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# die Reihe

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**Electronic  
Music**

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# die Reihe

A periodical devoted to developments  
in contemporary music

Edited by Herbert Eimert  
and Karlheinz Stockhausen

## Electronic Music

THEODORE PRESSER COMPANY

BRYN MAWR, PENNSYLVANIA

*in association with*

UNIVERSAL EDITION

LONDON · WIEN · ZÜRICH

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*Cover design: Willi Bahner, Vienna*

*Printed in England by The Stellar Press Ltd., Barnet  
and set in Times Roman type.*

ML  
197  
E43

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*THEODORE PRESSER CO. Bryn Mawr, Pennsylvania*

*UNIVERSAL EDITION*

*24 Gt. Pulteney Street, London, W.1.*

*UNIVERSAL EDITION*

*Karlsplatz 6, Vienna 1.*

*UNIVERSAL EDITION*

*c/o Pianohaus Jecklin, Pfauen, Zürich.*

## RECORDS OF ELECTRONIC MUSIC

The Deutsche Gramophon Gesellschaft in co-operation with Universal Edition has recently released three long-playing records of electronic music produced at the Cologne Studio. These records will be available very shortly in the U.S.A. and Canada, as well as in Great Britain, and the publishers will be glad to give full details on application.

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To be published shortly:

*Number 2* Anton Webern

In preparation:

*Number 3* Musical Craftsmanship

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For full details of these numbers see page 62

## TRANSLATOR'S PREFACE

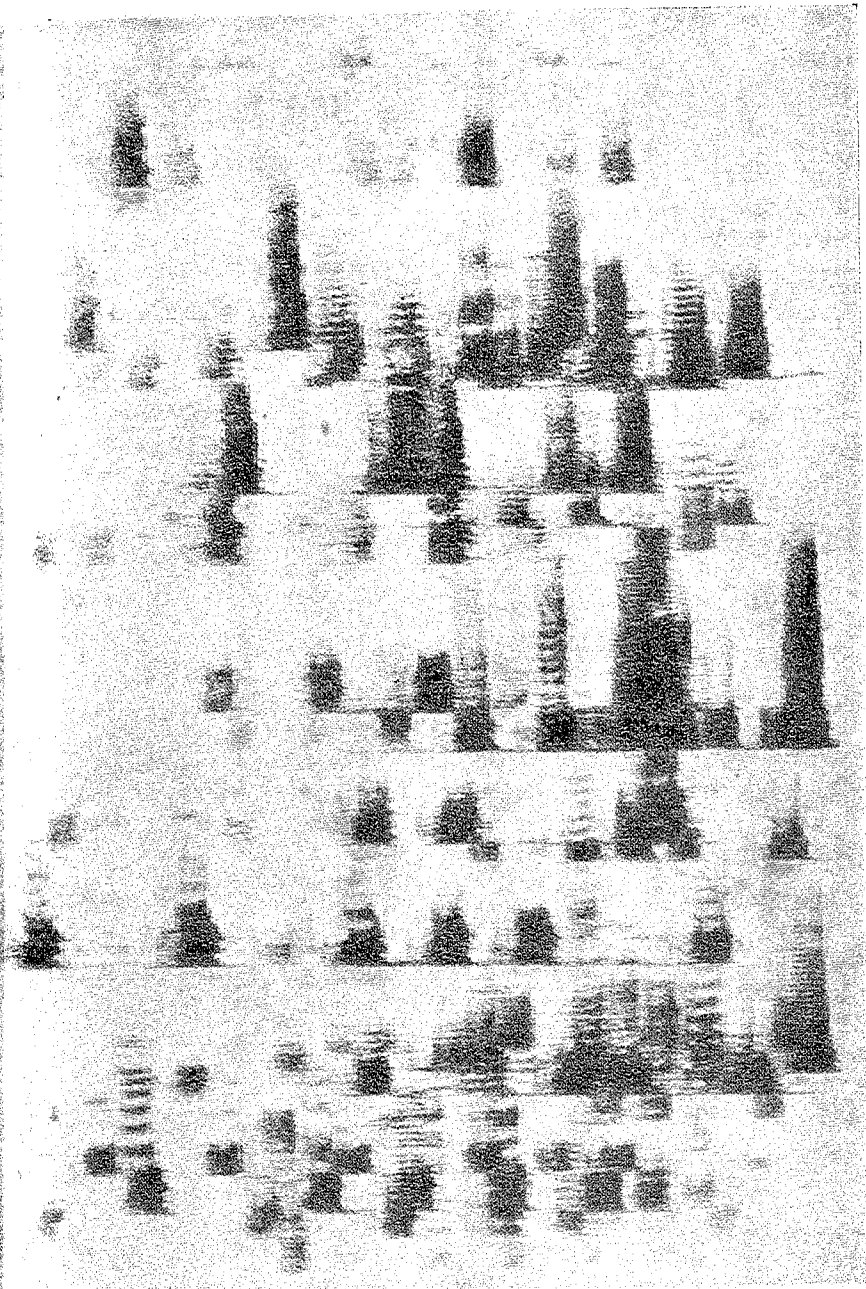
*Die Reihe I*, originally published in German in 1955, will introduce English speaking readers for the first time to some of the problems of 'Electronic Music'. These problems the writers of the various articles claim, are none other than the general problem relating to the composition of music in our time, for, as Dr Eimert writes, 'the electronic means fully correspond to the compositional situation'. These problems are adequately and variously described in these articles by Herbert Eimert (who has specially rewritten his article for the English edition), H. H. Stuckenschmidt and Ernst Krenek, who attempt to relate the very phenomenon of electronic music to its cultural background. Other articles by Karel Goeyvaerts, Paul Gredinger and Henri Pousseur not only 're-write' aspects of traditional history of music from a new angle but explain something of their authors' personal attitudes to the world of sound. Articles by Giselher Klebe, Gottfried Michael Koenig and Karlheinz Stockhausen introduce readers to the studio and describe actual 'work in progress'. Pierre Bouzel, taking a wider view of the whole of contemporary music, attempts the idea of a comparative synthesis between instrumental and electronic composition. Finally, Prof. Meyer-Eppler of the University of Bonn discusses problems of acoustics which throw further light on electronic music.

No apology need be made for discrepancies of viewpoint and definition on the part of the various individual contributors. There cannot at this point be any definitive terminology in the English language, as no actual work on electronic music has, as yet, been done in an English speaking country. Where possible the technical terminology corresponds to previous articles, broadcasts and books written in the English language. Elsewhere the reader is referred to the Standard Acoustical Terminology. The translator begs indulgence for any confusion caused.

LONDON, December, 1957.

Explanation of illustration on facing page:

Spectrogram taken according to the Visible-Speech-Process of the Institute for Phonetics and Communication-Theory Linguistics at the University of Bonn. The spectral combinations of sounds may be seen in their durational occurrence (vertical-frequencies, horizontal-durations). As opposed to traditional symbolic notation, this direct notation of sound allows the composer a precise control over the completed processes. Further information may be obtained by comparing this notation with the corresponding acoustical diagram in the score. (One sec. = 13.5 cm.; 1 kHz = 1.4 cm.).



'Glockenspiel': a spectrogram (for details see facing page).

HERBERT EIMERT,

## WHAT IS ELECTRONIC MUSIC?

HERBERT EIMERT

In the history of the 'Music of our Time', electronic music might be regarded as a final chapter or even as a postlude. It seems apart from the main stream of development, is the centre of violent controversy and it is ambiguous, as is anything which suddenly obtrudes itself uninvited on an already problematic situation. At the same time it is already of sufficient import to have come to the attention of academic study and pedagogical activity. To the ordinary music lover who listens to contemporary music, Stravinsky, Bartok and Hindemith are still the key figures; behind them stand Schoenberg, Berg and Webern surrounded by an international troop of twelve-note imitators; electronic music is seen as an enigmatic, extreme development. One thing only is clear - whether it be approved or condemned, it cannot be ignored any longer.

But let us see the situation another way with electronic music as the focal point of a progressive development, connected with the most recent instrumental school of pointillism. Next comes the only recently discovered music of Anton Webern, a point of departure for the present day composers, then Schoenberg's twelve-note music and finally the so-called 'modern classics'. In this arrangement we have at least a certain inevitability of human progress; what was seen as a postlude now seems like our prelude.

Despite the fact that electronic music is the outcome of decades of technical development, it is only in most recent times that it has reached a stage at which it may be considered as part of the legitimate musical sphere. The manner of its birth must in many respects be distinguished from all other beginnings which we have understood to be natural developments. Here there has been no extension of traditional procedure. By the radical nature of its technical apparatus, electronic music is compelled to deal with sound phenomena unknown to musicians of earlier times. The disruption by the electronic means, of the sound world as we have known it leads to new musical possibilities, the ultimate consequences of which can hardly yet be appreciated.

On the other hand there is an essential relationship between electronic music and the traditional world of sound, not only in the fact that musical elements are defined by pitch, duration and intensity, but also because of the connection between it and the most contemporary development of musical thought. Electronic music is, and remains, part of our music and is a great deal more than mere 'technology'. But the fact that it cannot be expected either to take over or to imitate the functions of traditional music is clearly shown by the unequivocal difference of its material from that of traditional music. We prefer to see its possibilities as the potentialities of sound itself. No position such as this could be reached by a mere transference of the traditional into the electro-acoustical. Here we touch on a most widespread misconception: namely, the idea that one can make music 'traditionally' with electronic means. Of course one 'can'; but electronic concert instruments will always remain a synthetic substitute. The fact that practically no music which can be taken seriously, artistically, has been written for electronic concert instruments is due precisely to the fact that its use as either soloist or

ensemble instrument does not transcend the old means of performance. New ways of generating sound stipulate new compositional ideas; these may only be derived from sound itself which in its turn must be derived from the general 'material'.

Electronic music is based on the composition of electrically generated sounds made audible by a generator, i.e. recorded on tape without recourse to any instrument or microphone. Electronic music exists only on tape (or on record) and can only be realised in sound by means of a loudspeaker system. That electronic music cannot be performed on instruments is due to the fact that the number of individual sound elements is so great that any attempt to find means of instrumental realisation is doomed to failure.

There has been much bewailing on the part of 'dilettantes' of the element of spontaneous music-making which is said to be lost in electronic music; these gentlemen conveniently forget that much of what is great and greatest in the literature of music from Bach to Schoenberg will always remain outside the reach of their spontaneous music-making. To say that the artist makes music on a platform is just about as true as saying that an Olympic champion wins a gold medal, without mentioning the long preparations, the gymnastic exercises that lead to fitness. In fact 'spontaneous music-making' represents something practised a thousand times, co-ordinated through repeated rehearsal, something which stipulates a well-lubricated, hyper-regular mechanism, an almost unique mechanical production in which its studied precision is nearer to a protracted electronic synchronisation than to 'spontaneous music-making'. It is not irrelevant to point out here that it is in no way the aim of electronic music to replace instrumental music. On the contrary, a deep kinship may be observed between instrumental music of recent date and electronic music, and the theoretical experiments in the elementary properties of sound phenomena which have been part of the beginnings of electronic music have not been without their influence in the instrumental sphere.

The invention of the valve in 1906 marks the beginning of the development of the phenomenon of electronic music, though naturally the invention had nothing to do with music. It is a coincidence, yet in a higher sense perhaps no coincidence, that at this very time Busoni and Schoenberg were first interesting themselves in the idea of an 'uninterrupted continuity' of musical material, thus touching the limits of instrumental technique. Busoni discussed the fissure of sound material, as it was known in his time, and Schoenberg invented the *Klangfarbenmelodie*. Busoni at that time referred to Cahill's electric organ which, for the first time, enabled a composer 'to attempt to fly'. Schoenberg did not pursue the idea of *Klangfarbenmelodie* in his later work but Webern was able to link it to his idea of a series of proportions which subjected harmony and melody to a common denominator of intervallic proportion. Webern was not able to extend the serial principle to all musical dimensions but did, at least, achieve sound structures generated according to the permutational principle of the series – in this he comes near to electronic music, which takes up his great idea and without imitating it, transfers it to the total organisation of the electronic sphere.

