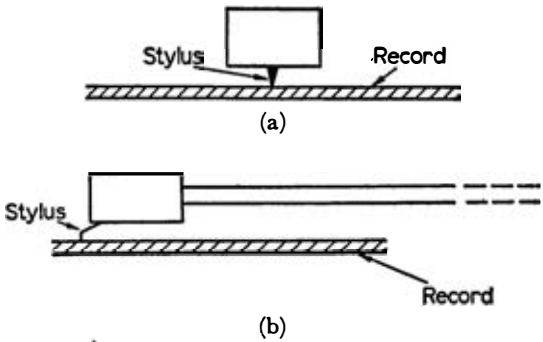


Fig. 9 Critical pickup adjustments: (a) the stylus must make a true vertical to the record surface; (b) the pickup must be parallel to the record surface.

Even very tiny errors are easily seen by this simple means. An actual record gives an image, but much dimmer and less-easily read than a mirror.

You may well ask if all this fiddling about is really necessary. Would not an approximation be good enough? The answer to that is a definite and unqualified no. Years of research have gone into achieving the reproduction quality laid out in the specifications supplied with your equipment. Those specifications presuppose certain conditions, and apply only if those conditions are met. The adjustments noted here are part of those conditions: fail to observe them, and you will get inferior results for which you must blame yourself, not your equipment. In fact, these adjustments are far easier to carry out than to describe; but if you find them beyond you, call in the services of a good dealer to make them for you: he has done them countless times.

The operations we have been discussing apply only to arms of the 'universal' type—that is those designed to accommodate any type of pickup. There are a few—of which the Decca is perhaps the best-known—which are

designed to work only as a complete arm-and-pickup assembly. That does make fitting simpler—though it still has to be precise—but it has the disadvantage that, should you change your pickup for another make, you have also to change your arm, whereas the universal types are merely adjusted for the new pickup.

If you think about it, you will appreciate at once that if, for example, the stylus is not upright in the groove it cannot track both channels accurately: the result is bound to be distortion. The same is true if it fails to lie, so far as possible, exactly across the grooves. So all this jiggery-pokery is a necessary hurdle, which should only need to be negotiated once for each combination of pickup and arm.

We have so far assumed that your pickup and turntable are purchased separately. There are, however, a good number of turntables which come ready-fitted with an arm. The arm has still to be adjusted for the type of pickup you choose, but the actual mounting of the arm is done for you. It is even possible to buy turntable, arm and ready-adjusted pickup all together, which is very nice if you are content with the collection offered. However, as transit may have upset some of the adjustments, do check before you use!

We are not, I fear, at the end of our adjustment problems yet. The tracking force of the pickup has still to be set. We saw that there is a range between approximately 1 and 2 gm over which the tracking force of the best pickups in the best arms may be set, and it was pointed out that too light a tracking force is more dangerous than one slightly greater than the minimum you can get away with (pp. 38–9). All arms are provided with a means of adjusting the tracking force. This was once done by springs, but nowadays the arm is provided with a counter-weight at the end opposite the pickup and behind the pivot. The general method—the detail varies with the arm—is that one balances out the arm, with pickup in place, until it rides level, with no tendency to swing up or down. This is the zero setting. The desired force is then applied by calibrated movement of the counter-

weight. The settings thus indicated are, on the highest-quality arms, very accurate; but it is possible to check this by reference to a stylus pressure-gauge, which is a miniature balance or scales. Once again, if your dealer be a competent audio engineer, he will have a gauge, and will make sure that you are tracking at the preferred pressure when he sets up your arm. See how valuable a good dealer is!

And finally we come to the question of 'bias' or anti-skating force. One can obtain a blank disc—that is, a record with no grooves on it and a polished surface like the part of the record between the end of the grooves and the label. (This device, by the way, acts as a handy mirror for setting the vertical angle of the pickup.) When the turntable is revolving it sets up centrifugal forces just like those which operate on a car wheel when it is revolving, though much smaller. But a gramophone record lies flat, so that when the pickup is lowered on to it—and this can be clearly demonstrated with a blank disc—the pickup is pushed towards the outer edge of the record. There is *no need* to try this experiment; but if you do, take good care that the pickup stays on the record, as it may be irreparably damaged should it slide off. This force is exerted whenever a record is played, although it is not strong enough to overcome the resistance of the outer side of the groove; but it is obvious that that outer groove is being tracked at greater pressure than the inner side. This results in distortion, and also in greater wear on the stylus on that side, as well as on the record. It should therefore be overcome.

Years ago, that great authority Percy Wilson, in his *Gramophone Handbook*, described a method, using a blank disc, whereby the motor-board was tilted until the stylus remained motionless no matter at what point on the disc it was lowered. Since then, and particularly with the development of stereo discs, it has been shown that such a correction is excessive, and that moreover the degree of anti-skating bias ideally should vary with the point on the record which the stylus has reached. The ideal correction cannot

be achieved, and a compromise must be aimed at. The manufacturers of pickup arms have done a great deal of research on this matter, and you may well find that they are able to recommend a degree of bias for your pickup in their arm. If not, the technical correspondents of the audio periodicals can often be helpful. Failing all such assistance, you can acquire a test record such as the Shure 'Obstacle Course' (these test records are useful for many purposes, and one is well worth acquiring) which contains a series of recordings, in increasing degrees of modulation. By playing these bands, and adjusting the bias to give the best possible rendering—i.e. the setting which gives minimum audible distortion—you can arrive at a satisfactory bias setting.

All good arms provide for this adjustment. The commonest method is by a very thin nylon thread which is attached to the arm and passes over a freely running bearing, with a small weight attached to the free end. By varying the position of this thread in relation to the pickup arm one can provide an adjustable anti-skating force. This method was originally described by John Crabbe, editor of *Hi-Fi News and Record Review*. In the unlikely event of your arm's not being provided with bias adjustment, kits can be obtained which supply the necessary components. Another, and more elegant, method is a magnetic bias. In this the arm is provided with an adjustable collar which can be moved nearer to, or farther away from, a magnetic field, thus increasing or decreasing the anti-skating force. It has this advantage: the thread-and-weight method must involve a degree, though slight, of friction as the nylon thread passes over its bearing; the magnetic method is friction-free. The weight-and-thread method, however, is still adopted by the makers of the SME arm, which is recognised as one of the world's finest.

Although you may have found this chapter a little daunting, do not be put off by its seeming difficulties. All the necessary steps will be fully described in the manual which accompanies your arm, with clear illustrations and

photographs which show exactly how to proceed. The generality of the descriptions given here make them seem complicated; but if, like me, you are no mechanical genius, get the job done by somebody more competent. Once you have seen it done you will do it yourself quite happily next time.

Raising and lowering the pickup

In former days we blithely lowered and raised the sound box by hand onto or off the record. With modern equipment, not even the steadiest of hands should be entrusted with this task: you will in time make an error and drop the arm, with consequent damage to the stylus, the record or both; at best you will render the first few grooves noisy. A mechanical means of raising and lowering the arm is essential. These devices are usually pneumatic or hydraulic in action, and consist of a piston within a cylinder, controlled by a small lever. The pickup is aligned over the first groove of the record, or over the run-in groove, the lever is swung over, and the pickup settles down into the groove with a light and smooth precision no hand can attain.

A raising-and-lowering device is commonly built into precision arms, and presents no difficulty beyond the possible need to adjust the height to suit one's own conformation of equipment. If no device is provided, add-on fixtures, such as the Ortofon 'Hi-Jack' can be obtained. Fitting directions come with the device, and basically consist of drilling a hole to take the piston, and adjustment of the height of the friction arm to suit conditions. The extra expense is well worth while.

Most manufacturers also provide a rest for the arm when it is not in use. This prevents the accidental knocking of the arm across when damp-dusting the turntable and inside of the cabinet, or other accidents. The arm should always be returned to its rest when you finish a session; and this position is also ideal for cleaning the stylus point (pp. 39–40).

6

Amplifiers

We have seen that the action of the pickup transduces the modulations of the record groove from a mechanical movement into an electrical voltage. This voltage is very small: a few thousandths of a volt (millivolt) at most on average. This is much too small to drive a loudspeaker and has therefore to be increased or 'amplified'. Hence the need for an amplifier, by which the tiny signal from the pickup is stepped up to an output of many watts (W)—as many as 50 or 100 W in each channel in some designs.

Ideally, an amplifier, like all other hi-fi components, should neither add to nor subtract from the signal it receives: it should only augment it, and be itself transparent. Good modern amplifiers come very close indeed to that requirement but, as in all human endeavour, not quite. All amplifiers introduce a certain degree of distortion, and it is time to look a little more closely at what that means.

Frequency response

We saw when discussing pickups that a wide and smooth response is needed to every frequency within and beyond the audible range. In this respect the amplifier is the best performer in the chain, and should deliver all frequencies at equal power through a range of, say, 20 to 25 000 Hz which in practice means that there is no deviation at any frequency of more than 1 or 2 dB. This specification is reached by all the best modern amplifiers, and should

present no problems to the purchaser. However, it is as well to read an independent test report to make sure that the model which appeals does in fact conform to this high standard.

Hum and noise

Like all electronic assemblies, amplifiers generate a degree of hum and noise, and the problem is made worse by the very high degree of amplification called for by the best pick-ups, which unfortunately have a very tiny output. The thermionic valves which were formerly used for audio applications were all noisy to a small degree. Naturally the noise becomes more apparent as the degree of amplification—often referred to as the 'gain'—is increased. Transistors also are inherently noisy; but as with valves, careful design and choice of materials can minimise it. So once again we have two signals: the 'wanted' one, which is the music, and the 'unwanted' one, which is the hum and noise. These can be compared by test instruments, and the ratio between them expressed in decibels. In a good amplifier that ratio, from the pickup input, will be in the order of −60 dB, which means that even in the quietest passages of music no unwanted sound will be audible from the listening position. Indeed, with the best amplifiers, only a 'breathing' sound will be heard from the loudspeakers when the volume control is fully advanced with no signal passing into the amplifier. In other words, hum and noise, though inevitably present, should not constitute a problem.

Harmonic distortion

Strike a note on the piano, and you will hear a characteristic sound. It is recognisable as the sound of a piano because of the nature of that instrument: a clarinet will sound quite different even when making a note of the same pitch on the scale. These notes, as we saw briefly earlier on, are not

simple, pure sounds like those obtained from an audio generator: what we hear is a note called the 'fundamental' and a series of 'overtones' or 'harmonics' which differ in power and give to each instrument its characteristic timbre and character. Hi-fi reproduction requires that these harmonics, and only they, be transmitted by the equipment.

If an amplifier or pickup (or microphone or radio receiver) alters the harmonic relationships of the original note, the result cannot be true. An amplifier may not transfer the original harmonics in precisely the strengths in which they were originally generated. That is to say, it is adding to, or taking away from, the original signal; and this is 'harmonic distortion'.

Amplitude distortion

When a signal applied to an amplifier changes in intensity, the amplifier should faithfully follow that change. If it does not, it is introducing a form of distortion called 'amplitude distortion', the effect of which is much the same as harmonic distortion. One result will be 'intermodulation', whereby components unrelated to the original signal are added to it by the amplifier itself. The differences in these forms of distortion are somewhat subtle, and need not trouble the beginner. The point to remember always is that the ideal amplifier would change nothing, but merely amplify what comes into it (including nasty noises if they are part of the signal!). None does that perfectly: there is always an 'unwanted' signal as well as a 'wanted' one. These can be separated out by test instruments and expressed as a percentage which, in good amplifiers, is very, very small. One manufacturer has demonstrated his product by passing a signal through a whole series of his amplifiers. He defies anybody to hear any difference between the signal from the first and last in the chain.

Gradually, design improvements are bringing distortion to lower and lower levels. If one amplifier sounds different

from another, all other components of the chain being the same, there is something wrong with one of them. The modern amplifier has come very close indeed to being the ideal, transparent medium of amplification and nothing else. It is many years since H. J. Leak first demonstrated what was then thought to be impossible: an amplifier with only 0·1% of harmonic distortion. Today, standards much higher than that are the accepted norm.

An amplifier consists essentially of two parts: the pre-amplifier and the power amplifier. In the days of valve amplifiers, these two parts were usually physically separated into two different instruments. One reason was that the output valves generated a considerable amount of heat, so that it was convenient to have the power amplifier at a distance from the rest of the equipment, in a well-ventilated part of the cabinet. This arrangement also helped to avoid hum pickup from the output transformer(s) which were necessary to match the high output impedance of the valves to the relatively low impedance of the loudspeakers to be driven.

With the universal adoption of transistors, few amplifiers are now divided into two units—one notable exception being the Quad, which still follows the older practice. In most cases, preamplifier and power amplifier are housed in the same cabinet, but remain functionally distinct.

The preamplifier receives the signal from the source—pickup, radio tuner, tape-recorder, etc.—and provides switching from one to the other. It also provides the correct impedance-matching (p. 62) for the different inputs, and makes provision for tone controls and filters—the function of which we shall come to in a moment. Discs are cut according to a standard known as RIAA (Record Industry Association of America). For technical reasons, it has been found best to make the recordings with a degree of emphasis at different parts of the frequency spectrum and to arrange replay with precisely the opposite emphasis. Thus in recording the treble frequencies may be boosted, and on replay restored to normal balance. Measures of this

kind are referred to as 'record (or replay) characteristics', and it is necessary for the pre-amplifier to provide the correct RIAA characteristic for replay. The extent to which it does so accurately is always examined by technical reviewers. The preamplifier, that is to say, passes to the power amplifier a signal equalised, and modified by tone controls if the user so wishes. This signal is still at a comparatively low power level, and the power amplifier has to step this up to a value sufficient to drive the loudspeakers.

Even this simplified account of what goes on in the amplifier will show that the task performed by the amplifier is complex; and it is by now perhaps unnecessary to add that each stage in the process opens the door to distortion. It is in this respect that designers have excelled themselves by, amongst other things, the extensive use of what is called 'negative feedback'. You may well have experienced the distressing effect of 'positive feedback' when the output from a public-address system is such that the microphone picks it up, passes it through the amplifier again, picks up that signal, amplifies it and so on, until we get 'howl-back'—a very unpleasant whistling howl. This persists until the gain of the amplifier is reduced to the point where the 'positive feedback', as it is properly called, ceases.

Negative feedback, as its name implies, is the reverse of this process. Part of the signal is tapped off, and fed back to an earlier stage in the amplifier in anti-phase—an expression which will be made clearer when we come to explain the action of loudspeakers. The effect of this is to reduce distortion and flatten frequency response, but it also carries a degree of reduction in power. It is by electronic wizardry of this kind that the distortion of the modern amplifier is so astonishingly low.

The facilities of the amplifier

In actual use, however, an amplifier does more than just amplify. To begin with, we often need to vary the amount

of sound which we generate within the room. This is done by means of the volume control, by which we can vary the sound from a whisper to the maximum of which the system is capable. Cheap amplifiers sound very nasty when used towards maximum power, so that another requirement of a good amplifier is that it shall remain virtually undistorted throughout its power range. You will therefore find, in specifications and technical reviews, figures quoted which show how much—or more likely how little—distortion is increased at very low or very high levels of power. Transistorised amplifiers originally had a tendency to increased distortion at low power levels—a fault which has now been rendered insignificant.

Tone controls

Were all records perfect, nothing more than a volume control would be needed. Regrettably, they are not. Nor, in particular, are loudspeakers, for reasons we shall come to later. Further, we do not all like exactly the same balance of sound: some like their music 'toppy', others like a hefty bass. These matters of taste are entirely for the individual; and the purpose of tone controls is to allow the user to vary the sound: the treble control will vary the intensity of the upper frequencies, usually in the region of 10 kHz, by about 10 or 12 dB in either direction. The bass control does the same for the lower end. The design of tone controls has been the subject of much research, since the act of varying signals in this way can be a source of distortion.