Developments in the building of electronic concert instruments began after 1920. The builders always attempted to imitate traditional sound, with the exception of Jorg Mager, who stated, referring to Busoni's idea, that it ought to be possible to 'make available to artists of the future all frequencies, melodically as well as harmonically, as

well as the partial tones which determine the timbre'. But the decisive means of maintaining and operating sound only became available some twenty years later with the discovery of the means of recording sound on tape.

Electrically generated sound could only be utilised as a genuine compositional element when this technique had been invented. In the ordinary way the tape recorder provides the means of playing back tapes. But the new tape technique which is no longer satisfied with a mere playback is of the greatest significance here. The normal studio technique of broadcasting is transformed into a compositional means. Tape recorder and loud-speaker are no longer 'passive' transmitters; they become active factors in the preparation of the tape. This is the essential secret of electro-musical technique. One might say that today we have perfected a 'keyboard' of this elaborate and differentiated sphere of radio transmission; now we lack only the virtuosi to master it.

The composer's equipment consists of a sound generator, a loudspeaker, tape recorder and filter; all this apparatus is to be found in any well equipped radio station. No especially expensive equipment is required, as has been generally suggested, and in fact there is no reason why electronic music should not be produced in any normally equipped radio station. The composer determines each note by its pitch, duration and intensity. Only he no longer has only 70–80 pitch levels at his disposal (this is the average number utilized in instrumental music; Bach's *Wohltemperiertes Klavier* utilises 50–55 different pitches), only 6 or 7 intensities from *pp* to *ff* and only minims, crochets, quavers, dotted and syncopated values. He now has at his disposal the entire range of frequencies from 50–15,000 c.p.s., 40 or more precisely calculated dynamic levels and an infinite number of durational values, measured in centimetres on tape. None of this material can be adequately notated by traditional means. The following example is given to illustrate this new world of microstructures which we have entered. Every musician is familiar with the note *a'* at 440 c.p.s. The next whole tone above is *b'* (492 c.p.s.). Within this major 2nd from *a'* to *b'*, we are able to generate 52 different pitch levels of which, when ordered in a scale, at least each fourth level is heard as a different pitch interval.

The multiplicity of forms of electronic elements far exceeds the possibilities of graphic notation. It is thus necessary to notate differentiations, which are unknown to traditional music, in a way which corresponds to acoustical phenomena. This cannot be effected by an extension of traditional notation; it is better to present the sound procedures of electronic music graphically in the form of an 'acoustical' diagram. Thus 'scores'<sup>1</sup> of electronic compositions resemble precise acoustical diagrams with their co-ordinates, frequency (cycles per second), intensity level (measured in decibels) and time (cm.p.s.). The composer is required to have a certain amount of acoustical knowledge. In this respect it is to be observed that acoustical conceptions do not always correspond to those of musical theory. Electronic sound is classified as: the tone, the note, the note mixture, noise, sound complexes and impulses.

1. The *tone*: is unknown to traditional music; is without overtones, is pure or sinusoidal; all sound phenomena may be reduced to it. No tonal system in the traditional sense may be constructed of sinus tones; they have no traditional place of a system, no tonal 'character'. Thus the sinusoidal tone system can only

<sup>1</sup> See the score of Stockhausen's *Studie II*, published by Universal Edition. UE 12466.

be a theoretical system of reference; the composer may build structures out of this system by means of serial organisation.

2. The *note*: is what every musician knows as a tone. It is built up from a series of harmonic overtones (partials, sinus frequencies). Thus, the 'tone' of an instrument is not the tone but the *note* which is immutable in its components, which determine its timbre. These partial components may only be varied by electronic means.

3. In the *note mixture*, the frequencies of the partials are not ordered harmonically; i.e. they cannot be expressed in terms of simple numerical proportions. Note mixtures are always sinus tone mixtures and are not the same as 'chords'; they have a higher degree of internal fusion of components and can be regarded as units more similar in category to the single note than to the instrumental chord. Note mixtures only exist in instrumental music where an attack is followed by a long reverberation (bells, pipes, plates, rods, drums). In electronic music, note mixtures may be realised without difficulty in any dynamic form (crescendo, diminuendo and unvaried).

4. *Noise*: defined by specific sound character and approximate 'pitch level'. Only 'blank noise' which fills an acoustic region may be determined in position. Filtered parts of 'blank noise' are called 'coloured noise' or 'noise colour'.

5. The *chord (note complex)* is identical acoustically and traditionally. It must be observed that the note and the chord are clearly differentiated in instrumental music; in electronic music the note mixture intervenes between the two with its particular levels of fusion of its constituent parts. Note and tone mixtures are electronically 'composed' not according to an harmonic or natural system but according to a composer's predetermined ordering.

6. *Impulse* or *pulsation*: also known as *Beats* or *Clicks*<sup>1</sup> (regular or statistic); at high dynamic levels corresponds to 'detonation'.

Uncontrollable sounds belong to the acoustical but not to the musical domain. They can fairly easily be produced by electronic experimentation or trick recording, and vague and 'atmospheric' effects can be obtained by cutting and assembling tapes. To demonstrate this, it takes two or three hours to construct a minute of good atmosphere music, often three or four weeks for a minute of real music. In connection with incidental music for film or radio, it is worth mentioning that no composer who intends himself to be taken seriously would have ever let himself in for electronic music if its entire resources consisted of vague experiments with noise and if all that could be produced were tapes of atmospheric sound. Whoever is attracted by the idea of the machine which 'makes things easier' and simplifies composition (in fact it makes composition considerably more difficult) is only comparable to the mediocre pianist who 'pedals' his way through the difficult passages of his concerto and hopes to get by by faking.

The stereophonic distribution of sound transmitters is a further element of the form of electronic music. The various loudspeaker systems around the hall are the 'concerting instruments' – a conception similar to the distribution of orchestral and choral

<sup>1</sup> c.f. page 47.

forces in church or concert hall. This special dimension is incorporated into the very plan of the composition. Multi-channel transmission can only be effected with multiple track tape recorders. At present radio transmission is only single channel. (Single- as well as multi-channel versions of electronic pieces exist depending on the purpose for which they are intended.) This spatial projection into the concert hall is seen as an entirely new dimension of the composition.

The basis for the production of electronic music were worked out in the Studio for Electronic Music of the Westdeutscher Rundfunk, Cologne, under the direction of the author of this article. The first studies were broadcast in an evening programme of Cologne Radio in 1951 and were performed at the International 'Ferienkurse für Neue Musik' in Darmstadt. In 1953 there was a public demonstration in connection with the music festival in the Concert Hall of the Cologne Radio. The first real electronic compositions were performed in a concert in the Cologne Radio on the 19th October, 1954; there were seven pieces, in all twenty-eight minutes of music, the second half of the concert being devoted to them. The composers were H. Eimert, K. Goeyvaerts, P. Gredinger, H. Pousseur and Kh. Stockhausen. Of importance for the further development of the medium was a concert in the Cologne Radio at the end of May, 1956, in which the 'Fünf Stücke' by H. Eimert, 'Klangfiguren II' by G. M. Koenig, the 'Oratorio for Pentecost' by E. Krenek and the 'Gesang der Jünglinge' by Kh. Stockhausen were given their first performances. The last mentioned works have in the meantime been issued as three long-playing records by the Deutsche Gramophon Gesellschaft. Since this time several small pieces have been composed by F. Evangelisti, G. Ligeti, G. M. Koenig and B. Nilsson.

Thus was the birth of electronic music. It seems to lack completely that surfeit of abundant vitality which so often characterises new movements. None would have taken the slightest notice if, after the First World War, the younger generation had begun by producing only a few isolated studies. But there are other beginnings. They come noiselessly and stay unheeded, like a biological transformation which ends in life or death; or like those in which the creative spirit is distilled into the essence of a new material object. The beginnings of electronic music may be seen as falling in this latter category. The composer concerns himself with a material to which the traditional, well-proven ways of his art do not apply. To begin to compose electronically means to select one single element from the limitless range of possibilities of the electronically emancipated material and to realise it in a compositional manner. It compares with the beginnings of polyphony in the music of the Middle Ages; what is practised is theory. So it is that, despite the apparent modesty of the preliminaries of electronic music, the full brunt of an experiment is borne in that a single creative selection and successful realisation can bring us face to face with the absolute nature of music. For this reason there can be no rules for electronic music in the sense of a traditional theoretical investigation of music; that which normally belongs within the scope of theory here remains bound up with the material object. Theory presents musical 'possibility' – this is valid here also, but with quite a different connotation, in that it is no longer permissible to fill out lifeless formal schemes.

These tiny beginnings and the limitless perspectives of electronic music cast a dim light on critics who would maintain that whereas there were 'possibilities' in electronic



music, at its present stage it had 'nothing to do with music'. Whether this viewpoint be the result of misunderstanding or whether expressing the sentiments of yesterday's avantgarde, it is clearly a waste of time to argue against it. Would one not be forced to the absurd conclusion that composers were occupied with the composition of something that was not music? We are not justified in attacking the authority of the composer from this point of view.

It is certain that no means of musical control could have been established over electronic material had it not been for the revolutionary thought of Anton Webern. Nevertheless, the compositional equipment of electronic music must be more than an extension of twelve-note technique. There are no gradual transitions from the twelve notes to the micro-structures. The barrier to these latter seems to have been broken at a single blow; we no longer see or hear chaos but rather the note, a sounding structure, consisting of its own analysable components. It is the most fundamental music-forming element. It is essential to have experienced and to know that the nature and perception of a note cannot be realised by simple physical devices of measurement, even if the physical and psychophysical qualities are only differentiated by the most infinitesimal fraction – the ways part here – one leading to nature, the other to music.

One of the most characteristic and prevalent misunderstandings of progressively-minded teachers and critics lies in the idea that music today has a dual existence: on the one hand a skeleton, on the other the living flesh and blood. There are, as it were, two separate aspects; one concerned with dry scaffolding, the other with expression and animation. We must point out to these critics that the scaffolding is inherent in the form of the note itself; the elements of construction are derived directly from it. Traditional twelve-note technique cannot suffice for this. In this is contained the fear that notes be lost from their rightful path and the hope that this loss be remedied by excited gesticulation. When the fundamental assumptions of the composer are naked and primitive he becomes involved in tragic-daemonic 'experiences', until we have the abrupt images and naked sensations of Expressionism. From a narrow viewpoint there exist those who are unable to visualise music as anything but 'psychographical': it would be of interest to conduct similar tests on Machaut, Josquin and Palestrina. Once and for all with electronic music we leave this 'psychographical' domain.

Alone among the twelve-tone composers, Anton Webern conceived the row non-subjectively, so that to a certain extent it functioned externally. Seen from Schoenberg's viewpoint this would be like cutting the threads of life in music: a silence, a dumbness, an end. In truth, this end is our beginning. If these procedures are made absolute it is not difficult to discern its negative, deadly side, as Adorno has done. It does not seem out of place here to question the possible objectivity of music. Clearly there can be no private self-portrayal identifying itself with Art within the broadly 'objective' historical context of music and of masters of non-subjective music; there can be none of that 'pathetic-bourgeois' pose which associates and presents Art as arrant, tragic-daemonic play-acting.

We know little of how emotion became involved in the practice of music making and even less of its intensity, which was observed for the first time in the 'musica reservata', around 1550. These questions cannot be separated into separate pigeon holes. We must ask: has not music always been made by men? Even Pythagoras' music of the spheres was the work of human fantasy. Is electronic volume control anything else but the old

dynamic? Though the directness of tape music has eliminated spontaneous performance, interpretation has remained in a new guise, for composing surely means performing music without the associations of time. What is then the human element upon which our humanists are always harping? One might wager that most of them are thinking only of the vibrato of Tchaikowsky's violin cantilena on the G string.

From the viewpoint of heightened *espressivo*, pre-expressive music appears to be subjectively under-developed. It has other traits in common with electronic music; most significant its distinctly material character. The material itself is made to 'speak' – not because it has found voice but because it has been arranged by human device, even if with theological help, at least without pathos and subjectivity in the modern sense.

Evidence of this may be found in the theoretical tracts of the time. They testify to the way in which the material played an active role, as if a secret rationality was contained within it. The validity of this impression is enhanced by the way in which the material itself is hesitatingly, almost blindly tested, leading finally to a logical, conscious procedure directed by intellectual principle. It is not without significance that so many post-Schoenbergian composers have studied the music of the 14th and 15th centuries. Here too Webern set the example. All this only goes to show how false is the argument so often raised against the contemporary composer that the fact that he must actually and, it is said, vainly grapple with the very material organisation of music, separates him from the legitimate concerns of traditional music. It is argued that this is a unique situation which may be compared with nothing. Our illuminating reference to historical precedent does not imply that we in any way seek justification in mediaeval theory for electronic music, which is characterised by a meeting of acoustical and compositional developments which are particular to our epoch. A further sign of its integrity is shown by its awareness of Expressionism. It has learned from the work of Debussy, who created form patterns which in the electronic sphere are called 'statistic structures' and which can exist only as a result of the quantitative multiplication and division of sounds in density and augmentation.

Objectivity stipulates objects, but the material of Art is objective in a sense which is different from that of Nature. If the barrier between these two is removed a fatal misunderstanding results. It has been assumed that the fundamental conception of music must be separated from the considerations of Art, and be approached physico-scientifically. According to this conception the definition of a note by its pitch, duration and dynamic intensity may be taken both acoustically and musically. Acoustics concerns itself with the nature of sound; physiological aspects of hearing are concerned with the relationship of volume and intensity, with registering variations in these and with the relationship of duration to the period of 'growth' (*Einschwingdauer*) in the ear or the perception of pitch levels. From the musical point of view the note exists for the listener as a unit and only as such is it recognised and analysed in its triple unity and entity. Nothing more about it can be learned by physical or physiological means. The 'musical' discovery of the conditions of a note's existence – first made by Messiaen, who worked on this basis, if not serially at least strictly modally, is certainly the right way towards electronic music. Here a definition of a note considers timbre as resulting from the proportional strength of partials in a fixed frequency.

It would never have occurred to a musician of the 19th century to define a note by its pitch, duration and intensity. At that time the note was understood through its

relationship to other notes, and through its relationships to tensions within the structure of a chord. The 19th century did not ask 'what was' a note, but only 'how did it function'? In twelve-note music it is still required to function, though it no longer can, and thus its function is no longer measured by any principle inherent in the music, but by an analogy of effect.

Webern was the first composer to move on from the single level conception of the twelve-note technique; namely that of a technique of organising pitch levels. In his work, for the first time, we see the beginnings of a three-dimensional row technique – of what in short, we know as *serial technique*. Webern restricted his music to interval and single note, and composed structures which are not in the traditional sense developed in a continuum, but which proceed by autonomous 'leaps', leaps which in the pre-electronic stage could achieve everything but that final step from the bounds of instrumentally tempered sound. Only in electronic music has the real sense of these developments been realised.

The relationship of note to row is only known as a principle of fixed constellation in twelve-note music. In electronic-serial music, on the other hand, everything, to the last element of the single note, is subjected to serial permutation, resulting in a completely new way of composing sound – the poetics of sound, as the mediaeval theorist would have called it. Examination of material inevitably leads one to serially ordered composition; no choice exists but the ordering of sinus-tones within a note, and this cannot be done without the determination of the triple unit of the note. A note may be said to 'exist' where elements of time, pitch and intensity meet; this fundamental process repeats itself at every level of the serial network which organises the other partials related to it. The fact that tone, duration and movement are almost tautologies, testifies to the pre-eminence of the time process. The note is subjected to time for its pitch levels and intensity – this we may call the 'tonality' of electronic music.

In traditional twelve-note music the row is already omnipresent yet discursively imperceptible and only determinable with reference to basic shape. This omnipresence remains incomplete; it applies only in one dimension and is only thrown into relief by the simulation of emotion. The procedures of electronic music cannot be understood from this point of view and from here stem the complaints and criticisms of lack of musical 'connection' and the insensitive or malevolent misunderstandings that proportioning of time and pitch be nothing but a 'calculating game' in which the composer fiddles about with formal problems and builds up a numerical framework which he later transforms into notes. What can one say seriously about such marble games? It remains of significance, however, that the electronic material as a musical material completely answers to the conditions of a compositional situation. It is not that music can be composed by electronic means 'too'; in the contemporary phase of music only one way can be seen of determining the compositional situation, that is: 'after Webern', the situation resulting from the discovery of 'the single note'.

Critics who have found this position inadequate have found plenty of points of criticism to raise. Two of the most important are, firstly, that music is a 'language', and that exactly in this post-Webern development of musical pointillism and electronic music, it is no longer spoken; and secondly, that the sinus tone is not a fundamental element of musical perception.

The 'linguistic' theorists of music do not refer to what is generally meant by 'musical

language'. They mean something else which has been taken out of its narrow context in Schoenberg. They mean a kind of wordless recitation with the accentuation of speech within the corporeality of sound; they refer to the flow and gesture of talking, the sequence of speech inherent in construction, which alone secures connection and context. In answer it must be said that the ear's ability to perceive effective connections is in no way restricted to the unique level of speech elements. Thanks to its many simultaneous dimensions, music is a language of many meanings and for this exact reason it is not formulated speech or talking. If the elementary components of a note are related in a new way, according to new musical principles and not arbitrarily or mathematically, the ear must do as it always has done; it must adapt itself to the demands of the composer and the composed notes rather than depend on fossilised ideas, newly revived. That the problem of appropriation and communication is raised by electronic music in its early stages, no one will deny. It is not to be avoided. On first acquaintance even the ear trained in the perception of a dodecatonic structure is faced in electronic music with a foreign musical language. This book testifies to the fact that it can be learned and is already spoken by some.

The second argument, that the sinus tone is not a fundamental element of musical perception, is rather the product of wishful thinking than of knowledge, and does not stand up to any practical or theoretical examination. It is essential to realise the properties of the sinus tone, on the one hand as a unit of measurement, on the other as a musical phenomenon. It has long been realised that the idea that formulating sound in composition – which means sinus tone composition – is perpetually measurable, is false. Electronic music has its own incalculable relationships of elements in overlaps, volume control of frequency and intensity as well as in all non-stationary elements. If anybody is simple-minded enough to imagine a robot violinist performing Handel's Largo with stationary sinus tones, he will immediately be compelled to realise that technique will only provide the homunculus with an electric plush-vibrato soul. This electronic music is not 'another' music, but is serial music. And being so, the series must necessarily be called upon to determine the exactly measurable area between the stationary and the modulating note.

Thirty years ago, in scientific circles, it was fashionable to conduct psychological examinations of the phenomena of sound by studying sound procedures in slow motion. In this way a whole organism of forces, movements, kinetic and potential energies was discovered, though no one is able to hear music thus, as it were, in slow motion. Today the physical magnification of a sound is known, quite apart from any musical, expressionistic psychology, as exact scientific data. It cannot, however, be the function of electronic music to make the sinus tone like the living 'parasite', to feign similarity where disparity exists. Talk of 'humanised' electronic sound may be left to unimaginative instrument makers. This is particularly important when, later in this book, we come to deal with aleatoric modulation, which becomes the further removed from music the more it attempts to imitate it and which is only significant when subjected to compositional ordering. Similarly with dynamics: any performance of piano music, which is, to some extent, differentiated in its dynamics (e.g. a piece by Mozart, which is made up out of three or four notated dynamic levels) will, when recorded, register at least 30 or 40 different degrees of intensity on a control indicator. It would be pointless to imitate these electronically but of the greatest significance to organise them.

This leads us to an understanding of the compositional microstructure. It runs parallel to instrumental sound not in the manner of accrued imitation, but as an artificial procedure of order. Everything is designed not to escape from the nature of electronic sound, but to go further into it. No composer would set himself this task were he not certain that the idea of order running parallel with Nature was something he could believe.

Our first little pieces of electronic music from the Cologne Studio were composed in this spirit of faith. They are not experiments, inasmuch as experiments forswear music. Nor are they mere products of technology or of the technocratic spirit. There need be no song and dance, as is so fashionable nowadays, about the human cost incurred in the attaining of technical progress. There is no more to it than that a new way of thought has found a new, transformed musical material. Sufficient is it that young composers are fascinated and committed to the great discovery of 'the note' in Webern. No longer is Webern seen at the centre of classical twelve-note technique. Although he was not offered the possibility of thinking serially in terms of microtones, he nevertheless stands at the outermost limits of instrumental material, as if he had already cut off the properties of the past and was on the point of moving on.

The music of the younger generation after Webern has taken the logical consequence of his work. For the second time in our century after Schoenberg, the painfully 'impossible' has been realised. It may be that 'pointillist' instrumental music closes the gap, but only in coming to electronic music can we talk of a real musical control of Nature. Its dependance for reproduction on the loudspeaker, which has almost imperceptibly revolutionised our way of hearing, leads us to reflect whether perhaps it is not the symphony recorded on tape or disc that is the synthetic, and electronic music the genuine article. For in the latter, we may find, is the genuine musical order.

## THE THIRD STAGE

### Some Observations on the Aesthetics of Electronic Music

H. H. STUCKENSCHMIDT

*Form is created of Necessity*  
(W. Kandinsky)

If it is of the nature of music to give substance and definition to nothingness and chaos, it is also its nature to be in a state of continuous self-renewal. Its only certainty is in the unheard. What has been already created is drained of its resources for re-engendering because of its very existence. There is, thus, a conflict within the creative process. On the one hand there is the fundamental desire to create out of chaos; on the other, a desire to repeat existing structures, allowing them to sound again and again, and to create through this repetition. This process may be compared to a crystal where the basic immutable shapes combine to make a whole. The musical form of the variation is, significantly, the result of a merger of these two forces, the engendering and the repetition of a structure.

The process of repetition must, obviously, be preceded by invention; otherwise there would be nothing to repeat. Thus, we may say, that the construction from nothing is the true and most important process in the creation of music from sound material.

The first results of compositions with electronic means have been available for a few years. It need hardly be stressed that we are not concerned with works for the Trautonium or Ondes Martenot concert instruments, but with music conceived purely for the electronic sound generator and which for its realisation does not require, indeed excludes, human interpreters. These experiments have been conducted principally in the Studio of West German Radio in Cologne, which is directed by Herbert Eimert and whose most promising composer is Karlheinz Stockhausen. Associated with the work and ideas of the Studio are, amongst others, Pierre Boulez (Paris), Luigi Nono (Venice), Henri Pousseur (Ypres) and Giselher Klebe (Berlin).

As spokesman for the group, Eimert has repeatedly drawn attention to the creative possibilities of electrically generated sound, but has disassociated himself from the 'fashionable and surrealist' *Musique Concrète* produced at the *Club d'Essai* in Paris, and any incidental manipulations or distortions haphazardly put together for radio, film or theatre music. He is opposed to all metaphorical synaesthetic interpretation – that is, he is opposed to the idea of composition and interpretation by association and reference.

Aesthetic understanding of the new art is not facilitated by this attitude. It cannot be denied that this associative effect, which the initiator denies as being of any relevance, has been the principal reaction of the majority of listeners faced for the first time with electronic music. There appears to be a considerable discrepancy between postulation and reception, a discrepancy which must lie in the very nature of the new art form.

In a revealing lecture: 'The Image of Nature in Contemporary Physics' (printed in

'Arts in the Technical Age', R. Oldenburg, Munich, 1954) Werner Heisenberg has drawn attention to the radical changes in the fundamentals of our existence and their effects on all other aspects of life. In a world completely transformed by human hand, he asserts, we are continually presented with humanly conceived forms. In the natural sciences, the object of research is no longer Nature itself, but a Nature deprived of its absolute autonomy of behaviour and controlled by human intervention. The natural scientist sees an image of Nature which is in reality an image of human relationship to it. Heisenberg concludes his lecture with the refutation of the Cartesian conception (*extensio cogitatio*): Man as a conscious being develops within an area which certainly has other dimensions than the single one in which he has developed throughout the last centuries. One would do well to apply much of this view of the present situation to any attempt to determine the relationship of man to this 'completely transformed' music with its 'humanly evoked' forms.