Filters

These are tone controls of a special type, which operate at fixed frequencies. A low-pass filter admits all frequencies up to a certain point, and then attenuates those above that point; a high-pass filter does just the opposite. The cut-off is not sudden: the effect is to attenuate the unwanted

signals by a degree of 'roll-off' which is expressed in terms of dB per octave. Obvious uses of filters are to tame discs which have a high hiss level, by low-pass filtering; and the so-called rumble filter, which sharply cuts off frequencies in the region where turntable rumble is likely to be troublesome.

Amplifiers vary in the degree of versatility of filtering which they offer: some have none, others have one or more fixed filter points which can be switched in or out, a few have elaborate filtering systems which permit alteration of the sharpness of the cut-off by means of what is called a 'slope' control. An example is the celebrated Quad amplifier, which has a number of filter frequencies and a slope control, and even a 'cancel' position by which the effect of any filtering can be compared with the unfiltered signal.

The facilities you need depend very much upon your own ears and your own needs. The purpose of filters is to transform an unacceptable recording into a tolerable one—a process which the writer has not found too successful. However, there are experts who will not tolerate any amplifier without a full range of filtering facilities. Should one have a collection of cherished old recordings, including seventy-eights, then filtering can be very useful. If not, you must choose whether or not you wish to pay for facilities you may never use.

You may come across instruments with, or references to, filters known as 'loudness controls' and 'presence controls'—the former especially in amplifiers designed for the American market.

The human ear becomes less sensitive to upper and lower frequencies as the volume is decreased. A 'loudness' control —very inaptly named in some ways—introduces greater emphasis in these regions as the volume is decreased. If, for example, one wishes to play at night at low volume so as not to disturb a neighbour, the control will compensate for the loss in quality engendered by the response of the human ear. Although based originally on the experimental work of

two engineers named Fletcher and Munson, the device has, in my view, little value. The answer to the problem is far better sought in good-quality headphones, which allow one to listen at any level while disturbing nobody.

A 'presence' control raises or lowers the middle frequencies, which are responsible for the sense of 'presence' in a recorded performance. A good recording should need no such thing; but some users like these devices. Once again, the control should not be needed often; if it is constantly needed you should certainly suspect your loudspeakers or the general design of the amplifier. In general, it can be said that the less one needs to tinker with tone controls, the better.

Inputs and outputs

Amplifiers vary greatly in the versatility of their facilities for connecting other equipment to them. The first requirement is an input for the pickup, naturally. Some models provide for the connexion of more than one pickup, such as a ceramic type and a magnetic one, or for two magnetics. The former is not likely to be of use to the true hi-fi man; but there are some who have two pickups and arms assembled on the same turntable or two different ones, as they prefer them for different types of music. For such, the facility is useful; for most of us, it is not.

One should certainly be able to connect a radio tuner to the amplifier; and the necessary input is always provided. More will be said of these later (pp. 117ff). Here let me just remark that no music-lover should deny himself the riches offered to him by the BBC.

An input should also be provided for a tape machine (pp. 99ff). The power-amplifier and loudspeaker(s) built into your tape machine will not equal in quality those you use for reproducing your records and radio.

You may want to take a signal from your amplifier and apply it to another piece of equipment—a tape machine at

once comes to mind. Various other facilities of in, out and output to tape machines will be considered later; but the very least you need is a tape output.

Most amplifiers also provide what is called an 'auxiliary' input and output. This usually resembles those for a tape machine or radio, and can come in useful for either.

Matching

Unfortunately, one cannot just connect any pickup, radio tuner or tape machine to any amplifier without further consideration. All these devices generate an alternating current, and when this current is presented to the input of the amplifier a phenomenon known as 'impedance' occurs. This term is descriptive: the input presents an opposition to the incoming current which is electrically somewhat complex, being made up of resistive and reactive components and measured in ohms (symbol:(Ω).) Here it is enough to point out that output and input must be matched in terms of impedance, or not only will the transfer of power be affected but distortion may also be created. It is therefore essential to make sure that the 'impedance matching' of equipment and amplifier is correct. These requirements are always stated clearly in equipment specifications, and necessary adjustments can be made by a qualified engineer. In general, the impedance of the input receiving the signal may be somewhat higher than the output received, but it should not be lower. Thus, if your amplifier has an output at the loudspeaker terminals of 8 Ω, and you connect to it speakers with an impedance of 15 Ω, you will lose power but not create distortion. As so often, your dealer will be able to advise you on these points; if you are thinking of acquiring any additional item of equipment, always make sure that it will match your amplifier in terms of impedance.

How much power?

Amplifiers vary widely in output power. In the normal domestic room, only a few watts of power need be emitted to fill it with sound, yet amplifiers are available with outputs of 10, 15, 20, 50 or 100 W per channel. Why do we need all that? Do we need it? There are several considerations.

First, most loudspeakers are very inefficient: most transmit less than 5% of the power handed to them by the amplifier. So we need reserves here. Secondly, all amplifiers reach the point where they overload; and when that happens they start distorting disastrously. No amplifier should ever be operated at or near overload point. Now, the amount of energy used varies very widely in the course of the same musical work: Brahms's Fourth Symphony, for example, begins with an enchanting melody played on the strings only but goes on to some huge climaxes for full orchestra. If you have to wind up your amplifier nearly full out to get adequate volume for the early pages of the work, you are likely to reach overload point in the climaxes. Therefore what we have to consider is the full force of orchestral sound, which may vary by 70 dB and more over the same record, and have enough power in hand to cope with whatever comes.

Thirdly, recall what was said earlier about transient response (p. 8). The first 'attack' of a cymbal clash, for example, or the magnificent beginning of Vaughan Williams's *Sea Symphony* ('Behold the sea!') will demand a great deal of power for the first few milliseconds. Unless that power is there, the result will be rough and distorted. The great Wilhelm Kempff playing Beethoven, to quote but another example, can crash out a chord of thrilling power, but it will sound horrible should the amplifier overload.

The example I always use is that of cruising down a motorway at 70 miles an hour in a family car. You can do it; but the car is very near to maximum performance, and should a sudden emergency occur there are no reserves to

accelerate out of it. In a high-powered car, however, the whole experience is different, though the actual speed is the same: a sense of ease, of everything operating under full control and well within its rated tolerances. One has confidence rather than anxiety. It is the same with amplifiers: reserves of power may never be used, but they should be there. Hence, something like 25 W per channel is the lowest power one can recommend for domestic use, and up to 50 W is desirable. Normally you will not use it; but it will be there for the few moments when you may need it.

However, a word of warning: your loudspeakers will be rated at a certain continuous power input as a maximum—probably less than the maximum power of your amplifier. Every now and then they may be called upon for a momentary output in excess of that figure and no harm will result, but do not be tempted to turn up your amplifier to the limit, or you will certainly damage the speakers: high power should be kept where it is needed: in reserve.

Multiple speaker connexions

Many amplifiers these days are provided with two sets of loudspeaker terminals and can be switched to give one or the other pair, or both. The object of this is to allow listening in different rooms, either one at a time or both together. Many people like to avail themselves of that facility. You can, of course, connect more than one set of loudspeakers to the same terminals, but if you do you will upset the impedance-matching mentioned above—two sets of speakers each rated at 15 Ω, for example, will give a combined impedance of 7·5 Ω and cost you power. When the amplifier is designed for multiple connexions, that is taken care of.

Dangers

Never operate a valve amplifier with no loudspeakers connected to it unless the volume control is turned right off. A

transistorised amplifier should never be allowed to short-circuit across the speaker terminals, though many are now provided with protection against that condition. Therefore *always* switch off the amplifier when connecting or disconnecting loudspeakers: better safe than sorry.

Again, a high ambient temperature may cause an amplifier to overheat, and most modern ones automatically switch out should that happen. Allow the instrument to cool down before trying it again. Should the condition recur, suspect an internal fault and get the thing examined: a component may have 'gone high' and need replacement.

Caution should also be exercised when connecting loudspeakers of low impedance (3 to 4 Ω) to a transistor amplifier having a nominal output impedance of 8 Ω. As the amplifier approaches overload point, the protection circuit may be triggered or, in default of that, the output stages of the amplifier can be damaged.

Balance control

All stereo amplifiers are fitted with what is called a 'balance control'. This is a two-way volume control, and controls the signal strength to one or the other channel. In many cases, it allows either channel to be faded right out. Its primary purpose is to permit small variations which are made necessary either by a recording that overstresses one channel at the expense of the other—which today is very rare—or to compensate for differences which arise from the acoustics of the room, the placing of the loudspeakers or the listening position.

When we are discussing setting up equipment, we shall have more to say about the positioning of the loudspeakers in the room (pp. 84–5); it may be impossible to place them in the optimum position, and then it may be necessary to balance the sound from each by means of this control. Normally, the mid-position of the control ensures that each channel is operating at the same level, though in practice

there are constant small variations which arise from the stereo process itself: in a solo violin passage in an orchestral work, for example, the left-hand speaker will be producing greater volume than the right-hand one, so as to place the violin in its proper position in the orchestral perspective. It is only when, owing to some circumstance, the recording as a whole is predominantly left or right that one need think of adjusting the balance control.

Another use for the control is to compare one loudspeaker with another. If the amplifier is switched to mono, both stereo channels will be routed to both speakers. Then, by fading down first one channel and then the other, it is easy to compare one speaker directly with another, and note its qualities.

The initial balancing can be done either with the aid of a test record, which carries special bands for the purpose, or by the technique outlined above. A stereo record is played in the mono mode, under which circumstances the sound should appear to come from a rather narrow area directly between the two loudspeakers. Should it not do so, the balance control should be adjusted until it does. After that the position of the control should be noted, so that it may be returned to the same position if disturbed.

Operating the amplifier

The various functions and facilities of the amplifier are selected and operated by means of knobs and switches usually located on the front of the amplifier, though those rarely used may be on the back. There is normally what is known as a function switch, which has a number of indicated positions, and is used to connect the amplifier to the source of signal. Thus there will be positions for pickup(s), tape, radio tuner and a spare position known as 'auxiliary', to which a second tape-recorder or tuner may be connected.

We then have the volume control proper, which may incorporate the on–off switch for the mains, and controls for

the filtering system. The number of these will obviously depend upon how elaborate the filtering facilities of the amplifier are. They will certainly include the bass and treble boost-and-cut described above. The filters will be controlled by switches if they are at fixed frequency, or by rotary controls if they are of the variable type.

There will also be a switch for mono-stereo operation; and if the amplifier provides for connecting more than one set of speakers, there will be selector switches for these.

Many amplifiers incorporate what are called 'pre-set' controls to each input. The purpose of these is to equalise the inputs from different sources—pickup, tape, tuner, etc. —so that when they are switched in each source produces the same level and there is no need to adjust the volume control. Should pre-sets not be provided on your amplifier, all you need to do is to turn down the main volume control before switching over, and then bring it up to the desired level.

If there are loudness or presence controls (p. 60–61), the necessary switches will also be supplied.

You should familiarise yourself with all the controls, so that you are able to make the best use of them. The operating manual provided with your amplifier will give you full particulars of how to operate it. Though all these controls have their uses, and are there to be used, a word of warning may nevertheless be appropriate against constant fiddling with them, which is both unnecessary and highly distracting to anybody else who may be enjoying the music with you.

7

Loudspeakers

We now broach the most subjective and personal of all hi-fi components. The loudspeaker is at present the most variable, varied and subject to individual taste of all the links in the hi-fi chain. Indeed, B. J. Webb, who designs them and should know, has said that he would as soon choose a man's socks or ties for him as his loudspeaker. All, therefore, that one can do is to offer guidelines and suggest pitfalls.

These days there are two types of loudspeaker: the dynamic, or moving-coil, and the electrostatic. Let us take the former of these first, as it is by far the commoner.

The moving-coil loudspeaker

We reminded ourselves earlier on that when an alternating current is applied to a coil of wire stationed within a magnetic field it vibrates in step with the current.

We also saw that when a wire is coiled round an iron core and an alternating current applied to it the core becomes magnetised. Now consider a magnet stationed around a coil of wire. When an alternating current is applied to the coil, it vibrates to and fro within the magnetic field. If we then attach to the coil a diaphragm, the diaphragm moves too, displacing air and giving out a sound corresponding to the current received. All sound, as we saw, is propagated by the sympathetic movement of air, which in turn vibrates our eardrums. This, very crudely put, is the loudspeaker. The modulations of the record grooves create a current in

the pickup, which is magnified by the amplifier, and then applied to the loudspeaker. Thus, ideally, the excursions of the loudspeaker diaphragm—or cone, as it is usually called—mirror precisely the original sounds which were picked up by microphones and transferred to the disc. The degree to which this ideal is successful measures the degree of high-fidelity of the equipment.

Clearly, a coil with attached diaphragm or cone cannot be suspended in a magnetic field on its own: it has to be supported. The coil is usually called a 'voice coil' because it is what makes the loudspeaker 'speak'. The cone is supported within a metal framework, to which it is attached by a 'surround'. It may be made of a variety of materials, including paper, plastic and metal; but the surround has to be constructed so that it allows the cone to move backwards and forwards freely. Sometimes the surround is of paper, with a series of corrugations in it, and is often treated with a sticky, non-drying 'goo' to keep it flexible, or it may be made of plastic or rubber. Centration is obviously of great importance, or the excursions of the cone will not be linear. The magnet is designed with a central pole-piece which goes within the coil, and has to be powerful, since its function is to return the coil to the initial position as quickly as possible after each excursion—and there may be 20 000 of those in one second. The magnet assembly is also mounted on the metal frame which supports the cone, and it is essential that manufacturing tolerances be kept extremely low, or distortion will be created.

The magnetic assembly, however powerful, cannot achieve the ideal, which is to return the cone to the stationary position in zero time after each excursion. This is a limitation of the moving-coil design, and cannot be totally overcome. The resultant 'hangover' of the speaker cone will clearly be more apparent at the lower frequencies at which the cone excursions are larger. Things are greatly cleaned up by adequate damping, both within the cabinet and also by the amplifier, which has what is called a 'damping factor'

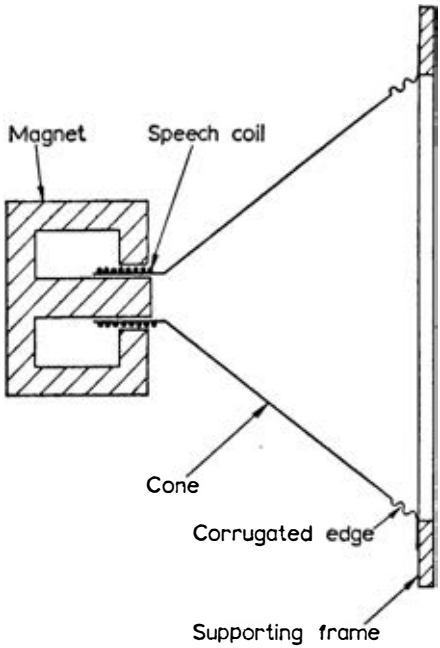
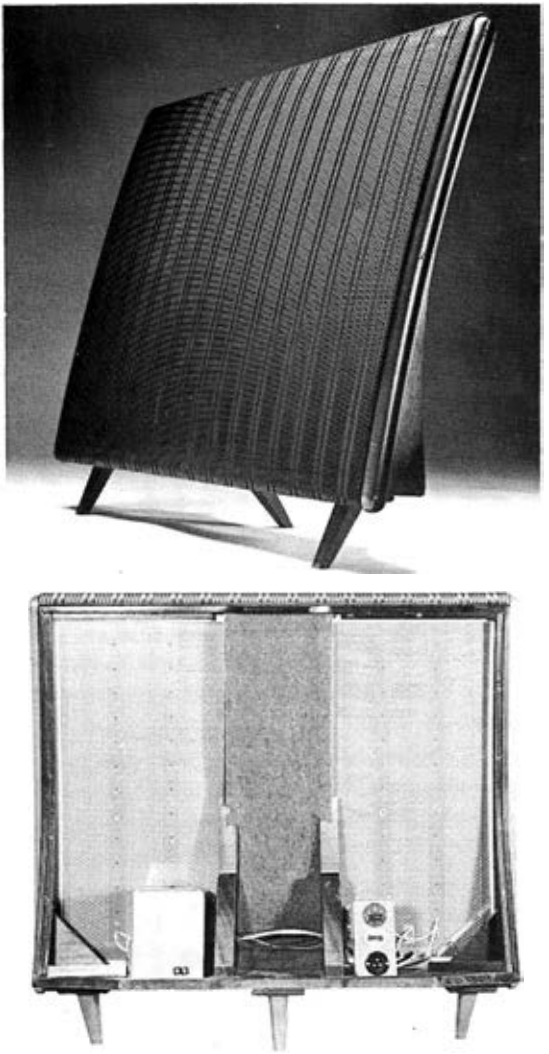