The first reaction of the listener to electronic music is one of perplexity for he lacks a point of comparison between it and vocal and instrumental music. In a J. C. Bach allegro or in a movement from a Mozart symphony one is still able to appreciate vocal origins despite instrumental elaboration. In the most elaborate leaps, virtuoso passages and colour mixtures in a composition for the Trautonium the listener is reassured by the fact that it is executed by human hand. Indeed, music is also apprehended from an associative viewpoint in that the associated object may be of a nature akin to the agency by which the music is made to sound: the human voice, the wind, string or keyboard instrument. As a result the association is practically imperceptible and is assimilated into the image of the music itself. The listener is lead along familiar paths.

In that nothing pertaining to electronic music is analogous to any natural existent phenomenon of traditional music, associations have to be evoked from elsewhere. Instead of being integrated, they remain, an ever increasing conglomeration of mentally indigestible matter. Thus the listener's reaction, in broad outline, corresponds to his relationship to a humanly transfigured world. The ear recoils from assimilating, in any accustomed manner, this music, 'totally predetermined' by human hand. (The pertinent phrase is by Ernst Krenek). Thus the relevance of the synaesthetic metaphor grows. The sound mixture is heard in such a manner as to associate it with phenomena experienced by any perceptive listener; it is associated with reverberating projectiles from the mineral domain, with sounding metals, with the music of cylinders.

That which is actually heard is, in fact, something which seems extremely complicated, without recognisable order, yet something which is clearly organised, more strictly ordered than ever was music before. The aesthetics of electronic music stipulate elimination and selection of material. The new means of production are not to be misused; they are not to emulate that which can be effected equally well or better by traditional means. So, the natural is abolished. Vocal and instrumental forms are eliminated, tonality, functional harmony, simple polyphony and symmetrical rhythm are suspended.

All elements of the music are statistically calculated. The serial principal of twelve-note technique and the isorhythm of mediaeval music are combined with an ordering of timbre and dynamic. In this way the music may be predetermined, allowing for modifications arising out of variants in the proportions. The composer is able to anticipate the consequences of the forces he has set in motion in the same way as an

astronomer is able to anticipate the movements of stars and calculate constellations, eclipses and cosmic collisions.

Thus music enters its Third Stage. The first was restricted; the music was written to be performed principally by the human voice, and as is the voice, it was limited in its range of expression. It was conditioned by the limitations of the voice in the execution of fast or loud passages; its range of colour was determined by the technique of voice production, developing from strict, monodic incantation to the virtuosity of bel canto. The second was the instrumental stage. Here also the human agency was the key factor, and instrumental technique was largely conditioned by its vocal precedents; e.g. the violin vibrato, the singing legato of the piano. At the same time development of the potentialities of the instruments, virtuosity, differentiation of timbres, rhythmic complexity and the augmentation of the dynamic range, brought it further away from its vocal origins. The third, the electronic stage, retains human participation in the compositional process, but excludes it from the means of realisation. Such a de-humanized music is conceived by the intellect alone; the range of experience derived from traditional procedure is transferred to a radically new material.

The new music is, in some of its elements, foreshadowed in the late works of Anton von Webern, in the montages of timbre and note complexes in the works of Edgar Varèse and in the isorhythmic pedals of Olivier Messiaen. A music of such severity and purity may be seen against the background of an artistic climate which has turned away from Realism and has reaffirmed the significance of the intuitive, the symbolic. It is not without significance that a manifesto of young French composers is dedicated to the memory of Mallarmé. Two of the foremost exponents of the new style, Pierre Boulez in France, Giselher Klebe in Germany, have made reference to Paul Klee. The former has taken a maxim of Klee's as a personal aesthetic, the latter has written a composition for orchestra which borrows the title and general atmosphere from Klee's picture, 'Die Zwitschermaschine'.

It would not be difficult to demonstrate the manner in which frontiers have been overcome and contacts established between the different arts in the contemporary world: a further corroboration of Heisenberg's ideas. It will be seen how, from the concrete realities of his environment, man turns back to the image of himself. Thus, unexpectedly, the whole circle is completed. Music has developed further and further away from its human origins; now, at what we define as its Third Stage, the Electronic, we are astonished and not without pride, to have before us an art, totally controlled by the spirit of man, in a way not previously imaginable.

## A GLANCE OVER THE SHOULDERS OF THE YOUNG

ERNST KRENEK

The question of the systematic formulation of musical material must clearly come up for re-examination in light of the new methods used by those composers who have composed with material derived from sinus tones. As we have understood it, the composers who, up to this time, have made the most significant contributions in this medium, have subjected their work methods to a discipline which, exceeding anything previously imagined, has stipulated the derivation of every dimension and detail of the composition from a pre-established row of proportions. The way to such a position has already been shown by the technique of composition with twelve notes, in that the basic tenet of that technique has been that all sequences of intervals in a given piece should be derived from a combinatorial ordering of the twelve notes and that to a certain extent harmonic elements should also be pre-established.

'To a certain extent' – in the course of the compositions, twelve-note composers found ways of utilising their pre-selected note row in an individual manner and showed that it was possible to be very free while retaining the essence of their conception and not in any way forswearing or omitting that which they considered the justification for and purpose of the technique. As far as we are able to see it, the majority of the twelve-note composers have found that the justification and purpose of the technique lay in the fact that in this way it was effectively possible or at least easier to remain faithful to the basic stylistic conception of Classical Music, namely, the development and variation of clearly defined musical ideas, without being limited by functional, tonal harmony. This mode of thought enabled, and in fact facilitated, twelve-note composers of the 'middle generation' to neglect the inherent idea of twelve-note music, i.e. the total determination of the musical continuity, and emphasise the melodic-motivic functions of the row. Technical procedures – the sub-division of the row into smaller groups and their independent utilisation, the rotation of notes within groups, etc. – were means discovered to facilitate the realisation of this conception. I have discussed these elsewhere.<sup>1</sup>

It would possibly be going too far to say that these composers had finally learned to dispense with twelve-note technique altogether. When a twelve-note composition is found by some listeners – rather against their will – to have a certain 'direct appeal', they come to the conclusion that the composer has succeeded in spite of his application of this technique. The matter is not so simple. One may safely wager that if the composer had set out to write the piece with direct methods (and direct here means 'traditional') he would precisely have failed to obtain this 'direct' appeal. If for the sake of argument one grants these 'traditional' critics that twelve-note technique stands in the way of an immediate style such as that developed by Puccini, Strauss or Verdi, and if one further admits, as every right-seeing person does, that this effect can no longer be attained with the methods of Puccini and Strauss, one comes to the conclusion that the

extraordinary directness of appeal of so many twelve-note compositions is due to the conflict (and the inherent competition) of two apparently contradictory principles: desire for spontaneous utterance and restriction imposed by technical procedure.

Once we have established this fact, we may admit that much of the technical justification and intentions of twelve-note composers up to this time, represents a rationalisation which does not stand up to definitive critical examination. It is certainly possible to follow the classical ideal of development and variation of ideas in an atonal idiom, free from the restrictions of twelve-note technique. It must, however, be remembered that this way only leads to valid results after the procedures of traditional twelve-note technique has been mastered. There was not much attempt at the development and execution of larger forms in the period of the so called 'Free atonality'. Historically this has been the endeavour of the middle generation of twelve-note composers.

It does not seem that the younger composers are particularly enthusiastic about this 'loophole in the rules' which allows so free an application, nor about the use to which it was turned. They do not want to limit serial pre-composition but rather to extend its scope. The formulation and development of individual musical ideas (*Gestalten*) is not part of their aesthetic programme. The desire for an all-embracing pre-formulation can be explained by the wish to subjugate material completely to the control of the human mind. Seen from an historical viewpoint, the development of music has been one in which man has gradually found, by the creation of his own methods of regulation, the means to put artificial manipulation in the place of natural sound control. A musician who blew into a reed pipe or sea shell could only produce very few notes and, consequently, was restricted in the extent to which he could create musical forms. As he improved his instruments technically, he was enabled to extend his range and produce other than the natural notes. Thus, he freed himself from the limitations imposed by nature. Clearly the purpose of this freedom is to create richer and more interesting artistic forms. The creation of these forms entails greater detail and precision in planning. If these plans lead to characteristic procedures which in their turn are related to extensive areas of expression, we reach that pre-formulation, which is our present subject.

The tempered system had already brought the pre-formation of material in the tonal system far from its natural conditions, though to a certain extent these survived in the system of natural harmonic overtones which provided a norm for intervallic consistency. Tonality as an artistic system was the realisation of these natural proportions in the principal dimensions of form (key relationship, modulation, the cadence). The organisation of detail in the musical procedure was left to the spontaneity of the creative genius and was considered as the achievement of a freedom wrestled from the confines of natural law. In those cases where the detail was subjected to constructive methods, precise contrapuntal working, density of motivic relationship and other similar procedures, it was regarded as a self-imposed limitation to spontaneity and was considered, according to taste, as the sign of remarkable mastery of the material or as useless pedantry.

Atonality dislodged the ultimate foothold<sup>1</sup> of natural pre-formation, when it suspended the norms of intervallic consonance and thus dispelled their hierarchic relation-

<sup>1</sup> 'New Developments of the Twelve-Tone Technique', *The Music Review*, May, 1943: 'Is the Twelve-Note Technique on the Decline?' *Musical Quarterly*, October, 1953 and *passim*.

<sup>1</sup> In light of the electronic development one had better say penultimate, for atonality did still accept the natural structure of notes, as delivered through the medium of the then existing instruments.

ship. One may speculate whether it would not have been possible to proceed from here directly to the final step, namely, the elimination of the natural structure in the musical molecule, the single sound – to the musical atom – the sinus tone. If liberation from the natural conditions in tonality was an essential step to the achievement of atonality, then the progress towards the neutral sinus tone would indicate a more complete realisation of that liberty.

However this may be, the final step has in reality been the consequence, the carrying to a logical conclusion, of that train of thought which led to the establishment of the twelve-note technique as a means of pre-forming atonal material. It differs in its essentials from the tonal system, as a means of pre-organisation, in that it is not dependent on a basis of natural conditions. In addition, it concerns itself not only with the larger aspects of musical context, but extends its control to the individual detail. Further, every single case demands a freely composed, arbitrary 'medium' for the pre-formation (*i.e.* the composer selects a different twelve-note row in each case) and lastly, the principle of pre-formation is the row (in concrete form the row of intervals); *i.e.* an ordering of the sequence of musical elements which can be expressed numerically as a Series of Proportions.

It appears that the extension of the serial pre-formation of intervals into the domains of rhythm, dynamic and to a certain extent, sound aspects in music, has brought the younger composers to a complete liberation from the offerings of nature, which cannot be improved upon at our present level of knowledge of the material. (The next step might surely be the 'splitting of the atom', *i.e.* the sinus tone). It is not without relevance to observe that this overall freedom has been purchased at the cost of an acceptance of total pre-determination. What would have happened if this stage had been reached directly, without taking the long way round of the twelve-note technique? Would there have been complete chaos? It is curious that in listening to the few pieces in the new idiom and based on the new methods, which have been performed to date, even the listener current in the ways of twelve-note technique had the impression that chaos, whether intentional or otherwise, was the final result of these efforts. The cause of this naturally lies in the abandonment of the exposition and development of defined ideas in the Classical sense. At this point in its evolution it is impossible for the present writer to decide whether the abandonment really is essential and whether the musical content which is meant to compensate for this deficiency really comes up to the standard of what has previously been considered the minimum necessary for the awakening and retention of the listener's interest, in fact, to make the music worth one's while to hear. To the superficial observer it appears that the phenomena demonstrated so far in electronic music: levels of colour, texture, density, consistency and mass of sound material, are of a considerably lower intellectual level of musical consciousness than the aspirations which were associated with the demanding music of the past. Perhaps this only represents a beginning; history cites us many examples of the way in which creative energy has been expended on the achievement of progress of one dimension while temporarily impoverishing the other dimensions of the subject. An apocalyptic vision of a music developed to a state in which thinking out is more significant than performing or listening, can bring us no fear. The idea that we should have been chosen to witness the end of time is, after all, just as presumptuous as the idea that ours is the best of all possible worlds.