Fig. 10 Basics of moving-coil loudspeaker. The signal voltage from the amplifier is fed to the coil, which is suspended within the field of the magnet

owing to the ratio of the impedance of the loudspeaker to that of the source impedance of the amplifier. Careful attention is given in loudspeaker design to this factor, so that a large ratio is provided to improve damping. Hangover manifests itself in a muddy quality of bass response, with a tendency to boom: one of the things to which to pay close attention when choosing a loudspeaker is the *quality* of the bass end, which should be firm and tight. It is only too easy to design a speaker with a resonant and larger-than-life bass response, and although this may sound impressive when first heard it soon becomes tiring. Listen to male speech,

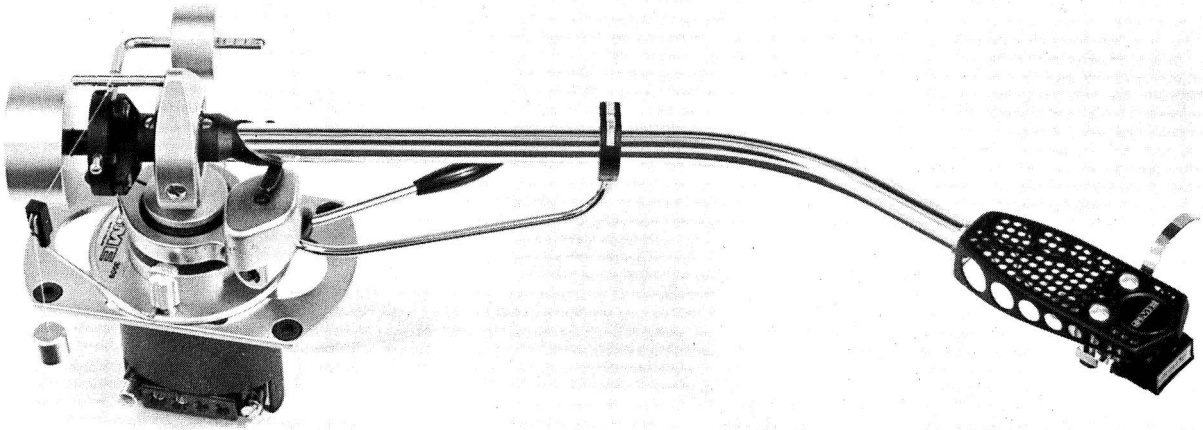
A high-quality installation. *Left–right*: Teac A450 cassette deck; Stolle Antenna Rotator; Sony STR 6200F receiver (tuner–amplifier); Dual 701 direct-drive turntable and arm with Shure V15 Type III pickup (not shown); Cambridge Audio R50 loudspeakers (*Photograph Mike Carwithen and Peter Turner*)



Electrostatic loudspeaker. Upper shot shows the shape and appearance of the Quad Electrostatic; the lower shows the back cover removed. Note the power-pack to supply polarising voltage to the power plates of the condenser (*Photograph courtesy of Acoustical Manufacturing Co. Ltd, Huntingdon*)

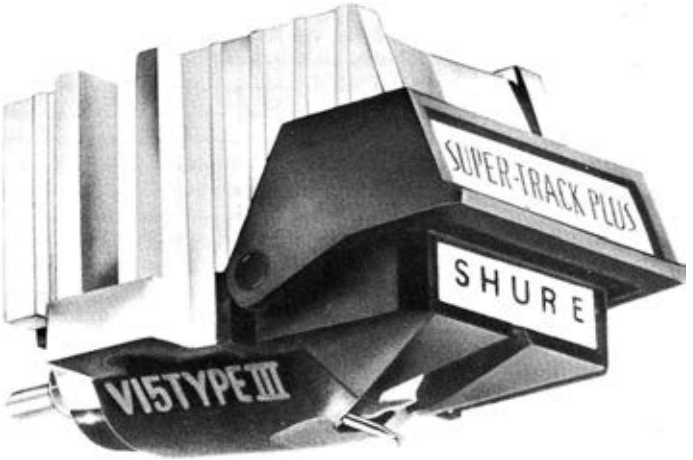
High-fidelity headphones. *Above*: PRO/5LC dynamic set. *Below*: ESP9 headphones (*Photograph courtesy of Tape-Music Distributors Ltd, St Albans*)

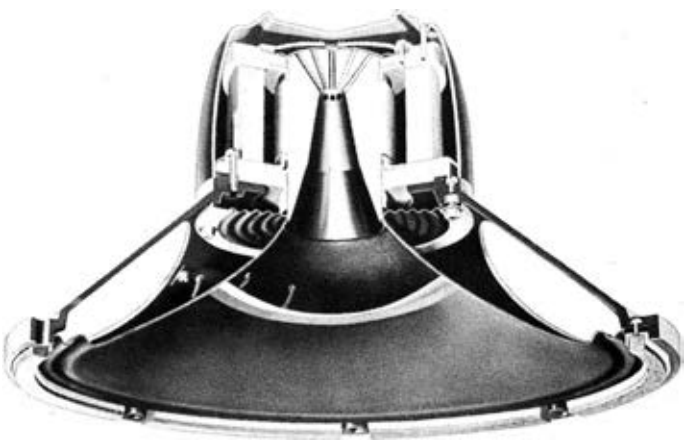
The SME pickup arm seen from above. Note stroboscopic markings on periphery of turntable (*Photograph courtesy of SME Ltd, Steyning, Sussex*)



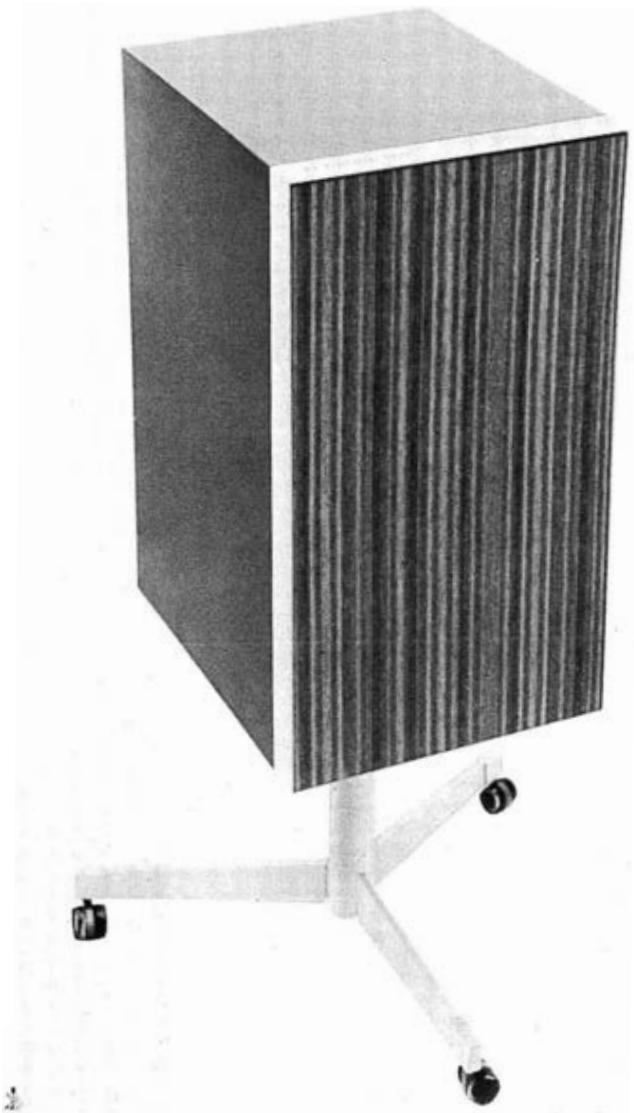
The SME pickup arm. The photograph shows the thread and weight anti-skating bias adjuster; the sliding base for precise alignment; the counterweight; an adjustable weight for tracking pressure; the raising and lowering device; the arm rest; the head-shell—on this model, not detachable (*Photograph courtesy of SME Ltd, Steyning, Sussex*)

Semi-professional tape recorder: The Ferrograph Series 75 Super 7 tape machine (British). Note twin VU-meters for upper and lower tracks when recording in stereo (*Photograph courtesy of Ferrograph Ltd, St Albans*)





Above: A high-fidelity pickup: the Shure V15 Type III. Note elliptical stylus mounted on its cantilever arm. The front assembly slides out for cleaning and renewal. The part marked 'Super-track Plus' is a hinged guard to protect the stylus when cartridge is not in use (*Photograph courtesy of Shure Electronics Ltd, Maidstone*). *Below*: The Tannoy Monitor Gold unit, cut away to show internal structure. Note metal supporting frame, speaker cone and magnet assembly. In this model (a dual-concentric design) the higher frequencies are covered by the small horn at the rear of the main cone (*Photograph courtesy of Tannoy Group, West Norwood, London*)



Dynamic (moving-coil) loudspeaker: the Ferrograph S1 Monitor. This is a transmission-line design, the internal construction of which is shown in Fig. 10, p. 70 (*Photograph courtesy of Ferrograph, Ltd, Slough*)

which should show no chesty coloration. Here, however, a word of warning is necessary: the most common source of speech will be a radio tuner. The BBC still sometimes uses ribbon microphones for speech reproduction, and these can show a marked bass rise when used at close distances and give a misleading impression of a speaker which is only faithfully reproducing the signal fed to it.

The cone is generally circular and cone-shaped; but it may also be flat or of elliptical or rectangular shape and with curved ends. The material has to be as light as possible consistent with strength, and some designs use sandwiches of more than one material. The voice coil is usually of copper or aluminium, and the ends of the coil are routed to terminals, to which are attached the leads from the amplifier. The whole assembly is mounted on some form of baffle-board to allow it to be positioned within the room.

A simple, flat baffle-board is in fact quite feasible, and at one time it was fashionable to use the wall of the room for the purpose—of course, with a suitable hole cut in it! But with the question of baffling we come to the first problem. Sound, as we saw, is propagated in waves, which have a definite length corresponding to the pitch of the note: the higher the note, the shorter the wavelength and vice versa, so that the wavelengths of the whole sound spectrum range

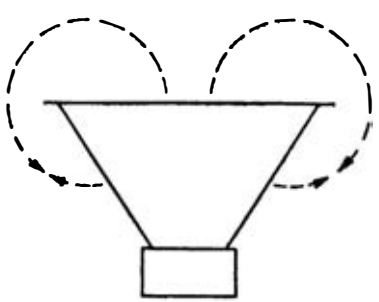


Fig. 11 Mutual cancellation of soundwaves radiating from front and back of an unbaffled loudspeaker cone

from a tiny fraction of an inch to many feet. So, while the wavelength of the note emitted is shorter than the size of the baffle, all is well; but should it be longer the sound can get behind the baffle and cancel itself out. This is why the loudspeakers built into the cabinets of small radio sets and television receivers have virtually no bass response. An ideal baffle would be infinite in size, which is why the wall of the room seemed such a good idea. Instead, it is customary to mount the speaker in a four-sided cabinet, which is in a sense infinite. This does wonders for bass response; but unfortunately the amount of air trapped in the cabinet is not infinite, and at once begins to offer resistance to the excursions of the cone, thus again lowering bass efficiency.

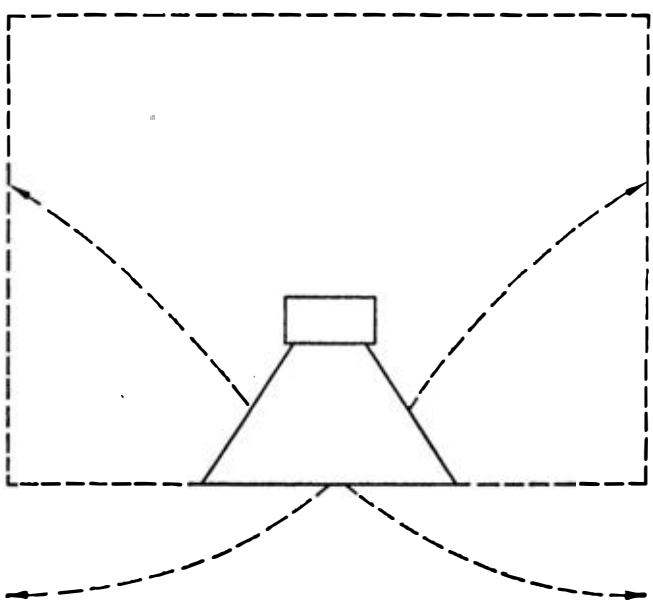


Fig. 12 Speaker mounted in cabinet (lined with sound-absorbing material) isolates front and rear surfaces of cone

Resonance

We must here introduce the notion of resonance. Tap a wine-glass with your finger, and it will give out a note—always the same note, though louder or softer according to how hard you tap it. This is because all materials have a frequency at which they resonate naturally. This phenomenon can be modified by damping, so that if one holds the glass with one hand and taps with the other, the note will be of a different frequency and has a strangled sound. The note can also be stopped instantly by damping with the fingers. Resonance is not confined to substances like glass or metal; it is even found in the tuned circuits of your amplifier, the arm of your pickup, the pickup itself—in nearly everything, in fact. It is a form of natural behaviour which can be used or become a nuisance, according to how we tackle it. Radio reception depends upon tuned circuits, while some resonances in amplifiers must be damped out to prevent instability and distortion.

Loudspeakers are no exception: every cone has its natural resonant frequency at which it operates with greater efficiency than at others. Place one in a cabinet, and the resonant frequency rises because of the damping effect of the air within. Below the resonant frequency, the efficiency of the speaker rapidly tails off. In free air a speaker may resonate at 30 Hz, while in a cabinet of some 2 cubic feet capacity the resonance may rise to 50 or 60 Hz. One way of getting round this is what is called the bass reflex design.

The bass reflex cabinet

Once the resonant frequency of the speaker within a cabinet has been determined, an opening called a 'port' can be arranged in the cabinet of critical size or 'tuning' so that sound below the resonant frequency is emitted from the port rather than the cone, thus extending the bass response. One

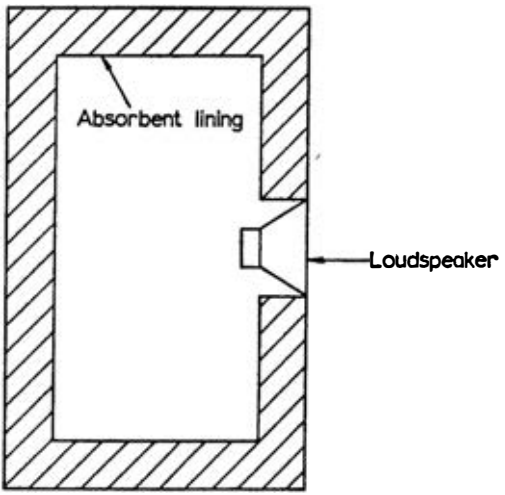


Fig. 13 Cabinet design: the 'infinite baffle' completely encloses rear of cone

can also 'load' the loudspeaker in various other associated ways, such as by a tunnel surrounding the port, or by a specially designed horn which is activated by the rear reflections from the speaker. Obviously when a cone is vibrating, it moves air in both directions; but the movement of the air on the return journey does not coincide with that on the outward one: the two are, in technical terms 'out of phase' with each other, and, in the absence of preventive measures, cancel each other out. The tuned port, pipe, tunnel or horn is designed to reverse the phase of the rear signal, and make it additive rather than subtractive.

The transmission line

One variant of the bass-reflex design which has become prominent in recent years is what is known as a 'transmission line'. In this design the bass speaker or 'woofer' is loaded

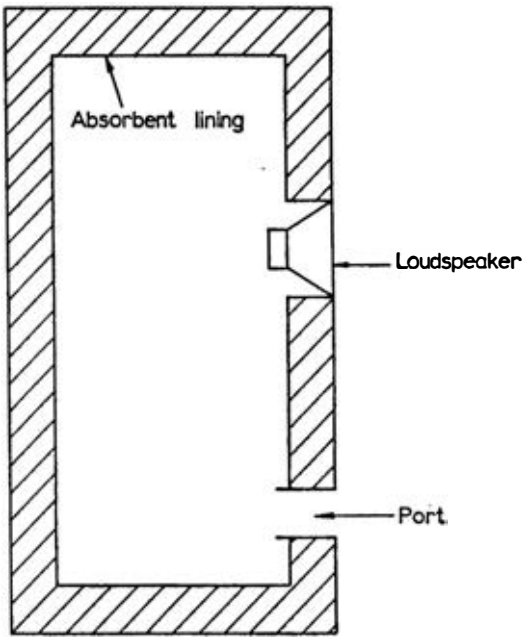


Fig. 14 Cabinet design: in the bass-reflex type a tuned 'port' or tunnel increases bass efficiency below the resonance frequency of the cone

With horn-loading or transmission-line design, a wooden horn or tunnel is built behind the cone, leading to a port designed to match

with a tuned pipe (usually made of wood) which is folded within the cabinet to give a total length of several feet—perhaps six. The pipe is suitably damped with sound-absorbent material, and emerges through a port at a chosen place in the cabinet. The result of this design is a much-improved low-frequency performance, both in terms of efficiency and also in 'firmness'—that is to say, the sound is clean and uncoloured, and free from boom.

In most contemporary designs, the mid-range and upper-frequency units are isolated from the bass unit(s) and from each other, either by the design of the speaker units themselves, or by their being mounted in separate small enclosures within the main one. The object of this is to prevent the radiations from one unit affecting those of the other(s), and thereby creating intermodulation and colouration. 'Colouration' is a word loudspeaker designers use to refer to objectionable additions to the sound made by the driver

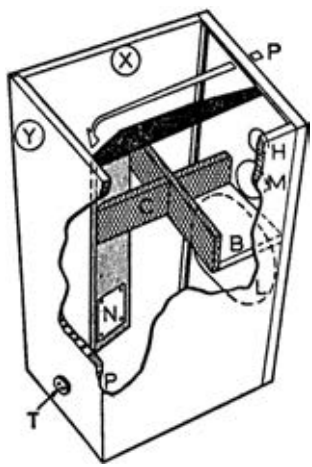


Fig. 15 Internal construction of the Ferrograph 51 monitor loudspeaker: a transmission-line design

Key: P Port (45° to X and Y)
C Cross-bracing
B Isolating baffle
H HF unit
M Mid-frequency unit
L LF unit
N Cross-over network
P Polyester finished chipboard (18 mm)
T Terminal panel

(Ferrograph Recorder Co., Slough, Bucks.)

units, the cabinet or interaction between these. Ideally, as with all the other hi-fi components, a loudspeaker should add or subtract nothing; but in this respect the loudspeaker at present is inferior to the other links in the chain.

Horn-loading

Another approach to the design of loudspeakers is to site at least the bass unit as part of a horn—to that extent reverting to the old, acoustic gramophone. Some designers go to the lengths of building concrete horns into the structure of their houses, and the result is indeed superb; but most designs confine the horn within a cabinet. The original design by Voight utilised the walls of the room as part of the horn, the sound being ported out of the cabinet, when placed across a corner of the room, so as to radiate from the walls.

The tradition of horn-loading has been faithfully followed by Donald Chave, of the Lowther company, who has refined his design, based upon Voight's, over many years. He uses units with a very large and powerful magnet assembly, with the high-frequency unit mounted within the bass radiator (that is, concentric with it). This design gives a speaker of great efficiency—something in the order of 70% —so that his speakers can be driven by amplifiers of much less power than that called for by other designs.

Other firms, such as Tannoy, also make use of the concentric design—in this case with the 'tweeter' loaded with a small horn. These speakers are notable for extreme robustness under long periods of use at high volume levels, which is one reason why they are often used as monitor speakers by recording companies. Both Lowther and Tannoy have many followers amongst the discriminating; include their products amongst your shopping list, as they may appeal to you.

Various types of 'loading' of speakers have been, and are, in use. Hence, the design of cabinets is just as important as that of the speaker units themselves, which are of very

limited use on their own. A loudspeaker is the combination of a unit with a cabinet; and it is no use just mounting any unit in any cabinet and hoping for the best. Much of this work has to be on the basis of trial and error, and judgement will obviously vary as to the quality of the result obtained. Techniques for the objective testing of loudspeakers are being gradually evolved; but they do not as yet reach anything approaching the sophisticated perfection of those available for testing pickups and amplifiers: speaker design is still as much of an art as a science.

Frequency division

We have noted several times that high frequencies have short wavelengths, and hence call for very tiny cone-excursions, while low frequencies have long wavelengths and call for large cone-excursions. Hence we are at once in a dilemma: how can one cone respond accurately to the whole sound spectrum, and reproduce accurately the sound of a triangle and of a bass drum at the same time? The answer is that it cannot, and the result of its trying is cone 'break-up' and distortion. Further, the type of cone which will best do justice to low frequencies is quite different from that best suited to the higher. It therefore makes sense to design special speakers for high and low frequencies, and let each get on with its own job. This is done by means of dividing networks or 'cross-over units'. A capacitor, or 'condenser', will pass higher frequencies and exclude lower ones in accordance with its rating, while a 'choke' or inductor has the opposite effect and passes the lower frequencies while excluding the higher; it is therefore possible to devise networks which will divide the frequency spectrum between two, three, four or any number of speaker units, so that each is handling that part of the range for which it has been designed. More recently, these networks have also been used to damp resonances in speakers, equalise their efficiency in relation to each other and produce a smooth overall

effect. Indeed, it is true to say that the development of the dividing network has been one of the major advances in loudspeaker design of recent years, and makes the simpler choke-and-capacitor units of a few years back look crude indeed. These networks also resonate, and that resonance can either be used creatively or damped out.

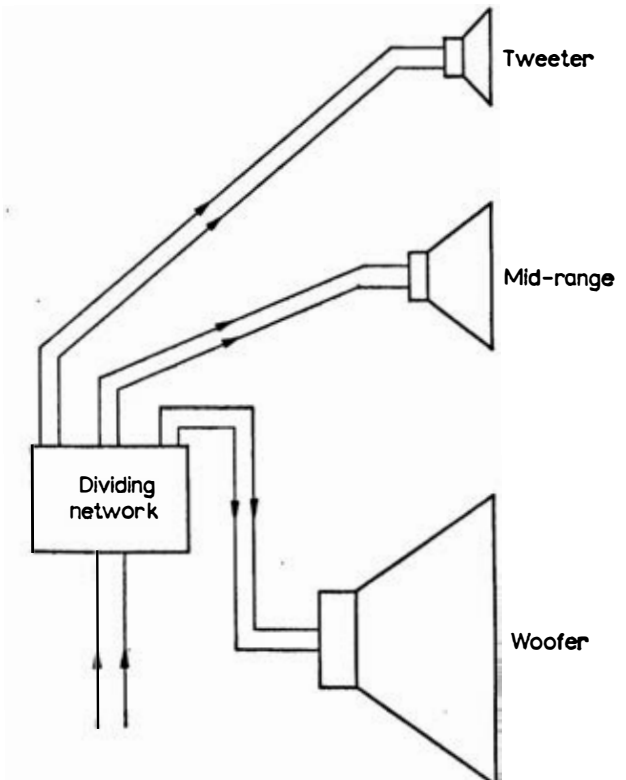


Fig. 16 Frequency dividing: in more advanced speakers, the signal from the amplifier is split by a dividing network and fed to units specially adapted to their sections of the frequency spectrum

Cabinets also have resonant frequencies—very much so, as you will find if you thump a tea-chest. The use of stout materials of precise density, internal bracing of the cabinet and sound-absorbent materials, such as wool or plastic foam, inside the cabinet as a lining also helps to damp resonances, not only from the cabinet but also from the speakers themselves. There are still crude and nasty loudspeakers around; but the best designs are the results of years of patient research and development, with new ideas constantly being tried and proved or rejected.

The electrostatic loudspeaker

Like electromagnetic loudspeakers these designs move air in sympathy with the applied voltage from the amplifier, but in a different way. A high-voltage, low-current charge is applied through a transformer to a fixed plate. In front of this is the radiator—another plate to which is applied the alternating current from the amplifier. The plates are insulated from each other, making a capacitor. The free plate vibrates in accordance with the voltage applied by the amplifier.

In this design, too, there are different plates to carry different parts of the sound spectrum; and the result is a remarkably open, distortionless sound, which can be matched, if at all, only by the very best moving-coil designs. There are, however, snags: the first is the need for a separate mains connexion, which is not serious; the second is that it is difficult—indeed it has not yet been accomplished —to provide the same degree of bass response. There is only one design of full-range electrostatic speaker on the market at the moment, at least in this country: the justly famous Quad. This speaker has qualities which place it, in my view, in many ways above all others; but it is a doublet (i.e. it radiates from both back and front) and there is no doubt that it does seem lacking in bass—though that depends upon taste and the kind of music one enjoys: it

will play the violin superbly, but is not too happy with a 30-foot organ pipe. It also seems to lack something in stereo definition; but it is strongly recommended that it be heard in the course of a selection programme, as, if you like it, no deficiency, real or alleged, will matter. It would be true to say that all advances in moving-coil design have been to make them sound more like the electrostatic but with the extended bass response which adds so much to the realism and enjoyment of music.

Hybrids

Designs have been produced which combine electrostatic units for the middle and upper frequencies with moving-coil units for the bass. Some of these are very interesting; but it would appear that the problems associated with the units (for the electrostatic poses quite different problems to the amplifier from the largely resistive nature of the moving-coil) will eventually be solved only by combined speakers and amplifiers with inbuilt dividing networks as an essential part of a whole design. Such systems will be superb; but will of necessity be costly, and the owner will not be able to change speakers at will.

The choice of a speaker is very individual and subjective. Do not plump at once for the most 'impressive' sound: that is probably the result of exaggerated response at certain frequencies ('chronium-plating') and is quite unnatural. Seek the instrument which to you sounds the most natural, for in the end that is the only one with which you will live happily. In general, a good big 'un will always beat a good little 'un; but huge boxes may not fit into a small room, and there are small loudspeakers which are excellent.

Moreover, a speaker is very much affected by the acoustics of the room in which it is played—though that factor has tended to become less important in recent years. Therefore a trial in your own home is the best way of deciding; and a good dealer will always let you have a pair

for a weekend, though he has every right to expect that you will treat them properly, and charge you if you don't. Listen to a wide range of music and reject any speaker which induces fatigue in you after an hour or so. Ask yourself above all one question: how does what I am hearing compare with the original sound? Don't be impressed by sales talk or, in general, by price. Trust your own ears, and if you genuinely like a speaker costing £30 better than one costing £100—buy it.

Kits

As with amplifiers and other items, there are speaker kits which can be purchased for home construction, at considerable saving in cost. Or, should you be a handyman, it is possible to obtain designs from the makers of units and do your own cabinetwork. These designs have been well tested. There is also a large second-hand market in speakers and, provided that you can hear before you buy, you are not likely to be deceived.

Headphones

The use of headphones, either in place of loudspeakers or as an adjunct to them, is becoming increasingly popular. There is no doubt about the clinical accuracy of these devices, if we are speaking about the best of them; and, of course, they cost considerably less than loudspeakers. Only one person can listen, of course, to one headset, but there is no difficulty in connecting several to the same amplifier. There is no question of positioning, and they are quite independent of the acoustics of the room in which they are used. Great advances have been made of recent years in their designs, which are totally different from those used in the days of the crystal set.

As with speakers, they may be of either magnetic or electrostatic design; and, again as with speakers, there is a

large subjective element of preference about their acquisition. However, one can be certain that the sound they give in the shop will be the same as the sound they give in your own home, given equal equipment.

The snag is that not everybody likes the subjective effect of listening through them. Many people find that the sound appears to come either from within the head or from round the back of it, rather than from the front. This can be disconcerting, as can the fact that when one turns the head the orchestra turns with it. There is also the question of comfort, as the earpieces have to fit snugly to the head in order to give an air seal within the ear and to exclude external sounds. This pressure can become irritating or even downright painful after prolonged wear; and the problem is made worse if one wears glasses. The writer has yet to hear a headset which, in his opinion, gives a standard of sound equal to that of the best loudspeakers, or which has truly adequate bass response; but there are those who would disagree with him. With headphones, of course, one can play as loudly as one wishes at any time and disturb nobody—which makes them ideal for late-night listening.

If you feel attracted to this mode of listening, visit a good dealer and try various models. You may well find one that you prefer or which you find more comfortable; and if you like the experience, by all means acquire a headset, either in place of speakers or for occasional use. They can be particularly useful for such things as setting up the bias adjustment on your pickup arm.

As with everything else, impedance-matching is important. The literature with your amplifier and the headset will tell you what impedance each calls for, and therefore which headset will match to your amplifier. Mismatching is particularly unfortunate in the case of headphones. They are not to everybody's taste, but you should certainly listen to some, as they might be your personal answer to the very individual matter of sound source.

8

Housing Your Hi-Fi

After many years as a dedicated hi-fi man, whenever I enter a room for the first time I find myself assessing it in terms of the reproduction of music. Now, it may be that you cannot entirely organise your room around your hi-fi, but let us at least look at that ideal.

The loudspeakers should look into the longest dimension of the room, because the lowest frequency which can be generated in the room is largely determined by the length which corresponds to the half wavelength of the note. That means, usually, speakers in the corners of the room. It is best to face the speakers in order to give a natural perspective. So, where do you normally sit in your room? Think about that in relation to the position of the speakers, remembering that your family will wish to hear too. Compromise is often necessary, and you may be limited by such factors as whether or not you sit by a fireside or have central heating and can sit in any part of the room.

Speakers should be angled in rather than face straight down the room: not only does that position give the longest dimension but it also widens the area in which stereo can be accurately heard. The old objection that there is only one 'stereo seat' in a room is rubbish. It is true that the *best* position is that immediately between the axis of the two speakers, but, as the diagrams show, the listening area widens as the speakers are angled in. One can even have the speakers actually facing each other. Here experiment is the best guide. Try the effect of angling the speakers a little

more at a time until the optimum position for your room is reached.

Speakers need not stand on the floor. Most of them have the bass units towards the bottom of the cabinets, and this can cause reflection of sound from the floor, which muddies the bass and tends to make it boomy. The speakers can be raised on stands—some makers supply them custom-made. Should your speakers be small, it will be necessary to raise them up. They are often called 'bookshelf' speakers for that very reason, and they do fit very well onto shelves. At all events, try to arrange things so that the high-frequency speakers (often called 'tweeters' in contradistinction to bass speakers, which are called 'woofers') are at about ear level, and clear of any furniture which may be between them and you. This is because the higher frequencies are very directional, while the lower ones are omni-directional and play very little part in creating the stereo image.

The turntable and amplifier, with any associated equipment, should ideally be situated where you can manipulate them from your favourite chair. This makes the adjustment of volume and the effect of tone controls much easier to judge, besides saving the need to walk about the room every time you need to turn over a record.

The equipment can be placed on a shelf or table, or it can be built into its own cabinet. There are specialist firms who make cabinets of many different kinds and styles to fit in with any décor, from the ultra-modern to Queen Anne. Here you—and your wife—can give free rein to your imagination and taste. However you decide to arrange things, make sure that the turntable is adequately protected from dust when not in use. If it is kept outside a lidded cabinet, you can get plastic dustcovers which cover the plinth; and many models come ready supplied with these, which hinge up for access and can be closed during playing. This helps to reduce the dust problem (see pp. 94ff).