## FIRST PRACTICAL WORK

GISELHER KLEBE

I had my first opportunity to experiment with sound created by electronic means in February 1955 at the studio established for this purpose by the Cologne Radio. Although I had thought a great deal about electronic sound production and its potentialities before this time, it was the instinct in me to seek a union between the artistic and the technical that first attracted me to it. This musico-emotional reaction is similar to the stimulus to composition provided by imposing certain technical conditions, or to the amount of purely musical impulse needed to give substance to a conception that may seem to be intellectual but which is, in fact, still consciously perceptive in its original form.

It was fairly simple for me to grasp the technical procedures, thanks to a certain amount of preliminary work. These procedures in themselves proved to be a considerable inspiration and gave me much to think about, modifying my previous views. I soon grew dissatisfied with the purely acoustical experiments of my first days in the studio. I endeavoured to limit my experiments by certain preliminary conceptions of a musical nature and in this way was able to apply some manner of aesthetic judgement to the results of my experiments. These first attempts in formulating and hearing a musical situation brought with them many surprises and fresh ideas. I found, however, that though modifying details, I did not have to change radically any of my basic tenets, stylistic or technical. Rather, were they enriched, in that the change of medium from vocal or instrumental to electronic cast a new light on old problems. For example, I discovered considerable divergences and sometimes even contradictions in my notions of consonance and dissonance, and a completely new world of sound resulting from the disassociated and independent manipulation of the three parameters (pitch, duration, dynamics).

Of particular interest to me were experiments with rhythm. I had assumed that, by electronic means, one would be able to realise complex rhythms, which in their rapidity transcended the technical possibilities of traditional instruments. To my great surprise, I discovered that the limits beyond which the ear could not differentiate in any detail, roughly corresponded to the limits of the traditional instruments. Of course, electronic music enables one to realise precisely rhythmic structures which, by the traditional means, can only be approximated. This power alone would ensure a substantial enlargement of the scope of the composer, for it would enable him to differentiate the most detailed structures by the great number of different possibilities made available to him by the electronic means. But the most powerful impression made on me was the possibility of abandoning the so-called well-tempered system of twelve notes to the octave and creating systems which would enable the composer to realise structures in sound and form which would be entirely new and at the same time characteristic of their electronic means.

I am convinced that in these possibilities are contained the beginnings of a new and



significant development of Western musical culture and I believe that the creation of sound by electronic means will bring the greatest stimulus to the composer.

## 'AT THE ENDS OF FRUITFUL LAND...'

PIERRE BOULEZ

Unforeseen difficulties confront the composer who enters the realm of electronic music for the first time.

If he intends to pursue the consequences of an aesthetic that transcends the instrumental medium, he will find himself in an environment which will appear to him as the sole admissible possibility.

It is certainly possible to overcome the preliminary difficulties of studio work by continually striving to master the new mode of expression. But the electronic means themselves will initially cause the composer to be confused; he will be unable to reconcile them with his own traditional ideas of sound. What previously have been fixed limits are now suspended; they even become a sort of negative cliché: everything which was limited becomes unlimited; everything which was 'imponderable' can now be subjected to precise measurement. Furthermore, this very idea of precision, which has for long been sought after, has now become a myth; the more one seeks to limit possible sources of error, the more limitless they seem to become. We have long since passed the stage when we were enticed by the lure of further inventions, were enthralled by the composer's power which, we thought, would enable him to free himself from the ever more constricting bands of tradition.

Considering the logical developments which are bound to come about, we will have to approach the two domains, the electronic and the instrumental, in radically differing ways. The natural sound world consists of sounds defined in their essentials, by a more or less variable timbre, a wider or more limited range, a certain dynamic scale and certain durations, controlled or otherwise. A use of this sound world stipulates a concern with the possibilities it grants us, and at the same time limits the executant by a kind of 'inertia' – that is, if the executant is not already limited by his own bodily limitations. For this reason several sound generating agents are required, each of which furnishes us with a different range of possibilities. We have already reached a point of development at which these possibilities of potential sound can only be utilised in connection with a precise method by which we supposedly regulate them. No such limitations of possibilities suggest themselves in the electronic sphere. Here, from a world undifferentiated in its timbre, pitch, intensity and duration, we are required to create a composition which is coherent not only in its internal structure but also in the constitution of its actual sound material.

Rarely in the history of music has the musician found himself in a more radical position, faced with as unaccustomed a task as the creation of the very sound itself. He is not faced (which would be banal) with a projection of the traditional problems of orchestration and instrumentation, in which the choice of sound material is made according to its decorative or predominant effect, but with a choice of material determined only by its intrinsic structure. The composer is simultaneously the performer: the realisation becomes all important. In that he has a direct control over the quality

of the realisation, the musician takes on a function similar to that of the painter.

There are two diverging reactions to these electro-acoustical phenomena. We are amazed, at first glance, by the radical means of production, transformation, or deformation of sound; we are amazed, whether we hear or whether we ourselves create, by what, literally, is unheard of. With electro-acoustical procedures we can create with little trouble what has never been heard before. Unusual conditions, simple procedures such as acceleration, slow motion, montage juxtapositions, already put us into a 'modernistic' atmosphere even if we can too easily anticipate its commonplace nature. Nothing is simpler than the composition of canons at the unison; just take one track with several heads. Different speeds suffice to make a fugue and there is nothing easier than making a tape-loop and so obtaining an ostinato. Unfortunately, this mechanical efficiency is of little use to us. For after all, who really wants to make canons which only function at the unison? Who, today, cares to compose fugues in which the tempo is automatically regulated by the transposition of the subject? Who requires ineradicable ostinatos? Only a primitive mind will be impressed by the wonders of the machine, only one which is ignorant of music evolution. This kind of thought represents an enormous retrogression from the achievements of the past, and our 'sorcerer's apprentice' will hardly be able to take his place beside his precursors in the art. It must, however, be said that though these experiences remain meaningless on account of the mechanical mode of their application, they do nevertheless show the beginnings of a synthesis of all the possibilities of sound, one which is certainly demanded by contemporary musical thought.

It is indeed here that we see a more serious, or at least less naïve attitude taking an increasingly more important role in contemporary composition. These procedures cannot be considered as the unique means of creating on the one hand electro-acoustical, on the other, 'ordinary' music; only illiterates could take so ridiculous an antithesis seriously. It should rather be observed that on the one hand we have a remarkable coincidence between the evolution of music and consequences which it not only implies but demands, and on the other a new freedom necessitated by the need of realising the very complex thought of a new technique or means of expression, the further consequences of which we are only beginning to grasp.

Despite this felicitous point of contact, it cannot nevertheless be agreed that it results entirely from a mature development; reciprocal contact has burdened the musical mind with questions which have hardly been formulated, while the technician is faced with a number of unusual problems which he must solve in order to 'realise'. We have mentioned above a real disturbance of the limits imposed on the creative artist; one of the foremost problems of this transformation consists of the fact that for the first time the musician has to deal with the idea of continuity. It must be pointed out that this is a problem not only of pitch level but also of duration, dynamic and, the most problematical of all, of timbre. Never has it had to be so clearly realised that pitch, duration and dynamic are irreducibly bound together both in the organisation and the actual production of sound. A final obstacle linked with 'interpretation' is the continuity of projection of a work in space; contrary to what has previously been said, we are here faced with definite limitations; the attraction of an 'objective' work is speedily dissolved, for psychological reactions of an audience to which the music is fed by loud-speakers can hardly be avoided where that audience is deprived of the possibility of associating

a sound with a gesture. Thus the arrangement in space becomes a structural necessity and represents considerably more than an appropriate setting for a more or less spectacular exhibition—though the very idea of this stereophony is enveloped in such a mist of confusion, owing to its continual vulgarisation in the cinema and in all kinds of 'out-door shows', that the best intentions are discouraged by the incidental experiences of similar appliances.

Is a concert-hall really necessary when the performing artist has been eliminated? Is it not insolubly bound to the idea of the instrument? Is it not then necessary to find new conditions for listening or are we to contemplate the reuniting of this 'artificial' music with a 'visual double'? We are touching here on the external influence of the performer on human communication; but further consequences of the elimination of the performer affect the internal conception of a work of art. Compared with the capacity of the performer the machine can, at once, do very little and very much; a calculable precision is opposed to an imprecision which cannot be absolutely notated. *Tempo* is in itself a key to the respective functions of the interpreter and the machine; one is tempted to say that extreme precision has only a limited efficacy by comparison with that imprecision which exceeds the limits of notation. Above all, we are interested in this small, ultimate margin of error rather than in a definitive realisation, which does not depend on individual fantasy, on the daily inspiration of a human being. We need only be disturbed at the passing of the performing artist, if some part of the 'musical miracle' goes with him.

Will the composer be able to transcend this liberty which he has himself sought for the sound material of his composition? Or will it in the end suffocate the potential poetics of his work? Will it never be possible again to imagine a synthesis in which the very contradictions of the two sound worlds will interact to widen the scope of our structures? Are we to be spared the nostalgia and transformations of a new 'total' art?

In considering his electronic means, the composer has first to free himself from the conception of absolute interval. This can certainly be done. The tempered system of twelve equal semi-tones seems to lose its necessity at the very moment at which it passes from chromatic organisation to the Series. There have already been experiments with intervals of less than a semi-tone, of quarter-, third- and even sixth-tones. Unfortunately, the works written as a result of these experiments proved to be of no great interest; a hyper-chromatism was developed which did not really modify the basic system of arranging intervals otherwise than by an enlarged modality. More recent experiments have been of greater significance. Here there has been no more hyper-chromatism tempered or otherwise, and the characteristic intervals used for each work were specified from a particular range of sound. In principle this has nothing to do with the interval as a basic unity. In fact electronic research has demonstrated that the idea of an absolute interval is fictitious and that the ear's capacity for differentiation is determined either by a basic unit or by the extent of the registers in which these intervals are heard. So we see that ideas of continuity and non-continuity overlap considerably and can hardly be applied mechanically.

In fact, to select a fundamental unit other than the semi-tone, means to conceive a kind of temperament peculiar to a single composition; all intervals are to be heard as deriving from this fundamental tempering, thus affecting the listener's conditions of



perception. But owing to the fact that our ears are conditioned by the semi-tone, we have an incorrigible tendency to reduce everything back to our traditional chromatic temperament and to hear new intervals as 'out of tune'. Nevertheless, one cannot deny a certain harmonic atmosphere to this arbitrarily tempered sphere in which the structural consequences and characteristic gestures are developed from this kind of premise. This tempering may take place within the octave, so that the traditional definition of scale in the tempered twelve-note scale will remain unchanged; or, it is equally possible to construct in such a way that the interval with which the *démarche* of the scale commences again is other than the octave; in this case the different registers of a note will appear as essentially dissimilar. Comparison of a flat and a curved surface suggests the kind of difference between these two systems.

We mentioned above that the ability of the ear to discriminate depended to an equal degree upon the extent of the register in which the intervals were heard. By this we mean that a micro-interval will only be distinguished within a very narrow range. This has already been ascertained with durations. It is most easily demonstrated if we take two very long durations which differ only by a very short duration: we will be unable to discern which is the longer of the two. Similarly, let us take a relatively wide interval, such as a twelfth (octave plus fifth); it is certainly true that at first hearing the ear will have considerable difficulty in establishing a precise difference between this exact interval and the same interval altered by the addition of a sixth of a tone. But if we modify a single whole tone interval by a sixth of a tone, the difference is immediately perceptible. There is thus in the ear a certain capacity for adaption, as there is in the eye. In a narrow area, where micro-intervals are the unit of alteration, the ear momentarily acquires a sensibility which it is unable to retain when the range is broadened, or, otherwise, the ear establishes its own scale of appreciation in proportion to the intervals utilised. This fact is true for a normal pitch level of medium frequency; the capacity for differentiation diminishes towards high and low extremities. As for discerning harmony, here the situation is even more delicate, in that the ear's ability to discriminate must intervene in a simultaneity of sound phenomena rather than in a succession, as in the previous case where memory can play an important role. Study of the various musical cultures of the Near- and Far-East has always emphasised the non-harmonic character which differentiated these from Western polyphony, thus explaining the greater richness and complexity of intervals utilised. (This is true, especially of Indian music, in which the rhythmic complexity is the consequence of the same fact.)