Generally, the amplifier should be close to the turntable, so as to give the shortest practicable run of cable between

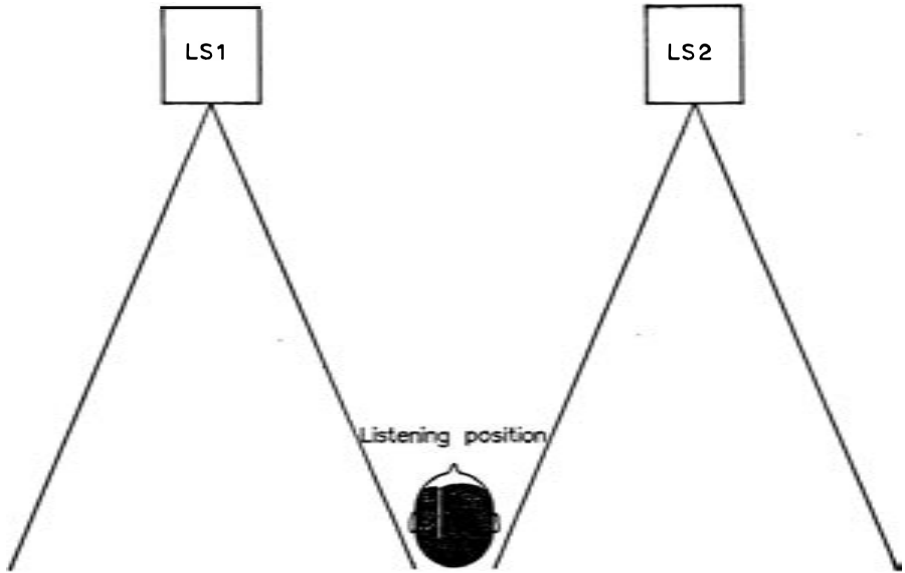


Fig. 17 Loudspeakers facing listener. Stereo area narrow. Diagram deliberately exaggerated

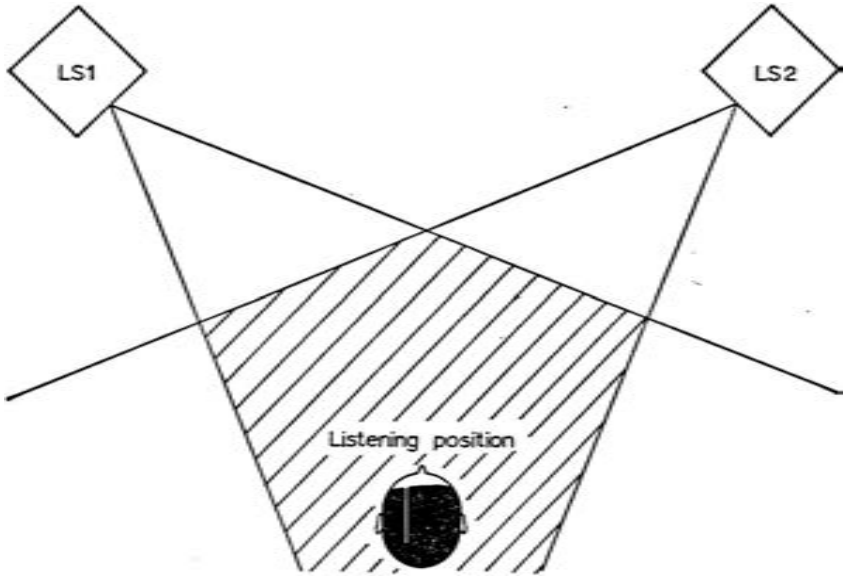


Fig. 18 Loudspeakers angled-in. Greatly widened stereo area. Diagram deliberately exaggerated

them. Anything up to about a metre is all right; but very long wires should be avoided as they can affect matching and are liable to pick up hum. A big advantage of a cabinet is that all wires are hidden within it; but in any case they can be routed and fixed so as not to show.

One thing is technically essential: the turntable must be absolutely level. Some models incorporate a spirit-level which shows this. If none be fitted, a small carpenter's level should be used, and the assembly adjusted until the bubble does not move when the turntable is rotated. Some cabinets incorporate feet which are threaded, which allows for tilt in any desired direction. Some turntables incorporate similar threaded mountings for the purpose. If yours has neither, you can level it by packing with any suitable, uncrushable material such as thin plastic strips. This can be a fiddling job, but it is mandatory, for a tilted turntable will cause uneven tracking of the stylus and make nonsense of your other adjustments, especially that for the anti-skating bias. Carpets or linoleum may settle a little after the cabinet is set in one place, so that a check should be made from time to time to see that all is well. Should a shelf be used, try to make sure that it is absolutely level when fixed, though it is quite possible to allow for some slight adjustment which may be needed.

If you are building your equipment into a cabinet, the board which carries the turntable should be very stout—say 1-inch ply. A hole—the dimensions of which will be indicated by a template which comes with the unit—will have to be cut in it, and the turntable is then commonly located by long screws in the corners which enter holes drilled to receive them. The table can often be permanently levelled by the use of thin washers pushed on to these screws and bearing on the motor-board. The board itself should preferably be supported on corners, and be slightly smaller than the cabinet, so that it does not touch on any side.

What is your floor made of? Most modern houses have a

screed of concrete on top of which the tiles or blocks are cemented; but if you have the older type of floor, with boards mounted on joists, there is danger of vibration from footsteps or passing traffic, which can be transmitted to the pickup and cause trouble—even, in extreme cases, groove-jumping. In these cases a shelf mounted to the wall is better than a cabinet; but sometimes spring-mounting of the turntable helps. There are some very versatile shelf-mounting units availble, and on these adjustments for levelling are quite easily made. Have a look round a good showroom to see what is on offer.

Remember, too, that later you may wish to add things like a radio tuner or tape machine, so leave space for them or you will have to rearrange everything later on.

Whatever you do, you will be bringing extra furniture into your room. Choose it with care, so that it fits in with your own ideas about décor. It will then enhance your home rather than clutter it.

Acoustics

All rooms have their own sound. We all know the heavy reverberation of large buildings: clap your hands in one, and you will hear the sound roll round. The period for which it does this can be measured, and is known as the 'reverberation time' of the room. Your own room has a reverberation time, though much shorter. However, a modern room can be quite lively, and if you have few soft furnishings and heavy carpets, you may find the sound a little echoey and brash. Try then to break up the room with furniture. In extreme cases acoustic tiles can be added to the ceiling. You may notice a difference when curtains are drawn at night: walls of glass are not very helpful to sound reproduction. These factors may influence your choice of loudspeakers, since what sounded good in the demonstration room may not suit your home. Here again, experiments with speaker-placing may help.

We spoke above of resonant frequencies. Rooms also have them, though there is little one can do about it. Many rooms have a 'rumble corner' in which any hum or rumble is more apparent than elsewhere in the room. Glass-fronted cabinets and ornaments may resonate too and can make annoying noises, which should not be blamed on your equipment. A little repositioning will often do the trick, or placing your silver cups on felt mats. Whatever some advertisements may suggest, shattering of glass is not likely!

Within limits, the length of the wires which connect speakers to amplifiers is immateral, but the wire should be of good quality. It can be routed under carpets or neatly round the walls, being fixed then into position with self-coloured tacks. These are special ones which are semi-circular at the non-pointed end, so that they grip the wire but do not pierce and short-circuit it.

Phasing of speakers

If a small torch battery is applied across the terminals of a loudspeaker, the cone can be seen to move. The terminal at which the positive lead from the battery causes a forward excursion of the cone is the 'positive' one, and is usually coloured red. It is necessary to connect both speakers in the same sense: otherwise, the speakers will be 'out of phase' and will cancel each other out, especially at the lower frequencies. Loudspeaker cones, as we have seen, radiate from both surfaces. Consider now what happens if a note is applied to two loudspeakers which are not 'in phase': one will radiate the note with a forward excursion of the cone, the other with a backward excursion. Since the speakers are mounted in a cabinet, one of the purposes of which is to damp out radiations from the back of the cone, the out-of-phase effect is one of *cancellation* and loss of efficiency. This is particularly noticeable at the lower frequency end, and the effect must be avoided. Hence the importance of correct

phasing. All manufacturers of speakers ensure that the phasing of the units is correct, and code the terminals so that there is no possibility of error within the speaker assembly; but the connexions between the speakers and the amplifiers are made by whoever installs the equipment, and have to be right.

With cabinet-mounted speakers, the battery test cannot be applied; but you will find that the terminals are colour-coded. Make sure that the positive and negative terminals of each speaker are connected to the corresponding terminals on the amplifier, which will also be marked. For this, one needs colour-coded wire, which can be had from your dealer, so that one can easily follow each wire through its whole length.

Should you be in doubt, place the speakers very close together and listen to the bass end. Then reverse the connexions to one speaker only. If there is an obvious loss in bass response, the speakers are out of phase: adopt the connexion which gives the best result and mark the wires with Dymo tape or by other means so that you know next time. Proper colour-coded wire, however, ensures not only correct phasing but also the right type and gauge of wire for the job.

9

Gramophone Records

The installation of your equipment may have sounded a somewhat daunting process. In practice, it is not so bad, but I cannot too often stress the importance of a good dealer in your own locality to whom you can turn for help and advice.

The moment arrives when all is set up, and you can sit back and have your first session with the new gear. That, of course, means placing your record on the platter and, however good your equipment may be, what you will hear from it depends upon what is on that record, and not only the music on it, either. A gramophone record is a plastic disc, cut with a single spiral groove from outer edge to inner, the groove being a series of minute hills and dales carrying the information which it will transmit via the stylus to the magnetic assembly within the pickup, thence to the amplifier and thence to the speakers. You should hear that information and nothing else.

All, therefore, depends in the last resort on the record. These days there are few bad recordings issued, but the standard does vary widely: you have only to look at one of the periodicals in which records are reviewed to see that. I am here referring to the quality of the recording as such, not to performance: on that matter opinions and tastes differ legitimately, and yours, as the listener, is as good as anybody else's. Recording is a great art, and there are many ideas about the way in which recorded music should be presented. You will, or perhaps already have done so, develop your own views about that. You may like to sit, as

it were, on top of the performers, or you may prefer to sit further back from them. You may like solo passages to be highlighted by special microphone techniques, or you may prefer something closer to the actual concert hall effect. These are all matters of taste.

However, the one essential about which all are agreed is that the sound one hears should resemble as closely as possible the original sound made by the performer. If an oboe sounds like a clarinet, a horn like a trombone, a violin like a viola—then there is something wrong.

Once the record is made, there is nothing you can do to improve it. You should not play the record in the shop before you buy it. Shop equipment is handled by a great many people; it may not be of the same standard as your own; you cannot even be sure that the stylus is not ploughing the record you are going to buy. No: always get unplayed discs. Should they be faulty, return them. A good dealer will accept your word and exchange the record. If he will not, find another who will or, as a last resort, return the record to the manufacturer. There are too many imperfect discs, which come with thumps, scratches, high surface noise and even actual distortion on them. At present prices, this state of affairs is intolerable, and the louder the complaint, the better. You are entitled to a perfect disc: see that you get it, or your money back.

No more advice can be offered about buying records; you care enough about your own kind of music to have set up fine equipment for playing it: your choice is your own. Do not forget, however, that there are record libraries of various kinds: many public libraries have a record department, and there are commercial libraries from which records may be hired, and then bought—often quite cheaply—if you like them. The records you get may not be in pristine condition, but they do allow you to hear them before you buy, and they do ensure a constant flow of new material such as few can afford to buy.

The static problem

As children we all at one time or another rubbed a fountain-pen, a stick of sealing-wax or something similar with a handkerchief and watched with delight the ability of it then to pick up small pieces of paper. The 'sticky' agent was static electricity; records, being made of plastic, are also very prone to the generation of static. Every time you slide a record into or out of its sleeve, it is rubbed and becomes charged. Dust is ubiquitous and cannot be avoided. It settles on a record even when it is not charged with static electricity; when it is, the record becomes a dust magnet. That dust then becomes part of the information in the grooves, and your lovely pickup will faithfully track it and produce from the loudspeakers that snap, crackle and pop which is the bane of hi-fi from disc source. In days of heavy pickups, the dust could be swept aside by the pickup, but modern lightweight ones can only do their job and track the dust.

It will do the same with any other contaminant which gets on the record; but these can and should be prevented. Anyone who spills anything on to a record deserves what he will get. Records should be handled gently and with great respect, and the playing surface should never be touched: the inevitable finger-marks which result from touching the grooves will be sticky and cause dirt to cling. When removing a record from its sleeve, allow the outer edge of the disc to rest between the thumb and first finger. Slide the fingers down the sleeve without touching the record until the label is reached. Tilt the sleeve and allow the record to slide gently out (static!), then bring over the other hand and hold the record by the outer edges only. Carry it so to the turntable, and drop it on to the spindle. After playing, reverse the process: pick it up with both hands by the outer edge, transfer to one hand with the thumb at the edge and the other fingers touching only the label, and replace in the

sleeve. I repeat: never, never touch the playing surface, and never put an unprotected record down on anything. When replacing the inner sleeve in the outer, make sure that the opening in the inner sleeve does not coincide with that in the outer: this helps to exclude dust. Some people buy additional clear plastic sleeves to cover and protect the attractive outer sleeves, which can soon get very tatty if unprotected. Should you wish to do that, again make sure that the openings do not coincide, and you have an additional dust seal.

Accidents happen, and you may inadvertantly touch the grooves and leave a finger-mark. Do not play the record until you have gently sponged it off with a lint-free cloth lightly damped with distilled water. Do not use tap water, as is may contain particles or other contaminants.

Dealing with dust

To overcome, or at least to reduce, static and consequent dust-trapping, one has to create conditions in which the static is partly prevented and then removed. That means a slightly damp state, referred to by the late Cecil Watts—who was the world's leading authority on the record groove —as a 'humid' condition. Sealing-wax will not pick up paper if the cloth with which you rub it is wet; nor will it if you charge it up with a dry cloth and then wet it, as the static charge has been removed.

There are various cloths and fluids advertised for cleaning records, but the best advice is to use nothing whatsoever which leaves any residue on the record surface. Cecil Watts designed a number of items of equipment designed to do this job and leave no residue. Prevention is better than cure, and the idea is to keep a new record in new condition. To do this, Watts designed what he called a 'Preener'. It consists of a plastic cylinder, with a cap on each end, covered with a sleeve of velvet. Inside the cylinder is a 'wick' moistened with water, which has the effect of making the

Preener 'humid' but not wet. The Preener is lightly pressed onto the playing surface while the record revolves, and at one operation relaxes the static and removes the dust, which can be clearly seen on the hairs of the velvet; the dust can be removed with the finger or, better still, with another 'wick' kept for the purpose. Watts recommended that the side *not* to be played first should be cleaned first, whether or not it is to be played; and the advice is sound. Watts wrote a small brochure on the care of records, and there is no better guide. He also designed the well-known 'Dust Bug', a lightweight plastic arm, fitted on the end with a small brush and a circular velvet pad which track the grooves slightly in front of the stylus, removing any dust which may settle while the record is being played. The writer has found that with the very lightweight pickups used today this device is either superfluous or not helpful.

A more recent invention is called the 'Zerostat'. It resembles a toy pistol made of plastic and contains a 'piezo-electric' device, one of the kind we discussed under 'crystal' pickups. The one deployed here generates a high voltage when the trigger is operated, which is applied to a needle in the nozzle of the gun, producing what is known as a 'corona discharge'. This produces positive ions (atoms carrying an electric charge) on the pressure of the trigger, and negative ions on releasing it. These ions are attracted to any oppositely charged surface near-by, thus neutralising any charge upon it—in our case, the record surface. By this means a static-free surface is produced, giving the best conditions for cleaning it, though it must be remembered that removing static does not of itself clean: it only relaxes the grip upon the particles of dust and dirt already present so that they can be more easily removed.

Older records, which have perhaps got into a bad state, can be washed with water containing a few drops of detergent; but a better method is provided by the 'Record Doctor', a device patented by Keith Monks, which first scrubs the surface of the record with a mixture of distilled

water and alcohol, and immediately sucks it off through a vacuum tube. Avoid all other methods of wet cleaning, because unless the water or alcohol is *removed*—not just allowed to dry off—it can make matters worse by creating a sludge which is left to dry in the grooves themselves with disastrous results. Some people find that a container of water with a wick of some cloth material to assist evaporation, kept under the cover of the turntable, helps to build up a humid condition in which static does not arise; and there are available mats for the platter which are made of a conductive material which allows the static to earth away.

There is, unfortunately, no final answer to the problem of static and dust; but with care it can be reduced to a tolerable minimum. This does take time and care, but does not great music deserve such?

Centrally-heated houses get very dry and encourage the build-up of static. Some form of humidifier in the room may help. Smoking produces condensates which can settle on record surfaces and contaminate them, and also the stylus which traces that surface. Closing the lid during playing can help here; but never forget the need to keep the immediate surroundings of the turntable dust-free, as the rotating platter sets up a 'vortex' effect which causes loose dust to shower upon the surface of the record.

Storage

Your records should always be returned to their sleeves immediately after playing: do not leave them on the platter or lying about the room. They should be stored upright, not flat, and under gentle pressure to prevent any tendency to warping. This pressure can be supplied either from springs —as in the 'Paddock' series of containers—or by plywood end-boards, with wedges gently inserted to create a light pressure. There are many record-cabinets available commercially and of attractive appearance; or you may wish to

make your own, or adapt some piece of furniture you already have.

Indexing

While you only have a few records, you will be able to find the one you need without trouble; but if you intend to build up a collection, some means of rapid identification is very useful. It is therefore worthwhile starting from the beginning. The system need not be too elaborate, or it can be a scientific classification. The simplest way is to number the records as you acquire them and note on cards or in a loose-leaf book the work, the composer and the artist(s). You can go further and include conductors, dates, opus numbers and any details you wish. The main point is to know where a record is, so that the shelf should also be numbered and recorded. Some people classify under the type of music, such as chamber, vocal, orchestral, concerto, rock, soul, blues and the like. Indexes can be bought, or you can make your own. Some people even note the number of times they play the record! Should you find that a particular record requires a certain setting of tone controls or filters, it is worth noting that too: with a large collection one can easily forget such things.

You will find that if you index each record as you acquire it, the chore is not excessive—indeed, it is quite enjoyable, and well worthwhile.

10

Tape Machines

The invention of the tape recorder was undoubtedly a major advance in the recording and reproduction of sound. In the early days, a horn was connected to an instrument very like the sound box used to play back a recording, and the performer played or sang into the horn while the master recording was made direct. This created enormous difficulties where anything approaching the full orchestra was employed, and there was the additional problem of the very short time for which a cylinder or disc could run—about four minutes per side in the case of a 12-inch record running at 78 r.p.m. Movements had to be chopped up; the music had sometimes to be slowed down or speeded up most inartistically to fit in the record sides. But the main limitations were, of course, poor frequency response, high background noise, high distortion and the difficulty of arranging the performers round the horn.

The so-called 'electric' recordings were a great advance on the old technique; the horn was replaced by one microphone and then by several. These microphones were connected to an amplifier, which in turn provided the power for the cutting stylus. Every aspect of the technique of recording was vastly improved; but the handicap of the short run on each side of the records remained. Replay machines were designed which changed the records automatically; on long works the records were made in a series such that side two became the first side of the second record which presented itself to the pickup for immediate replay.

When the set was played through on its first sides, the pile was turned over for the linked set of second sides. In between each record, one had a series of clanks and clunks from the auto-change mechanism. This makes one smile today; but then it was a major advance.

Before the last war the BBC was using a device known as the 'Blättnerphon' which utilised enormous reels of metal tape travelling at a high speed. Useful though it was, the quality was not very high. During the war, the German forces used a machine which utilised plastic tape, coated with an 'emulsion' (though it is not, of course, an emulsion in the chemical sense) of tiny particles of iron oxide.

Basic principles

The tape recorder takes us back to those elementary principles of magnetism which we have used before. A tape recorder uses a system, by which a reel of tape is made to pass at constant speed over a recording head. This is one of our familiar electromagnets: a core shaped like a ring but with a very tiny gap in it (very tiny indeed: a matter of microns only). Round the ring is wound a coil of wire, and you will recall that if an alternating current be passed through a coil of wire wound round an iron core, an electromagnet is created. The sound to be recorded is picked up by a microphone, amplified and passed to the coil of the recording head while the tape is transported across the gap. The current thus created is modulated by the incoming signal, and as the tape passes the head the iron-oxide particles are magnetised and remain so, thus creating magnetic patterns in the oxide.

To replay the tape, the process is reversed: the tape is again transported past the head, but this time the current is generated in the head by the magnetised tape—a very tiny current which has to be amplified to make it sufficient to drive a loudspeaker.

That is the essence of how a tape recorder works; but

each stage in the process has its own problems. To begin with, magnetic tape is an inherently noisy medium; but this is being constantly improved by careful research into oxide materials, one introduction being the use of chromium dioxide in place of iron. Again, the frequency response which can be recorded on tape is dependent upon the size of the gap, and upon the speed with which the tape passes the head—the narrower the gap and the higher the speed, the wider the frequency response. High-frequency response is improved by a narrower gap. It was discovered that freedom from distortion could be greatly enhanced if a constant current, called a 'bias' is applied during recording, and the incoming signal superimposed upon it. Research has produced the modern tape machine, which is the basis of all commercially available records.

The advantages are many. No longer did the length of a side matter when recording, as many hundreds of feet of tape can be accommodated on one reel, and as many reels as necessary used. The problem of a large number of performers was solved by the use of many microphones, the output of each being led into a 'mixer' where all could be balanced together into a natural sound. With the development of the micro-groove record, which allows twenty-five minutes or more per side, the recording of the longest works became possible without cutting and playing about with tempi. The quality of tape-recorded sound today is superb, as anyone who has had the good fortune to hear direct playback of master tapes can witness.

There are also mechanical problems to be solved in the tape machine. The moving tape is subject to those twin bugbears of wow and flutter, so that the transport system has to eliminate them so far as possible—to the point of inaudibility on a good machine. A revolving spindle called a 'capstan' is engaged by a roller called a 'pinch wheel', thus trapping the tape and pulling it past the head. The torsion of the capstan is, of course, derived from an electric motor. As the tape is pulled off the 'supply spool' and across the

head, it is wound on to a 'take-up spool'. In some designs, these three—capstan, supply spool and take-up spool—are all driven from the same motor; but it is common practice today to have a separate motor for each. Again, the speed with which the tape passes the head has to be extremely accurate, and constant through the whole run of tape. As the effective diameter of the two spools is constantly varying with the amount of tape on each, a clutch device varies their speeds in proportion to the amount of tape on them.

Tape tension is also critical. Commonly a small current is applied to the supply-spool motor, which pulls it in the opposite direction to that of the pull of the tape. Thus a tension is created on the tape, so that it winds evenly. Contact between head and tape used to be—and sometimes still is—brought about by 'pressure pads' with felted surfaces, which bore on the tape by spring pressure. Today many machines dispense with these, and rely upon the contour design of the tape path.

The magnetic pattern on the recorded tape is virtually permanent, unless it be disturbed. This can happen unintentionally if the tape be brought into contact with a powerful magnet, so that care must be taken to avoid contact with things like loudspeakers which contain such magnets: your tapes can easily be rendered noisy, if not spoiled completely. The ability to remagnetise the tape has a very positive result, however: it makes possible the cleaning or 'erasure' of the tape deliberately, so that it can be used again for another recording.

This is done in two ways: the commonest is to pass the tape across an erase head which precedes the recording head on the tape path. This head is quiescent when a tape is being replayed, but when recording it emits a supra-sonic tone. This renders the tape silent so far as the human ear is concerned, but it can have another, audible recording impressed upon it when it passes over the record head.

The second method of erasing a tape—and it is the one

always used by professionals—is to use a 'bulk-eraser'. This is a mains-driven electromagnet with a spindle in the centre of the coil, on which the spool of tape is located. The current is switched on, and the spool is slowly rotated within the magnetic field and then slowly removed from it. The result is a much completer erasure than is achieved by an erase head, though the latter is normally quite sufficient for amateur purposes.

In early machines, the whole of the record head was used for recording, and this is still done in some machines designed for mono recording in the field. Other machines, especially those designed for stereo recording, divide the head into two 'tracks', each utilising only half the head height. As a result, two mono recordings can be made on the same spool of tape: one on the top track and the other on the lower. The tape and spools are reversed at the end of track 1. This effectively doubles the length of the tape. In stereo the upper track is used for the left-hand channel and the lower for the right, both being played back simultaneously; in mono only the upper track of the replay head is used, the lower remaining silent.

For some years now, quarter-track recordings have been growing in popularity, and have been made possible by improvements in tape, heads and electronics. With quarter-track machines, either four mono or two stereo tracks can be recorded on each tape. The standard tape width is $\frac{1}{4}$ inch, and it can be had on several different thicknesses of base: standard-play, and the thinner long-play (giving half as much tape again in the same size spool) and double-play (giving double the length of tape). Triple-play is available; but it tends to be rather fragile and can be subject to slippage.

For best results, recording tape needs to be adequately saturated but not overloaded: trying to push too much signal onto the tape results in gross distortion. The volume of sound coming into the microphone(s) will vary from moment to moment according to the dynamic range of

what is being recorded. Exact indication of the level being recorded is given by a meter—two meters in the case of stereo machines. These meters are calibrated during assembly and show a red sector towards the end of the travel of the needle. When the needle enters the red sector, overload is taking place. The idea, therefore, is to control the input amplification by means of a control similar to the volume control on the amplifier, so that overload is avoided. This process can be a somewhat hit-or-miss affair unless it is possible to observe the deflection of the meter during a rehearsal or trial run. It is possible, by special circuitry, to incorporate auto-record levels in the machine— sometimes called 'limiters'. These, however, tend to flatten out the overall dynamic range and are best avoided. Live recording demands much practice and some skill, and it is better usually to set the level for the loudest passages in the score (which are not always what one might think they will be!) and then let the microphone(s) 'float' for the rest. The result is much more realistic, in the writer's experience, than too much effort at 'compression' or levelling-out.

In the simpler machines, the record head doubles as replay head, with suitable switching. In more advanced—and all professional—machines there is a third head, specially designed for replay only—the requirements of recording and replay not being entirely the same. By means of the third head, which is placed after the record head, it is possible to listen to the recording a fraction of a second after it has been made, and by suitable switching to compare the signal coming into the recorder with that impressed upon the tape. This process is known as an '*A*–*B* comparison', *A* being the signal coming in to the recorder and *B* that recorded on the tape. This facility enables one to be sure that a recording has been made and is satisfactory, and it enables one to compare recorded with incoming signals. On the best machines the two are so similar that it is easily possible for an astute demonstrator to fool his audience into thinking that *A* is *B* and *vice versa*. There could be no more

exacting test of the performance of a recorder than that; but good ones pass it with honours.

The discs we buy today all originate as tape recordings, and will probably be made up from a great number of individual 'takes', by which unsatisfactory parts of a performance are removed and a different version substituted. This is a not unmixed blessing, for it often destroys the freshness and spontaneity of a live performance, and leaves a pastiche of 'takes' in which something is lost.

Here you may well ask why we do not use tapes instead of discs for our own records. That is a good point; and it may well be that before long we shall. But tapes have to be copied end to end from an original: there is no other way of multiplying them. For technical reasons, the higher the speed at which the tape passes the heads, the higher the standard of fidelity. Studios always use at least 15 inches per second of tape passing the heads, and that uses an awful lot of tape. Commercial copies are issued at either 7, $3\frac{3}{4}$ or $1\frac{7}{8}$ inches per second; and the loss of quality resulting from changing to the slower speed is greater than that involved in making up a matrix and stamper from the tape and pressing discs from it. Further, to facilitate the copying process, the 'slave' machines on which copies are made, and the master machine, are speeded up. That process, too, induces losses. These problems, however, are being tackled and will one day be overcome. When they are, the disc, with its problems, may disappear in favour of tape recordings.

One snag of tape, however, cannot be overcome: in order to get to side 2 one has to wind the whole tape, which is irritating; and it is very difficult to identify individual items on a tape as one does on a disc by 'banding' them.

Types of tape machine

For our purposes, there are two types of tape machine. One uses 'open' reels, which means that a spool of tape is placed on the machine, threaded through the tape path and

anchored onto a take-up spool. The other is a 'cassette' machine, in which both supply and take-up spools are enclosed in a plastic envelope from which they are never removed: all one has to do is to place it in position on the machine and turn it over, very much as a disc, for side 2. The result is greater convenience and speed in use.

Reel-to-reel

Professional tape machines used for studio recording are always of the reel-to-reel type, and most enthusastic amateur recorders also use them. The idea that they are difficult to use can be dispelled in a few minutes: I have taught blind people to use them in less than an hour, and any woman who can use a sewing-machine can master a tape recorder with ease. This is not the place to go into the technicalities of design and use of the tape recorder, but for the highest quality of recording one requires a machine which operates at a relatively high tape speed. Everything which was said about wow and flutter when we were discussing turntables applies with equal force to the tape transport of a tape machine, and the problems of frequency response and distortion also. There are machines made for amateur use which approach very closely to professional standards; but, of course, they are not designed for continuous use as are professional machines, which have to be able to maintain their specification over arduous usage.

Cassette

Cassettes were originally introduced for dictation machines, in which quality was not too important. They use tape only half the width of reel-to-reel machines, and operate at the very slow speed of $1\frac{7}{8}$ inches per second. However, very great advances in head design, types of oxide and tape transport systems have now made these machines capable of a standard of performance undreamed of when they were

first made. Twenty years ago, when the writer first began tape recording, nothing slower than $7\frac{1}{2}$ inches per second was regarded as feasible for high-quality recordings of music. Things are very different today, yet the limitations imposed by the narrow tape and slow speed of cassette machines still make them inferior performers to reel-to-reel machines. If one wishes to edit tape in the professional way, by physically cutting it, the cassette machine is virtually useless.

We have seen that designers go to great lengths to eliminate unwanted noise. With tape machines, one has not only to contend with the noise inherent in the record and replay amplifiers, but also with that inherent in the tape itself. Noise obviously becomes more apparent in the quieter than in the louder passages of music (signal-to-noise ratio once again), and on some records what is usually called 'tape hiss' is very apparent and can be distracting.

An important advance in the science of recording was made when Dr Dolby invented the noise-reduction system which bears his name: the Dolby system, often abbreviated to just 'Dolby'. This system is now used by all the major recording companies in the production of their records. Put simply, circuits are employed which raise the volume of the quieter passages while they are being recorded, and upon replay reduce them to their original level *and the noise with them.* The result is a dramatic reduction in background noise.

The original 'Dolby A' system, still used by professional recording engineers, is a rather complex one, involving division of the frequency spectrum into different bands. A simplified system, 'Dolby B', was then introduced which can be adopted in domestic equipment either as a built-in or as an add-on accessory. Today all the high-quality cassette machines incorporate Dolby B, or a similar system, and commercial cassettes are recorded by the Dolby system too. Since noise levels rise as the tape speed is slowed down, and cassette machines operate at the low speed of $1\frac{7}{8}$ inches per second, the introduction of Dolby has done a great deal to

transfer the casette machine into the realms of true hi-fi. If you buy a cassette machine, it should incorporate Dolby.

Cartridge

For applications like talking books for the blind, background music and entertainment in the car, there are machines, some of which do not record at all but only play back eight-track cassettes, automatically reversing the tape at the end of each run. At present the standard of these devices is such that we need not seriously consider them in terms of hi-fi.