We have thus to resign ourselves to the fact that we must find an idea more complex than that of a *continuity* which frees the composer from all limitations, and must realise that our famous continuity is conditioned by aural capacity – be it to a certain extent a dialectic, apparent or real, between the idea of temperament (regardless of the basic unit) and the idea of dimension of range used. Electronic music will have a higher aim if it dispenses with this unlimited area in which neither can anything be apprehended by the ear nor can transformations be registered (which is 'theoretical' and completely unmanageable), and replace it with a multi-dimensional range which is based on the aural capacity for adaption, a multiple dimension which, furthermore, may be suitably expressed by a real multiplicity of dimensions in a stereophonic space. This question must be discussed in greater detail. For the time being we will deal with the problem of a synthesis between electronic and instrumental dimensions with sole

regard to pitch-levels; it seems unlikely that, if any such synthesis is to come about (we are not here concerned with the question of its necessity), it will do so without some reference to this idea of multi-dimensional space; a successive or simultaneous multi-dimension with either single or several basic units. In this way it would be possible to derive from one structure based on wide intervals, *i.e.* having a wide compass and a semi-tone as the unit, a corresponding structure based upon micro-intervals, in which the compass would be greatly reduced and where the unit would be either a very small interval or irregular intervals defined by a series. An example of this kind enables us to imagine the possibilities of various different modes of transitions from tempered to non-tempered, from micro- to macrocosm. Electronic music would be the sole means of exploiting these transformations to their fullest, and instruments, whether normal or with some kind of tablature, would represent certain fixed points in an evolution, the continuity of this evolution being represented by the electronic dimension. This idea must be seen above all as a project, as a working hypothesis; certainly, working experience, yet to be gained, will show us fallacies in such Utopian ideas, which nevertheless have to be described.

We have already mentioned above that with tape the composer can avail himself of any duration, whether or not it is playable by human interpreters, merely by cutting the tape length which corresponds to the duration. Nevertheless, three problems to which the composer must find an answer are posed by this seeming simplicity: they are the perceptibility of the duration, the definition of tempo, and the continuity of non-formulated time. Certainly the first problem is of slighter importance than the second. This poses the relevant question of the severed relationships of composer and interpreter; nothing is *indicated*, everything has to be *realised*. Can it not be said that, essentially, an interpretation is defined by tempo, as it is the tempo which determines the various phases within a composition; and can it not be said that the transitory *accelerandi* and *ritardandi* are here only fictitious, potential simulations, which defy precise control, even though any number of irrational values be utilised? For our third problem, that of a non-formulated time, it is appropriate to consider that at their limits arithmetic and logarithmic progressions become a real continuity. But where are these limits?

Let us return to the first objection which may be raised against this new concrete way of dissecting time: namely that there is a danger that the unit will not be perceived by the listener; that it exceeds the lowest limit of differentiability. We have already referred to irrational values; their use does not represent only a written out *rubato* but a point of contact between the variation of a unit value and the variations of the particular duration itself. This meeting point gives rise to fractions of irrational values within a group of irrational values at another level! . . . In short, to realise these instrumentally and at the same time to retain the sense of pulse of the unit value, the player must be able to realise three mental operations, the one deduced from the other, almost simultaneously: supposing the initial pulse to be established, we have the metre, the irrational value of the first level, the further irrational value or the fraction of it, which depends upon it. Strictly speaking, it is just within the realms of possibility for the interpreting artist to realise this kind of value if he has to perform these operations successively and if he has a sufficiently detailed knowledge of the score; the process of simultaneous

deduction is, however, for all practical purposes impossible. It is better to substitute an alteration of tempo and thus simplify passages which are otherwise inexecutable. We have only described these difficulties of rhythmic micro-structure to enable us to extend our examination to the electronic sphere. Is one to consider that the only function of working with tape is the facile solution of problems of transmission? What is the point of it, one might well ask, since man will be unable to perceive that which he is himself unable to perform, without recourse to a mechanical procedure external to himself. Reasonable as this argument appears it does, however, depend to some extent on a belief in some absolute law of intervals. Besides, it has not been established that the ear is incapable of perceiving subtleties which the hand cannot realise; even if a subtle differentiation is not exactly perceived, it is at least registered and that is almost enough. But electronic music is not to be reduced to the role of robot which fulfills inhuman tasks; it is certainly possible to realise otherwise unrealisable values on tape, but the very simplicity of procedure demonstrates the poverty of the idea. It is of more value to reconsider fundamentally the whole problem of musical time and its organisation. This can straightway be done by starting with the durational lengths themselves.

To do this we must refer to a series of unit values within the relationship of a single value and its double. Thus we are able, as it were, to make a registration of durations. An idea which until now has only been concerned with pitch levels will be extended to time. As we have shown with pitch levels, we can modify this so that we will be able to cover all eventualities which a composer might encounter. How electronic music fundamentally differs from instrumental music is demonstrated by the fact that it may be based on a series of unit values as opposed to a single pulsation or a particular unit. This constitutes a completely new conception of rhythm, one which refers to the past only in its use of normal and dotted units (the relationship of 2 to 3); precedents for this may be found in certain folk music cultures. We may define it as a registration of durations based on a changing unit duration. As has been seen with pitch levels here too we may observe that the ideas of continuity and non-continuity can hardly be separated.

Our second stage towards a conception of duration as length (measured on tape): a definition of *tempo*. Our usual simple proportions of abstract values do not appear to be a valid system for electronic music. We are disturbed here by a lack of tempo, in the traditional meaning of the idea. We must ask the exact meaning of tempo (though more has been written about it than about any other aspect of music, it is certainly the least clearly defined). In any case, there can be no question of a certain 'speed' of notes, as one would speak of the speed of the current in a river. Certain fast movements have a very low density in their rate of events, while some slow movements, on the contrary, have a much higher density. Nevertheless, they are clearly perceived as characteristically fast or slow movements. We have to take into account the harmonic rhythm, a greater or lesser ornamental character in the sounding phrases; we must reckon with the so-called agogic of development. In instrumental music certain conventions enable us to find answers to these questions without too much difficulty. The interpretation of durations is subjected to a whole series of modifications and, in fact, if there is one aspect of instrumental music which has not been adequately studied, it is the particular duration of a sound unit in absolute time. Emphasis has always been placed on the relativity of tempi, one to the other, or on the constancy of rhythm of procedure. A rhythmic pulsation of greater or lesser complexity, whether it be appreciated

physically or mentally, is established and all principle points are related to it. On tape, however, the absolute duration of a unit of sound is alone of significance, since no psychological consideration is possible and the duration must be appreciated regardless of a regular pulsation; strictly speaking, there is no tempo. In electronic music, the most general substitute for instrumental *tempo* is that of an augmented registration in the general scheme of the composition. The meaning of this registration of duration has been described above; we must be able to extend this phenomenon to a group of durations which would in their turn lead to other groups in which the tempo was not specified in advance. Combinations of these two variable registrations would create networks of variable *lengths* – as happens to an absolute duration of time when transposed to tape. The significance of the same length would vary according to which group it belonged. Thus, in a more general category of order such as that of tempo, electronic music will depend on a conception of non-continuity; at the same time instrumental music will increasingly depend on one of continuity with its variable tempo, within which transitional procedures such as *accelerando* and *rallentando* will take on a greater structural significance. A particular definition of a duration is common to each of these two worlds of sound; at the same time contrasting conceptions may be discovered which cause a fundamental differentiation between them and give to each its intrinsic physiognomy. To recapitulate, these two contradicting conceptions are: in the first case, an unchanging *tempo* within which durations may be subjected to almost unlimited degrees of variation; in the second, a *tempo* which is itself subject to the greatest degree of variation but within which there are limits to the degree to which values may be varied. We see the possibility of a synthesis in the simultaneous registration of time, which reveals itself directly in the unity of the duration and at a higher level in the tempo itself.

Perhaps the reproach will be made that we have been too concerned with the idea of a synthesis, too obsessed with the similarities and contradictions between the respective domains of instrumental and electronic music. Let it be remembered that it is hardly reasonable to suppose that one sound world can supplant the other; and further, that it is futile and inconsequential to conceive the relationship of one to the other as a simple 'progression'.

Before we leave the subject of duration we must examine the principle of *unformulated time*, such as is given us by tape montage. Formidable obstacles could arise out of this procedure. We have examined how temporal organisation implies a network of durational *lengths*; we have not, however, mentioned the fine degree to which these networks may be potentially differentiated. At the present time, with careful cutting, the nearest millimetre is the limit to possible precision in measuring and cutting tape; this represents, at a speed of 76 cm.p.s., a duration of 1/760th sec. This precision certainly oversteps the limits within which the ear is capable of differentiating two durations differing by this amount, whatever be their actual duration. There are maximum limits for the aural appreciation of rhythmic structures which in effect forbid the use of continuity which is not in some way restricted. Fechner's law stipulates, with regard to pitch, that there is a logarithmic relationship between sensation and stimulation; in fact, as we have already observed, the same law is maintained by a classical rhythmic usage in the temporal dimension. The different values are established in logarithmic scales from simple to imperfect (1:2), from the demi-semi-quaver to the minim (a 32nd

note to a whole) or from simple to perfect (1:3), (dotted values in a ternary measure). We see that one arithmetical difference may be negligible or considerable, according to each case. If the amount of difference is a small fraction of the original value, the effect will be small; e.g. a minim plus a demi-demi-semi-quaver ( $1 + 1/64$ ) is a proportion of 64:65. As has been described above, the ear is incapable of distinguishing two durations of similar length differing only by a very short interval, though two values of shorter duration differing by the same amount may be easily appreciated. Thus it is hardly possible to take only 'neighbour' durations ( $1/64$ ,  $1/32$ ) into consideration. The ear does not appreciate so much absolute differences as general proportions. Logarithmic and arithmetic scales are to be utilised in some way analogous to the way in which micro-intervals are related to large intervals. An arithmetic scale will be best appreciated where the degrees of the scale are close to one another. A logarithmic scale may be utilised to cover a wider 'time-area'. Here we see that same *power of adaption* of the ear, of which we spoke with regard to pitch. A consideration of it clearly determines the rhythmic life of electronic composition; as we have looked forward to a multi-dimensional area of pitch, so we hope to work out an analogous multi-dimensional area of time. Once again the idea of a synthesis; only electronic music enables us to reach the *limits* of rhythmic transformation; the principles of writing being, however, statically applied to instrumental music.

It will not be necessary to deal at any length with the problem of dynamic intensities. In this dimension there have been no real modifications nor are there really any new problems. This is due to the fact that intensities have always been applied in a continuity in instrumental music through the use of *crescendo* and *diminuendo*. On the contrary, a precise application of a non-continuous scale of intensities is the only real innovation in this sphere resulting from the use of the medium. Nothing has proved of greater difficulty for the performer than to adapt himself to those needs of contemporary musical thought, which require him to separate emotional power from the idea of an intensity – in other words, to go from *nuance* to *dynamic* alone, i.e. the establishment of a certain number of levels of intensity which are to be strictly respected wherever they are indicated in the score. In practice it is almost impossible for an instrumentalist to grade the dynamics he uses; and the same *forte* is rarely executed in the same way; it is influenced by its context, the mode of its attack, by certain psychological factors, quite apart from the nature of the instrument itself. Thus, let it be clear, scales of intensities in an instrumental work are modified by the mode of attack and give rise to certain undefined areas within which the interpreter acts; the composer in the writing of his works is bound to concern himself with what one might call a psychological notation as much as with a real notation.

With the use of electronic instruments on the other hand, the maximum precision desirable can be attained in the registration of dynamic degrees. New problems are raised here. Strictly speaking, a dynamic scale is only valid for a limited and small area of sound; to obtain the identical acoustical effect throughout the entire range of sound it must be modified according to the curve of audibility. Thus the measurement of a sound level is not an absolute conception, but a relative value, in its turn modified by the nature of its timbre.