Live recording

Tape recorders are ostensibly made so that the owner may make his own recordings rather than copy existing ones. Live recording is an art, and an absorbing one, about which many books have been written. We cannot here go into the fascinating world of microphones, their placing in relation to performers, mixers, pan-pots, artificial reverberation and all the other aspects; but anyone who owns a recorder should certainly have an attempt at live work. It is, however, only fair to say that the results he will get are not likely to approach those to which he is accustomed from his hi-fi reproducer. The professional may well spend more money on one microphone than the amateur does on his entire equipment, and may use half a dozen or more of them at the same time, coupling them to a mixing console costing thousands and into a studio tape machine costing many pounds more—we are not comparing like with like. Nevertheless, there is satisfaction in doing it for oneself, and in getting the best possible result from limited resources, which makes live recording a fascinating pursuit.

One has also to remember that the amateur, in general, can record only artists who are not the equals of the great virtuosi he will be hearing on his discs, so that his results, however

well done, will hardly give the same artistic joy. However, it is possible greatly to help an aspiring musician—even oneself—by letting him hear what he is playing and analyse it at leisure; and that is well worth doing. It is safe to say, nevertheless, that the vast majority of tape machines sold are used for the purpose for which they are ostensibly offered only to a very small degree. When a machine is acquired, it is great fun to experience the horror of hearing one's own voice for the first time, and then inflict that shattering experience on others. After that, and similar domestic snapshots such as the baby's gurglings, the machine is rarely, if ever, used to record, save by dedicated enthusiasts who collect natural history sounds, trains, fairground organs and such. Indeed, many hobbies, such as ciné-photography, can well be supplemented by sound, and there are highly skilled amateurs who do this to a remarkable standard and produce material of considerable scientific or social value.

Dubbing

'Dubbing' is commonly used to describe the copying of an existing recording, or the addition of recorded sound to such things as film. It is for this purpose that the majority of hi-fi enthusiasts purchase a tape machine. In practice, that means the copying of discs, and the recording of radio broadcasts.

We saw when looking at the specification of the amplifier that provision is made for input and output of a tape machine; it is possible to play a tape or disc through any amplifier you are likely to buy, and at the same time pass the signal to a tape recorder for copying. The simpler tape machines use the same head for recording and for replay, so that a recording can only be played back after it has been made; but the more versatile have separate recording and replay heads (pp. 104–5).

It is therefore perfectly possible for the owner of a high-

quality tape machine to make copies of discs, tapes or broadcasts which are indistinguishable from the original. This is a very attractive thing to do. The tape may well cost more than the disc would have done; but the advantage of tape is that when one tires of a recording one can erase the tape and use it for another—and do that an indefinite number of times. It is for these purposes that the majority of tape machines are installed into a hi-fi system, and not for live recording. One must in conscience, however, refer to the important matter of copyright.

Copyright

Copyright—that is, the right of the owner to prohibit copying—exists in musical compositions, plays, novels or any form of creative work. To infringe that copyright is an offence in law; and copyright is the basis of those royalties which form an important part of the income of a composer, musician or writer. For every disc you buy a contribution is paid by the manufacturer to the composer and artists; and if you 'dub' that disc instead of buying it you deprive those people of their just reward, and break the law in doing so.

The same principle applies to broadcasts: the BBC may waive the right it has in the broadcast itself, but it cannot and does not take away the right of those whom it employs, be they composers, authors or performers. Every disc you buy, if you examine the sleeve or label, will warn you that any unauthorised use of it for public performance, broadcasting *or copying* is an offence; and it is well that you should know that.

In practice, of course, nobody is likely to discover that you have committed the offence, and discs, tapes and broadcasts are widely and frequently copied without any penalty. You can get away with it, but it may make your conscience squirm.

Authorisation

Music itself is subject to copyright, and even live recording of copyright music is an offence unless done for the purpose of study and then erased. A licence for such recordings may be obtained from the Mechanical Copyright Protection Society for a modest annual fee.

In addition, those engaged in the production of audio-visual compositions, such as soundtracks for amateur movies and accompaniments to tape-slide sequences, can obtain a licence to use gramophone records for these purposes only. In all other cases the sanction of the record or tape manufacturer has to be obtained in each case; and I warn you that this is not given lightly!

Many people take the view that having bought a record they can do what they like with it. In law, that is not so; and the writer feels bound to call attention to that fact.

Recorded tapes

In the past, many recorded tapes (often referred to as 'pre-recorded' as the recording is made before you buy the tape) were issued in this country both in mono and in stereo, for reel-to-reel machines. The quality of these varies considerably, and they were expensive when compared with the cost of the corresponding discs, so that they never caught on sufficiently to be a commercial success. In America, however, they were much more successful, and may still be issued there, and imported into this country. Some are superb, others vile. However, the danger of damaging tapes by playing them on showroom equipment is not so great as playing discs under the same circumstances, so you can at least listen before you buy if you can find a stockist. In general, you will not find the search very rewarding.

More recently, however, a considerable upsurge of in-

terest has been created by the issue of recorded cassettes. A good number of newcomers to hi-fi are now basing their systems upon these recorded cassettes, and not acquiring discs at all. Many more are going in for both. The standard of quality which one can attain with the best cassette machines and the best of the recorded tapes is astonishing; but at the moment the quality of these tapes tends to be variable, and the writer has yet to hear a demonstration of them which gave a standard equal to the best discs.

On the other hand, a cassette machine, though expensive if of the highest quality, compares well in terms of cost with a turntable, pickup and arm; and the extra convenience of merely having to pop on a cassette, instead of carefully handling and cleaning a disc, is well worth thinking about. The fortunate can, of course, have both—or a casette machine can be added later. I recommend that you listen carefully to both systems, and decide whether or not you can be content with cassette quality. If you can, then your choice is clear; if you cannot, then go in first for a disc player. There seems, however, to be little doubt that in the future tape will oust the disc to an increasing extent, and perhaps finally altogether.

Entertainment in the car

Stereo cassette players and eight-track cartridge players are available for installation in a car. They are so simple to operate that they constitute no traffic danger—far less, indeed, than lighting a cigarette. Many people like to have music while they drive; and the cassette player enables one to choose one's own programme, which a radio does not. Though not strictly hi-fi, these installations can give very great enjoyment and pleasantly while away the tedious miles. They are, of course, powered from the car battery and suppressed against interference.

Creative tape recording

Although the use of a tape recorder as a substitute for a disc reproducer is perfectly legitimate, and indeed the tape machine may well oust the disc in the not too distant future, it would, in my opinion, be a vast pity to overlook the creative potential of magnetic tape, which, unlike the disc, can be used for creating recordings as well as playing them back.

A word was said above (pp. 108–9) about live recording, and about the limitations which the amateur is likely to encounter when he tries it. Nevertheless, as was hinted previously, there are forms of music recording which, though not concerned with immortal masterpieces of interpretation, are nevertheless worth while. The author has often recorded amateur operatic societies, chamber groups, youth orchestras and the like, and has had discs cut from the tapes which have served both as a memento of the occasion to those who took part and as useful self-criticism for the players. These occasions also give useful practice in the difficult art of recording, and as such present a stimulating challenge to create hi-fidelity in its best sense: as the closest approach to the original sound, even though that sound bore scant resemblance to La Scala or the Festival Hall. Sound recording is a fascinating pursuit.

There is, moreover, one musical field in which it is not too difficult to get access to real excellence, and that is organ recording. The churches of all denominations contain instruments, many of which are of great merit (the author vividly remembers a tiny baroque, tracker-action organ in a Cotswold church which produced the most exquisite sounds when played by a blind friend) and are in the hands of far more than competent musicians. Given a tactful approach, it is often possible to arrange a recital, and then to tackle the daunting task of finding the best microphone position in what may well be an over-reverberant acoustical

environment. With all recordings of music, the rights of copyright must be observed; but much of the music likely to be played in such recitals will long since have passed from the realm of copyright into the public domain—Bach, Handel, Mozart, Tallis, Byrd and the rest. (Note, however, that the particular *arrangement* played may be itself still under copyright.) This is an enjoyable activity which might well be explored by any who care for the music of the organ; there are also many quite fine church choirs which are willing to give a session, especially if they are afterwards supplied with a copy of the tape for their own instruction and enjoyment. A thriving society exists for the support of theatre-organ music, and much recording takes place at the recitals arranged, with highly professional performers who are leaders in their field.

Music, however, is by far from being the only sound (though fairground organs, street pianos and other instruments of that kind are now often demonstrated at steam rallies, and have an appreciative audience amongst the knowledgeable in that field). There are the sounds of nature: of birds, mammals, insects and the rest. This is a field in which the amateur (in the best sense of the lover) can actually contribute to the sum of scientific knowledge: a friend of mine was the first, so far as is known, to make a satisfactory recording of the song of the dipper. Those with an enthusiasm for natural history can add greatly to their own and others' knowledge of the world about us by the creative use of the tape recorder: another friend of mine, shortly before her death, had completed a study of the song of a warbler which included calls not previously studied in any depth.

For such purposes as these, a mains-powered machine is of little use—though it is possible to obtain a converter which will operate such a machine from a car battery. A much better solution is a battery-powered machine; and the best of these certainly qualify for the epithet of hi-fi, and even accept 7-inch reels of tape so that they can double up as a home recorder as well as a field machine, especially as

all can be operated from the mains by means of a suitable transformer.

More humble, perhaps, but nevertheless deeply satisfying, is the use of the tape recorder for correspondence. If one has friends or relations who live at a distance—perhaps overseas—the exchange of tapes in place of conventional letters is a far more personal communication. The author has recordings of the voices of those who have passed away, and these are most consoling. To begin with, one tends to be a little embarrassed and stilted when talking into a microphone to somebody who is not there; but that soon passes and one learns to chat as if to one who is there. So much more can be said: a fifteen-minute tape carries news which would take hours to write, and would probably never be written. Domestic sounds tend to be picked up by the microphone, and these add to the sense of realism and communication. I have developed close friendships through tape with people whom I have never met face to face. If one strives to make an accurate recording of one's own voice, one again enters the realm of hi-fi.

Mention was made previously of the tape recording as an adjunct to photography; and indeed the two hobbies go well together. Slide presentations backed by stereophonic sound, or soundtracks to amateur ciné, create a new dimension and lift the mundane into the realm of art. Very considerable skill and craftsmanship are called for here, as well as aesthetic judgements; and if one is interested in competitive activities there are many awards to be won in both fields, to say nothing of the social contacts which can be gained by them. Photography is concerned with its own kind of hi-fi; and when combined with sound calls for even higher artistic and intellectual gifts.

Another field is social documentary work—again in both sound and vision if you wish; the collection of folk music and verse; children's games; industrial archaeology while survivors of obsolete techniques yet remain to be recorded—especially the agricultural and rural life which has largely

passed away. The list is virtually endless, yet thousands of semi-idle tape machines gather dust under the stairs or in attics.

All these creative uses of the recorder can be combined for the amusement and consolation of the elderly, the blind and the physically handicapped. This is a most rewarding and worthwhile field of activity. The blind often show great ability with the tape recorder themselves; recorded books, intelligently read onto tape, are a great source of enjoyment. There are libraries for such purposes which are badly in need of good readers. Having for many years made a small contribution to such services, I know well the satisfaction and appreciation it brings.

It may be apparent that this subject is something of a hobby-horse of mine. Nevertheless, to ignore the creative side of the tape recorder in favour of the purely passive use of one as a substitute for the gramophone is a waste almost comparable to keeping a Stradivarius merely for the pleasure of looking at it. As a creative tool, as an album of reminiscence, as a means of communication, the recorder is as valuable as it is as a source of high-fidelity in musical reproduction. You are warmly recommended not to overlook this potential.

11

Radio Tuners

A high-quality radio tuner must be regarded as an essential part of a full hi-fi installation. Today, the quality transmitted by the BBC, particularly in live broadcasts, provides probably the highest standard available, and it would be foolish indeed to deny oneself such a source of musical pleasure. Radio 3 puts out a wealth and variety of music of all kinds which would be impossibly expensive to acquire by any other means, even were it so available, as it often is not. I, for one, owe an enormous debt to the BBC for providing much of my musical education.

Another dimension was provided to radio reception when the BBC commenced stereo transmissions on Radio 3, which have been extended to other programmes. I well remember the first such transmission I heard on my own equipment: a live broadcast from the Proms of Bach's *Mass in B Minor* which was totally thrilling. Stereo reception is more demanding than mono, and not everybody can yet receive it; but even should you at the moment have to content yourself with mono transmissions, these are far too good to miss.

You will have noted the expression 'radio tuner'. As you already have an amplifier and loudspeakers far better than any built into a complete radio receiver, there is no point in getting a complete receiver for hi-fi purposes; listening to the news and the rest is a different matter, and most people have one or more transistor sets round the house. A

tuner consists only of the receiving part of a radio, amplified to the highest standards sufficiently for the radio input of your amplifier; that is all you need, though the best radio receivers have an output placed before the power stages from which a signal may be extracted to load an external amplifier. This is known as a 'diode output'; but in this book we cannot go into the technicalities of radio reception.

AM and FM

Early broadcasting was all 'AM', which means 'amplitude modulation'. These transmissions utilised Long Waves (LW), Medium Waves (MW) and Short Waves (SW)—the last for transmissions over long distances, and beloved of that dedicated band of enthusiasts, the 'radio hams'. These transmissions were—and are—very subject to interference both from electrical sources via the mains and also from other transmissions on a frequency close to that of the broadcast. After dark, particularly, we have all experienced this hash and 'monkey chatter' which can render listening a torment rather than a pleasure. In order to minimise this interference, it is necessary sharply to restrict the frequency band which is transmitted, so that the resulting signal, particularly on music broadcasts, is very far from hi-fi standards and becomes tedious to one accustomed to listening to discs or good tapes.

A technique was then developed which uses much shorter wavelengths referred to as VHF (Very High Frequencies) which are measured in megacycles, or millions of cycles, per second. This, combined with another technique known as Frequency Modulation (FM) gives reception much less subject to interference of all kinds—though not totally so—and also allows the transmission of a much wider frequency band. The result is music of a clarity and naturalness which is a revelation to one who has heard only the older AM broadcasts, and which brings broadcast music within the definition of hi-fi. Now stereo has been added to that, and

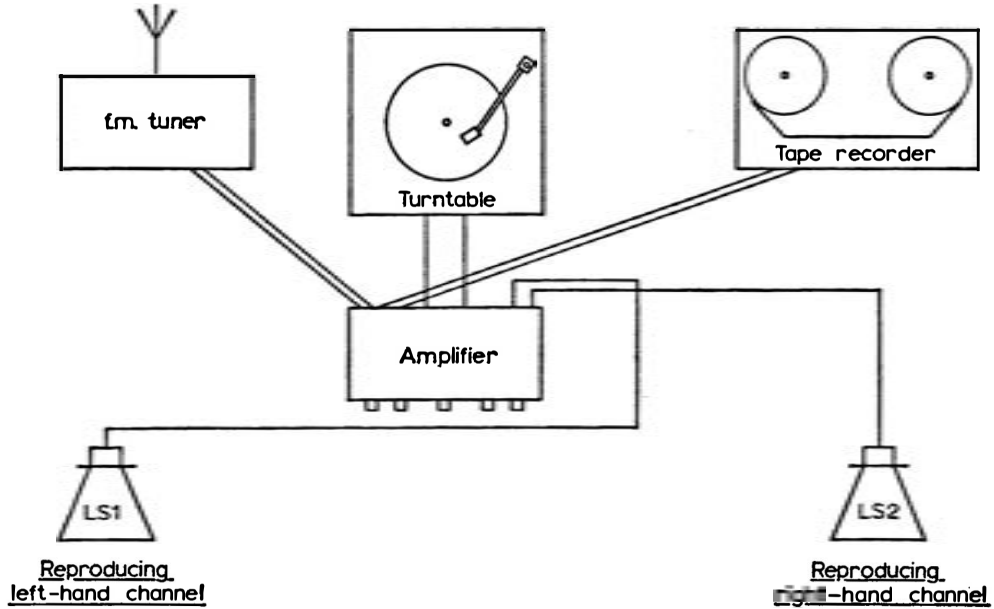


Fig. 19 Schematic diagram of a hi-fi rig, showing channel separation. The tape recorder would have both input and output connexions to the amplifier

everyday music of all kinds, including jazz, is poured out—free save for the cost of the equipment to receive it.