Suffice it here to observe the interferences between real and psychological intensities;

in opposite senses they are of importance both in electronic and instrumental music. If they are co-ordinated with other conditions of hearing we find that nothing is more relative than a dynamic scale and that no new problem is really presented. Despite all efforts to integrate it with the other components of sound, the intensity of dynamics must finally be regarded as a kind of superstructure, with a demonstrative function rather than a real factor of structural organisation, since it is always impeded by a degree of vagueness, unless it is made to participate in the elaboration of the timbre. This we will now examine.

Of all the separate dimensions which go to make a composition we have chosen to leave timbre to the end of this study. There are two reasons for this: first, that within the timbre itself are combined the three elements with which we have already dealt: pitch, duration and intensity; secondly, because in the timbre we have the greatest divergencies – one might say the essential antithesis between the traditional and the electronic sound processes. This is due not only to the fact that the composer is here compelled to choose his own material but also because he has to consider in a completely new way the problem of a continuous timbre, an idea which is the most disconcerting of all he has to face and one never before encountered in the history of music.

The manufacture of instruments has always tended to create families of characteristic timbres; these were differentiated according to the sounding body utilised, the way it was made to vibrate and the way in which the resulting sound was maintained. Actually the instrumental apparatus has undergone little variation in its basic forms for several millenia; we have the strings which are bowed, struck or plucked, wind instruments making use of various kinds of bevel reed or mouthpiece, the essentials of the percussion family which, whether of defined or undefined pitch, have been skin, wood and metal. These three families further sub-divided into three groups, give us the majority of all *natural* sounds. The use of the melody of timbre and, following this, the series of timbres in the orchestra has altered the whole approach to sound combinations in shifting the emphasis of what really may be called orchestration to the acoustical aspect of these combinations. As with intensity, orchestration no longer has only the decorative function which was attributed to it in the 19th Century. The way it is organised imbues it with a significance which it has never known before; it is no longer the 'dressing', it is the sound phenomenon of the entire manifestation. Nevertheless, a free use of orchestral timbre is still based on the clearly defined instrumental families even if the boundaries between them are frequently traversed. It is worth recording that these timbres result not only from the super-position of several overtones but as much from the transitory events, the attack, the appearance or disappearance of certain overtones, the proportion of their intensity.

Electronic music compels us to assemble each note as we require it. This is not a question of substituting copies of natural sounds; in this domain there are structures of a complexity which are practically impossible to reproduce synthetically. The idea of creating an ersatz natural sound world is very questionable; neither would it attain to the quality of the original, nor would those properties which one might expect to find in fact exist. Here exactly we have the rub of all those specialists in hybrid, sexless, electronic paraphernalia who never really concern themselves with the real condition of timbre in the *artificial* sphere.

There are various ways of achieving a real sound complex: one can either start from sinusoidal tones which are superposed in a manner sufficient for the creation of a single aggregate complex, or one may utilise the sum of the frequencies contained within an area limited by two frequencies. This *noise* is then filtered until it becomes a real sound. No need here to recapitulate the various discoveries which have been made with sound aggregates; we take the most general viewpoint as to experimental procedure: valuation only with reference to the effective resultant obtained in the composition of sounds. Our first question is: can one abstract the proportions of harmonic or natural sounds; are we to rely on arbitrary connections which are dependent solely on the composer's whim? Whether one or the other method is utilised the danger of obtaining either pseudo-natural sounds or aggregates of harmonics which do not resemble the homogeneity of a single sound is always present. For the time being a methodic empiricism still seems to be the best way of finding solutions which are aurally satisfactory: an empiricism derived from the interferences between a system based on non-harmonic acoustical relationships and a conjugation of harmonic relationships.

It is possible that from a result obtained in this way, one might have to elaborate further the created *sound object*. Just as in composition the development consists of the working out of single complexes extracted from a simpler, more general series of relationships so the working out of *sound objects* formed in the above mentioned way, consists in their subjection to a higher order, in which transformations are parallel to those which contributed to the original function of the object. In this way it is possible to free oneself from a dogmatic organisation, and to imagine a multi-dimensional development in which one transformation generates another. One would no longer be bound to a unilateral system which rather tends to impoverish by the limitations of its sound phenomena. Taken in this sense the sound object appears to enable the composer to attenuate the confusion with which a dimension of absolutely differentiated timbre confronts him. He will be able to corroborate it into the morphological procedure of composing in the rhetoric of the work. To sum up, if we wish to make any progress in the methods of working with sound objects, the idea of the series must be extended to include the primary interactions of temporal phenomena resulting either from the differences between manner of organisation arising from the objects themselves or from within a single family of objects deduced one from another. It must be remembered that this is only a hypothetical course of action which has been thought out on the basis of past experiences, successes and failures. Let it only be asked whether control will not restrict and obtrude if sound phenomena are not considered, or whether these new considerations are not flexible enough to make the unexpected a real participant.

To draw logical conclusions from our investigations of the concept of continuity which faces the composer in all dimensions, we will have to extend still further the idea of a *real spatial continuity* into which the sounding aggregates are to be projected. The instrument is a fixed source of sound, but stereophonic projection is easily adapted to a dynamic relief. It is the only means of avoiding the impression of a pseudo instrument, where the ear is turned to a single loudspeaker in a fixed direction. We discussed above, at the beginning of this study, the psychological reflexes required of an audience having to assimilate a music which is not linked to any visual action, which is not evoked by any gesture of an executant.

We are led to certain considerations on the aesthetic aims of electronic music. In the first flush of electro-acoustic experiment there were many grandiose, if naive, conceptions: freedom, precision, the unlimited possibilities which a truly modern civilisation gave the composer; this was to be music's own 20th century. The very freedom which he sought becomes chaotic and if it is not limited all work loses its point; the further we investigate the less tangible seems the very precision we seek, nor is the margin of error any smaller. The conceptions of continuity and non-continuity are imbued with such ambiguities that one is compelled to utilise their very internal contradictions in order to obtain some positive result.

We cannot believe in any 'progress' from instrumental to electronic music; there is only a change of field of action. What will attract us most? We can only repeat, by way of conclusion: to confront the two sound worlds with multi-dimensional structures: an activity which will doubtless lead us, if not drive us, to what, as Paul Klee called one of his pictures, lies 'at the ends of fruitful land . . .'

## FORMAL ELEMENTS IN A NEW COMPOSITIONAL MATERIAL

HENRI POUSSEUR

We had arrived at a fairly precise idea of the new technique of composition and the results it was likely to achieve before the problem of actual composition with electronic means was attempted. We saw it as a means of bringing the smallest dimensions of sound processes within the scope of compositional form. It had nothing to do with anything pseudo-scientific. Rather was it the result of an unequivocal desire to direct our musical sensibility along new channels. We sought a means of expression that would take its place in the natural evolution of music and at the same time be rooted in our own deepest consciousness.

It cannot be denied that the character of music has been significantly altered in the last fifty years. Even in Debussy the exclusive attention of the listener is directed to the phenomena of sound itself in a way which radically breaks with the sentimental conception of the 19th century. In what is generally known as the 'Emancipation of the Dissonance' we see the real beginning of an evolution which leads directly to our own composition with electronically generated sound. Increasingly complex finely differentiated sound structures are brought within the scope of musical form. The powers of human invention are applied to elements which have previously been considered outside the realm of music: these are the non- or semi-formulated oscillations of what we know as note- and sound-mixtures, of rustles and noises. Even repeated figures, with variable pitch or dynamics, had only to a limited extent been considered independently, although they have always been a logical consequence of instrumental technique. Except in the case of dynamic alteration or in the 'expressive' use of vibrato and glissando, these elements have been left unnotated. Gradually the expressive elements within the material itself and their relationships have come to be recognised once more and examined for their own sakes. This led to a significant extension of musical possibilities.

The chord amalgams in Stravinsky's early works (from *The Rite of Spring* to the *Symphonies of Wind Instruments*) demonstrate the manner in which simultaneously sounding pitch-levels result in impenetrable opaque sound-complexes. In the context of other superimposed pitch-levels where durational values are short, the ear can register these sounds only in the most general terms. At most the outside frequencies or the predominant pitch-register can be absorbed: everything else merges into a collective phenomenon. We may ask ourselves whether such sound phenomena, which are explosive in effect, can not from a compositional point of view be regarded as inexact. Or is it not rather that the means with which we have attempted to measure them are utterly inadequate? Can one assume that a figure is imprecise because it cannot be easily circumscribed by straight lines? It must not be forgotten that even acousticians have given up the inflexible methods of harmonic analysis in studying the problems of psycho-physiological relationships. In their analysis of sound they are no longer satisfied to discount the most important of all the co-ordinated elements, time, as a pseudo-spatial dimension; consequently, they come much closer to an active perception

of it. According to the principles of aural perception they accept a certain degree of inexactitude in the pitch dimension. But it must be remembered that Stravinsky himself has not drawn the ultimate and only valid conclusions from these procedures. The manner in which he relates one sound to another and in which he organises them within a context to a fixed polarity, neutralises the explosive effect of the sound-complexes and reduces them to an elementary augmentation of percussive noise whose only function is accentual.

We see an entirely different state of things in the work of Schoenberg. Here tonal necessity leads to a world of sound in which the listener is expected to adapt his ear constantly to the reception of new phenomena and the simultaneous sounding of the most variegated formal elements and tensions. This is particularly the case in the pre-twelve-note compositions, the so-called atonal pieces, between the composition of the second string quartet and the pause in the composer's output which followed Op. 22: (*Five Orchestral Pieces*, *Erwartung*, *Pierrot Lunaire*). In his later work the new forces are too often cast into a rhythmic scheme and subjugated by the imposition of academic formal principles, so that sometimes only a caricature, intended or otherwise, remains.

With Webern, we come closer to the problems which are our special concern. We will demonstrate the clarity of his vision with a single example. The fifth of his Six Bagatelles for String Quartet is built up of the simultaneous sounding of minor seconds. Of all the intervals of our tempered system, the minor second produces the most complex structure of oscillation. Of all simultaneous soundings of two sinus components, the minor second may be regarded as the least rational interval. Although the conception of 'rationality' of an interval has been disputed, we nevertheless see sufficient musical considerations to justify its retention. Despite the apparent paradox, a further conception, that of a rationality of perception, serves effectively to define the idea. Given two individually sounding frequencies, such a conception would regard the resultant vibrations not as a combination tone, but as the indices of rationality in the interval. This indices would naturally be related to the inner structure of the resultant frequency; in a static event of this kind the particular frequency curve would be contained within two points, i.e. it would be circumscribed by a single rationality period. The greater the frequency of the rationality, the shorter and structurally simpler is the total period, and vice versa. In this way an arrangement of intervals might be undertaken, which would, of course, respect the limits of differentiation imposed by the ear. What is valid for the dyad remains true for combinations containing a greater number of frequencies. Account would have to be taken of fragmentary sections arising from some part of the total components and obtruding by a particular tendency to polarization or isolation. Anyone who has worked with strict twelve-note composition, will know what we are talking about and he will know how difficult it is to attain this purity.<sup>1</sup> This concept of rationality would only partially depend on the duration of a sound phenomenon or a stationary section of one. Naturally it would not become perceptible in a duration of value shorter than the minimum of rationality. The loudness level intensity must also be considered as a determinant of rationality.

In all that has been said we have referred only to stationary phenomena. Where the

<sup>1</sup> A further principle might be formulated: if the rationality frequency is above the lowest limit of audibility, the sound combination may be regarded as being rational; but if it is below ca. 20 c.p.s., it must be assessed as being 'irrationally perceived'. I have found justification for this hypothesis in practice.



time element effects a certain minimum rate of change in the quantities, frequencies and superpositions of them, the possibility of discerning parts of a collective phenomenon is further reduced. Webern was well aware of this fact. He writes a minor second and, a certain duration of time having elapsed, introduces a third note, which is related at the minor second, to one or other of the original notes. One of these two original notes then disappears; the picture is transformed. At another place, one note of the dyad of the minor second grows louder, the other softer; or the introduction of a third note is effected by a pizzicato. In this way the composer is enabled to realise varied structures which embrace the innermost properties of his material. In fact, they cannot be considered as entirely unrelated to what, until now, has been known as noise. But, today, 'noise' is formulated creatively and so gives rise to entirely new, unknown, aspects of conscious hearing.