A radio tuner, then, should certainly be part of your initial or prospective purchases. It should contain a 'decoder' so that stereo can be received later even if it is not yet available where you happen to live. There are now many instruments which combine radio tuner with amplifier—they are called 'tuner amplifiers' or 'receivers'—and the best of these offer the highest quality in both aspects and can be cheaper than buying them separately. Otherwise, most makers of amplifiers produce tuners which match not only electrically but also in appearance.

Tuners are regularly reviewed by the audio journals but, as with all other items, one is best tried in your own location, as FM reception is a rather tricky thing. For that same reason the aerial is important.

The aerial or antenna

We have become accustomed to needing no external aerial with our domestic radios; there is one built into the set, and reception is improved by orientating the set so that the best pickup position of the aerial is presented to the transmission. A good aerial is necessary with an FM receiver; again one will probably be built into your domestic set, though not into those designed for hi-fi reproduction. Such an aerial may well be adequate for mono reception in a line of sight from a transmitter; but generally an external aerial is essential. Where the incoming signal is strong, a simple aerial (called a 'dipole' because it consists of two simple wires or alloy bars, each connected to a terminal on the receiver) may well be enough for mono reception, though rarely for stereo. Much more probably, it will be necessary to have a more complex array, which may well be sited in the loft or roof-space. Should that not prove efficient enough, it will be necessary to mount the aerial externally—usually attached to a chimney.

The signal arriving at the aerial is very tiny indeed—a matter of microvolts only, or millionths of a volt. This tiny signal has to be picked up and amplified with the addition of as little noise as possible. The more signal one can get at the aerial, the more satisfactory will reception be, and more independent of propagation conditions, which vary with weather and time of day. VHF waves are much more easily masked or deflected by buildings, hills and the like than AM waves, and there may be a strong signal only a matter of feet away from another point where it is hopelessly inadequate. This makes the choice and siting of an FM aerial a skilled job; should difficulties arise it is best to call in a professional, who knows the district and how best to cope with its problems and choose the right type of aerial. Mistrust anyone who does not bring with him what is called a 'field strength meter' with which to measure the signal strength and choose the best site for the aerial.

This question really is crucial, especially for stereo reception. Not only does the BBC reduce the modulation from the transmitter so as to allow a wider dynamic range (i.e. the ratio between the loudest and softest passages of the music) but also stereo transmissions have an inherently worse signal-to-noise ratio and tend to have background hiss absent from mono. It is well worth devoting time and money to getting the aerial right, as the difference it makes is enormous. There are constant improvements being made in aerial design; the tendency today is to use one precisely tuned to the frequency of the transmitter being picked up.

Foreign broadcasts

FM transmissions are designed to have a limited range—which is one reason why they are freer of interference than AM ones. Nevertheless, a certain amount of globe-trotting is possible, and those who live towards the southern coastline can often pick up continental transmissions of superb

quality. Rotating aerials can be aligned precisely to give best reception. Many enthusiasts enjoy this kind of adventure; and there is a regular feature dealing with the matter in *Hi-Fi News and Record Review.*

12

Hi-Fi Pleasures and Pitfalls

The greatest pleasure of hi-fi—in a sense its only pleasure—is the enjoyment of music, or of any other sound, reproduced as perfectly as the state of the art permits. Through it, the greatest artists are there to play for us our own choise whenever we desire to hear them. We can study our favourite works, or explore new ones, in detail and with a leisure which is denied to all save the accomplished few who can 'perform' music to themselves from a score. We can compare performances and interpretations. We can listen again to the playing of those whom death has silenced; and a good recording will often reveal detail and structure in a way we may well have missed in the concert hall. Although there can never be any substitute for live music-making, the discomforts and distractions of the concert hall do not exist in one's own home; and one can enjoy music either alone or in company. Provided that the comfort of neighbours be considered, hi-fi provides a civilised recreation free from all harm to others, and rich in profit and satisfaction which makes life a fuller thing. Technology is not an unmixed blessing; but here at least it has given us something about which there can be no regrets.

There is another side to the matter, which is also a source of legitimate interest and satisfaction, and that is the technical nature of the equipment which produces those lovely sounds. I use loudspeakers whose development I have been able to watch over many years. Since two men exchanged ideas and started a long process of experiment,

years of devotion and experiment have gone into the present commercial product, which was never even thought of when those early ideas were explored. The same kind of story underlies every component part of the hi-fi chain; and the motive which drives the best of the hi-fi designers is not financial, it is a compelling desire to make things just that shade better, a restless search for unattainable perfection.

Many who cannot create in this way can and so ardently follow the development of the art; but they do so with a certain peril. The two men I mentioned are both dedicated music-lovers, and both can and do forget all technical considerations and concentrate on the music being made. The danger is that one may become so absorbed in the technicalities of the subject that one ceases to listen to music, and listens only to signals. Playing hi-fi then becomes a matter of listening for the smallest element of distortion; of comparing one component with another; of restless experiment which never relaxes into calm enjoyment. This state of mind is more akin to neurosis than to the pleasures of music. It leads some to misery rather than to enjoyment: to a never-ending feeling that there is some different equipment, somewhere, which is better than what one has now, and to a compulsion to acquire it. This attitude is extreme; I have seen more than one case of it. Other hobbies have the same danger, of course; but it is as well to foresee it—and perhaps from time to time to profit from it by purchasing the little-used cast-offs of the compulsive equipment-dabbler.

The truth is that once one has acquired a good outfit one can safely sit back and enjoy it for some years without any fear that something new has suddenly made it out of date. Advances are not so swift as that; one can be quite sure that improvements in fidelity will get smaller and smaller, and more and more expensive. It is now possible to reproduce small ensembles, solo instruments and voices with such perfection that it is difficult to distinguish the recorded from the live performance, so it is not very likely that the excited

encomiums of advertisement copy-writers about 'totally new experiences' will really be true. Only very recently I listened with the greatest of pleasure to a rig which was, by the standards of the enthusiast, very old hat—yet it made most beautiful sounds, and one could readily concentrate on Shostakovich and forget all about the equipment reproducing his work.

There are also, inevitably, equipment snobs—as there are in every other hobby. One has so often met the man with the expensive camera who rarely takes a photograph, and then not a very good one; and the curious fact is that the hi-fi snob rarely plays his equipment when there is no victim present to whom he can demonstrate it. Nor will he ever shut up and allow one to enjoy anything: he has to keep chipping in with comments which rarely reveal any depth of technical comprehension. Such people should be ignored and avoided: there is too much great music to be explored to waste time with them.

When planning to buy your first hi-fi set-up you should certainly hear as many installations as you can, in order to discover where your own tastes lie. You should choose carefully and without haste, ignoring the pressure of sales-talk and the purple prose of the ad-writer. You may well discover that the difference in sound between the very expensive equipment and the rather less expensive does not justify the extra expense. Having made your choice, and made sure that it is properly installed, you should settle down with it and listen to music, not to equipment. Experience may well lead you later to wish to make changes, but never for the sake of change. Given a wise initial choice, it is better to spend money on more records than on more equipment. Hi-fi is expensive, though a very good rig can be acquired for the price of a colour television, and perhaps offer much more joy. Not everybody can afford to indulge the latest whim of the equipment-maniac, nor do they need to do so. Good sound today will be as good tomorrow.

Eras do end, and new ones begin: of recent years a new

generation of pickups has come on to the market which do totally outperform their predecessors. It is at such moments —and they are rare—that one should think of a change.

Points about listening

A few years ago, I was assisting my old friend B. J. Webb in a demonstration at the National Federation of Gramophone Societies' annual weekend. The demonstration began with a piano solo, played so loud that a whispered message of alarm went to the demonstrator. 'It's all right!', was the reply. At the end of the item the audience was asked for an opinion. 'Too loud!' was the universal comment. The audience was then told that at a live recital the previous evening, measurements had been made of the sound level in the same hall, and that they had just been listening to precisely the same level. Nobody could believe it, but the measurement had been made with an accurate, professional meter.

This incident is illuminating, because hi-fi enthusiasts are often accused of playing too loud. I attended a professional demonstration of equipment during the same weekend, sitting right at the back of the room. Afterwards I was asked by a man who had been sitting right at the front what I had thought of it. 'Quite nice,' I replied, 'but why so blastingly loud?', 'Rubbish!' I was told, 'That is the thrill of hi-fi!'

The truth is that in the concert hall we happily accept volume levels which would crush us if reproduced in the home. This, unfortunately, is partly due to the fact that the distortion level of reproducing equipment, small though it be, creates nervous tensions absent from the live performance. Nevertheless, realism does require a certain volume level, and there is quite an art in setting it correctly.

I am quite prepared to base my judgement of the knowledge and sensibility of a demonstrator by reference to the

volume level at which he plays. On the other hand, it is perfectly true that the full capabilities of a hi-fi system cannot be judged without what Raymond Cooke, of KEF Electronics, aptly calls 'a healthy belch of sound' somewhere during a demonstration.

The hearing of women tends to be more sensitive than that of men; and one loudspeaker designer I know always makes a point of taking his wife's opinion after he has satisfied himself that a certain improvement has been achieved; and his lady does not always agree with him. . . .

The dynamic range of modern orchestral recordings tends to get ever-wider, so that either one fiddles with the controls, or else sets them for the quieter passages and allows the room to reverberate with sound in the tutti passages. Here the size of the room in which one is playing makes a considerable difference, as does freedom from extraneous noise.

People hearing full-range equipment for the first time, after being accustomed to the more restricted range of domestic radios and radiograms, often complain that it sounds 'shrill' or 'harsh'. I well remember being invited to hear some newly acquired equipment in the home of a friend, and being vastly disappointed until I glanced at the tone control settings and found the treble control well set back, and the bass advanced. Gently adjusting these controls to the 'flat' position, I enquired if that did not sound better. 'No,' replied my host, briefly. Knowing that he regularly drove more than a hundred miles each way to attend concerts at the Royal Festival Hall, I enquired, 'When you go to the RFH, you have to take in the full range of the orchestra in a lively auditorium. Why then do you so restrict it when playing your records? There are no volume controls there!' 'No,' answered my friend, 'but if there were I should use them'. To such an opinion, of course, there is no answer, but at least my friend knows what he likes, and sticks to it.

That attitude, perhaps, is the motto of this book: your

own taste is the arbiter of what you buy and of how you use it. Hi-Fi is for pleasure: your pleasure, not anybody else's. My only plea would be that you do all you can to educate your taste by careful comparison between the real and the reproduced. What you then enjoy is for you and you alone to decide.

The reader will not, it is hoped, be affronted by a word about listening to music, which is much more than a passive wallowing in glorious sound. To be sure, there is nothing immoral about doing that; but it is only part of the real pleasure of music. Although much music has a strong emotional content, some has not, and that applies particularly to some contemporary music, in which the intellectual content takes precedence over the emotional. It is a great mistake to limit one's range of musical experience to the familiar and well-loved: the attitude of 'I know what I like' is all very well, but dislike is often a synonym for ignorance or obstinacy.

During our musical lives, most of us have experienced changes in taste, a widening of the range of our appreciation. That should be a continuing process, in which we constantly strive to understand and appreciate music which hitherto has been inaccessible to us. Dismissing what we do not like as rubbish may be little more than laziness or lack of proper curiosity. An obvious example is the music of Schönberg: the early music of Schönberg was richly harmonic and highly romantic, so many a listener who can allow *Verklärte Nacht* to wash over him is revolted and angered by the later, twelve-note music of which Schönberg was the main originator. When Stravinsky's *Firebird* ballet music was first performed, it was received with outrage; yet now it brings the house down during every Prom season. Would Schönberg change his style so radically unless there were a good reason for it? What was that reason? Was it justified? What *kind* of music is the later Schönberg? These are all questions which the gramophone will help us to answer if we be prepared to make the experiment and

listen with an open mind—*mind*, notice, not just ears.

The same sort of thing is true in other fields of music. If, for example, you adore 'trad' but cannot endure the Modern Jazz Quartet, are you sure that you have ever really tried to discover what modern jazz is trying to accomplish?

Listening to music demands total concentration: nothing less does justice to one of the highest attainments of the human spirit. Background music is not sinful, but it is not enough: great music deserves and demands all that we can give it, and the rewards are immense.

It helps to know musical notation, and to have some familiarity with performance. Neither, however, is strictly necessary: I once plucked up the courage to ask Sir Malcolm Sargent if the full enjoyment of music demanded the ability to recognise a retrograde inversion when one heard it. His reply was typical: 'Music is a natural thing: enjoy it naturally—that is all that is required.' But by 'enjoyment', I am quite sure, he meant total involvement, not just 'listening'—perhaps only with one ear while doing something else. To learn to keep attentive to all the different voices of a fugue; to apprehend what is happening to all four instruments of a quartet; to recognise the reintroduction of a theme used earlier in the work; to follow a development or a variation—these are all joyous things, which bring deeper understanding, higher appreciation of genius and ever-deepening gratitude for the gift of music.

In widening one's musical field, in deepening one's appreciation of it, the gramophone is of immense help. So, too, is the output of the BBC, which transmits much music which is not on record and can be heard only through the broadcast.

Music adds so much to life; and hi-fi, properly understood, is the servant of music. It is in that spirit that this book has been written, and in that spirit that the greatest of hi-fi designers have worked. My life has been vastly enriched through the gramophone and the broadcast. It is my hope

that you may have been guided through the early stages of an appreciation of what hi-fi is and does; that you will choose wisely; and that your equipment will give you the lasting joy that mine has given me.

13

Further Reading

Books

J. Crabbe, *Hi-Fi in the Home*, Blandford Press. This is by far the best general book ever written on the subject. The author is editor of *Hi-Fi News and Record Review*, and is a sensitive and knowledgeable music-lover as well as a technical expert. Make sure you get the latest edition.

John Borwick, *Know Your Gramophone*, and *Living with Hi-Fi*, General Gramophone Publications.

G. A. Briggs, *More about Loudspeakers*, Rank Leak Wharfedale. G. A. Briggs, founder of the Wharfedale line of loudspeakers, has for many years been a pioneer in loudspeaker design, and his books are very readable.

Clement Brown, *Introduction to Hi-Fi*, and *Questions and Answers on Audio*, Newnes.

J. Burrell Hadden, *Practical Stereophony*, Iliffe.

J. Walton, *Pickups, the Key to Hi-Fi*, Pitman. This book is out of print and in many ways out of date, but it shows clearly the main problems of pickup design, as well as the way pickups work. It should be available in libraries.

B. J. Webb, *Stereo for Beginners*, Henslow Year Books. This book is also out of print but worth searching for, as it is a mine of information, clearly set out and highly comprehensible.

Booklets

Clement Brown, *All About Stereo*, and *Introduction to Hi-Fi*, Haymarket Press.

Audio Talk—Audio Terms Defined, Link House Publications.

Cabinet Construction Sheet, Rank Leak Wharfedale.

Loudspeaker Enclosure Design, KEF Electronics.

Goodmans High Fidelity Manual, Goodmans Loudspeakers.

Journals

Hi-Fi News and Record Review, Link House Publications. This is the most advanced journal technically, maintaining the highest possible standard of equipment reviews, constructional articles and general hi-fi chat. It also contains a full record review supplement, with special emphasis—though by no means exclusively—on quality of recording. Its standing permits of total impartiality of comment and reviewing.

The Gramophone. This is primarily a record review, and those who review for it are musically highly qualified. The writer has not found himself always in agreement with comments on technical quality. There are also stringent reviews of equipment and general articles of great interest.

Hi-Fi for Pleasure.

Hi-Fi Sound.

Studio Sound. This journal comes from the same stable as *Hi-Fi News and Record Review.* It was formerly a journal on

amateur tape recording with the title *Tape Recorder*, but some years ago devoted itself to the professional side of recording. Not in general recommended to the beginner, it nevertheless provides valuable information on advanced recording equipment and techniques, for those interested. It reviews equipment from the semi-professional up, with ruthless impartiality.

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