Further experiments have taken place since the end of the last war before actual work with electronic means was begun. Though they were frequently disappointing, they have nevertheless taught us something if only what not to do. Outstanding among these, for the thoroughness of their musical thought, are the two *Concrète* studies by Pierre Boulez. They are based on a richly characterised material, but in the actual composition this is reduced to its barest necessities. They hold the attention of the listener by a process of perpetual self-renewal. Despite the efficiency of the realisation, one cannot but observe the extreme contradiction of the means. It was hardly two years later, at the Studio in Cologne, that Karlheinz Stockhausen undertook the realisation of the first composition specifically based on the electronic means. Other compositions followed and today we may consider that a first stage has been completed. The time for a re-assessment of our eventual aims is clearly needed.

It is not my purpose here to give a chronological description of the various experiments which have been carried out at the Cologne Studio. Nor will I examine formal considerations here, except in so far as they are relevant to the specific questions of a formulation of the material. It is important, however, to examine the various solutions that have been offered and, consequently, the attitudes they imply, to the questions described above.

In his most recent work, Paul Grelinger has devoted his entire attention to one important question: how, unobtrusively or continuously, to alter the timbre which is peculiar to a given pitch level. Notes produced by combinations of partial frequencies seem capable of reaching dynamic levels which, especially in the extreme bass, cannot be achieved with sinus tones and mixtures. This is clearly of importance. Notes of this kind have, however, a peculiarly instrumental character which is clearly derived from the structure of their formant series, *i.e.* they are based on a condition which prescribes a single timbre for a fixed pitch level. Although this kind of sound is not really part of the language of electronic music, it is nevertheless worth examining, in that it reveals to us certain synthetic qualities of our hearing capacities. Much controversy has been raised over the question of timbre. One thing, however, is certain: as long as partials are heard as individual frequencies they can have no effect on the timbre. Timbres of frequencies are completely swallowed up by the principal frequency and are subordinated to it. They effect the inner structure, the detailed form of the, in its turn subordinated, periodicity, which is determined by the acoustically verified pitch levels. They may be taken as statistic phenomena, a kind of source of prob-

abilities; their density is determined by secondary oscillations, by the smaller or greater degree of complexity in their internal proportions and by the degree of inequality between them. This attitude nearly coincides with aural experience. It would be seen to what extent the sound and the invention of the timbre are affected by those supposedly subjective qualities, which have been so richly described. Will not the characteristic quality of the sound depend on the nature of its secondary accompanying partials? Is not the whole basically unaltered and regular in character, even if the smallest units within it are varied? We hear a fixed, linear pitch level; this exactly contradicts our intuitive idea, for we imagine a much higher and more general degree of transformation. We see the search for ways of breaking this regularity, even to the microscopic details which go to make up the frequency of the sound phenomenon as the principal task of our generation, starting as it does from the apex of Webern's work.

The basic material used in *Studie I* by Karlheinz Stockhausen, *Study in note mixtures* by H. Eimert, and in my own *Seismograms*, is, in its essence, totally opposed to the work of Grelinger. Sinus notes were utilized in fixed constellations, but not according to the ordering of the harmonic series. We argued that as a harmonic timbre was the resultant of harmonic partials, it followed that a non-harmonic quantity would result from the setting together of non-harmonic sinus notes. We anticipated that these would be well suited to our ideas of form. Many factors were found to contradict this idea: the small number of partials (which gave rise to fairly high rationality indices), the fact that generally they began and finished sounding simultaneously in time, and the constancy of the relationship which existed between their relative dynamics. This became evident in my *Seismograms*, where the individual note mixtures had no enveloping curves proper to themselves and remained static in regard to their overall dynamic strength. Where the loudest of the constituent partials did not simply swallow up the rest and in cases where, despite its brevity, the process remained aurally perceptible, one tended to hear 'chords' in which the components were related in a fairly complex manner but still remained as isolated, fixed pitches. At the same time they had a soft transparent timbre which characterises sinus note production. Even the method itself was doubtful in the fact that it was at the opposite pole: 'a harmonic synthesis', which amounted to little more than harmonic analysis.

We tried to overcome these difficulties in the first part of the *Seismograms* by building up note mixtures from various areas. Each area would consist of a determined number of sinus notes at selected pitches, chosen in such a way that the components were more or less dissolved into one another. Each area was furnished with its own separate enveloping curve. Sometimes this could be opposed to a curve, proper to other areas. In this way, living, 'gyrating' sound procedures were created. It was only a partial solution. Further difficulties were raised in the co-ordination of preselected quantities with a durational ordering. Though they were theoretically correct, they did not have the anticipated effect. We were not satisfied with the actual curves of intensity. Like all enveloping curves drawn at Cologne up to the present time, they had to be executed freehand. Thus they could clearly only be approximations of the original plan. Their regularity depends on a steady control of the hand and there are certain limits to accuracy. This does not matter for certain overall *crescendo* and *decrescendo* curves which are only intended as such. Complex curves, however, are closely related to their durations of execution, thus affecting the resultant rhythm. Because of this, I limited

myself in the second part of my work to the utilisation only of static note mixtures and thus obtained a dynamic movement only by the juxta- and superposition of the various grades of the mixtures. Where a danger of continual alteration existed in this procedure, I selected durations which were shorter than the so-called 'actual density' (*Gegenwarts-dichte*). At present this still raises difficulties due either to the time taken up by these delicate montages, to shortcomings in the technique of tape cutting or to the impossibility of coming closer to the problem of phase lengths in oscillations.

The automatic determination of continuous alteration procedures of amplitude or frequency might lead to better results. It would be fairly simple to produce controls with a photo-electric transformation implement. A sufficiently sharply focused result could surely be obtained by photographing differentiated degrees of light on a film-strip. Experiments of this kind would only be valid for structures which in some way are derived from fixed oscillating frequencies.

Stockhausen demonstrates further possibilities in his *Studie II* which represents the most advanced stage of development so far attained. Apart from Gredinger's *Formanten*, it is the only piece in which sinus notes are utilized so as not to be perceived individually. They are dissolved into oscillating complexes. The process is carried out here in a manner quite different from that of the *Formanten*. In *Studie II* the note mixtures are arranged by the equal distribution and equal loudness level of their components in such a way that they resemble a 'coloured noise', like that derived from the filtering of blank noise from the tape. In that they are still far from a really static predominance of contextually possible frequencies, they sound like 'filtered' noise, but more like a complex network than a flat sound. The density of this network is determined by the constant interval which divides the component frequencies... Really remarkable results are obtained at places where several of the five note-mixtures are superimposed and differentiated rhythmically and dynamically. In parts, this study fully exemplifies the aesthetic ideas discussed above. In our further work we will have to build on the basis of what has already been done. At this point we may conceive of musical structures which no longer abstain from all the variegated riches of the sounding world, but which replace 'natural sound' with the decisiveness of the consciously devised. One can imagine more or less gradual transformations from relatively light note mixtures to denser noise structures; structures which combine elements of pure noise and sinus note mixtures and which unite principal frequencies in which the various levels undergo a continuous alteration with regard to loudness, frequency, tape breadth and timbre. Most important of all is further work on the actual realisation of electronic music! Our final problem – it is almost paradoxical – deals with the co-ordination of technical means and ideas. Much that in principle is possible is not in practice at our disposal. There is a special need for the development of two technical processes: a precise controlling apparatus for the gradual transformation by automatic means, referred to above (this process would, by utilizing the variable tape recorder speeds or the buzzer, be able to control the loudness level as well as the frequency of all forms); secondly, a way of transposing frequencies and durations of previously formed note structures independently of each other. This would considerably simplify the composer's work in certain situations.

So we enter our second stage. Now may deeds replace our words.

## THE SOUND MATERIAL OF ELECTRONIC MUSIC

KAREL GOEYVAERTS

On closer acquaintance with electronic music, one is astonished by the apparently artificial nature of its sound material. Indeed, in that it utilises pure vibrations it appears to stem from the basic components of sound production; and even the combining of these vibrations appears so artificial that spontaneous music-making as such seems unlikely to survive. For many musicians this will surely be felt as a loss – indeed the question arises whether music has not thus been deprived of an essential condition of its existence.

A sound phenomenon is relevant musically in as much as it conforms to the requirements of a spiritually conceived form, to which it has given rise. The relationship is hardly conscious and almost impossible to define, but it remains immutable, to the extent that it is to be considered a constant factor of historical evolution. Clearly, it does not follow that the choice of a sound material is determined purely by particular considerations of an intellectual order. It is to a far greater extent determined by intuition, and we find no exception to this rule in the case of electronic music. In short: every form of music demands its own material. While it is true that the composer's intuition is largely guided by his conscious judgement, nevertheless, the ultimate choice of a material is intuitive, whether it concerns a simple material based upon a single dimension of sound, or one compounded of many.

The sound material that went to make the polyphony of 14th Century music was formed of many elements of divergent sound character, the choice of which was left to the interpreter. The variegated nature of the sound elements was particularly suited to the fundamentally horizontal conception of compositional technique, in which a cantus firmus or a free melodic line successively gave rise to further counterpoints, duplum, triplum etc. In a technique of this kind the sound character of a tone is no more to be clearly defined than its intensity. Worthy of mention in this context is a remarkable reversion to this manner of thinking in Hindemith's vocal and instrumental music, Op. 45. In the 15th and 16th Centuries, the sound complex tended to become more and more homogeneous. This is clearly connected with the fact that the instrumental groups, the viols, flutes and oboes were completed at this time. At the root of this development lies the concept of blocs of related parts bound together by procedures of complementary rhythm. At the same time imitation and interweaving of melodic parts took on a greater importance in that they gave rise to harmonic sequence. The fact that the composer of the period was to a greater extent concerned with problems of homogeneity of sound character in no way altered his fundamental attitude towards the nature of sound: at this time versions of the same piece for alternative groups of instruments (voice, violin, organ or lute) were customary.

The concentration of intellectual forces which gave birth to Opera, the forces which to a great extent characterised the life and artistic achievements of the Baroque period, discovered an increasing strength within the substance of notes themselves, which at

once lead them to a thorough re-investigation of the very elements of sound material. The period saw the rise of individualism in the composer; he sought his purpose within himself, and attempted to realise it with the means at his disposal. The tension of this situation led to the creation of a type of music in which genuine structure was replaced by one from without, dramatic or literary, and in which all elements were valid in as much as they contributed to the realisation of dramatic intensity. In this light, the note was examined purely with regard to its evocative powers. It is clear that the orchestra of Monteverdi, and later of the Roman School, was assembled at random, the instruments being selected in each particular case at the composer's will.

While musical language became more and more inseparable from the kinetic structure which characterises Baroque style, an organic sound apparatus was developed from the continuo in which the evocative property of a single sound was retained only as a decorative element. At this period man saw himself in relation to absolute limits, having as the source of his activity, the totality of himself. This resulted in regular rhythms with unchanging dynamics. This trend was interrupted for the first time by the rationalist spirit of the 18th Century. Thereafter musical language had its own dynamic range, an augmenting and decreasing intensity within the structure of complementary phrases. The sonata form, rooted in the thematic process, was derived from this. This hierarchy of sound was replaced by patterns in which instruments or instrumental groups were superposed to obtain perfect blending of timbre. Thus, musicians were enabled to reproduce the whole gamut of musical dynamism.

The influence of a new transcendentalism marks the end of this period of musical upheaval, causing the nervous and restless spirit of one unable to reach his goal. The classical orchestra remains the foundation of a rapidly expanding organism. New instruments are added, particularly those suited to a heightened mode of expression. This leads to an increased exploitation of the psychological effects of sound. Such an expansion, increasingly complex in its technical apparatus, long outlived the Romantic era, as a nihilistic tendency derived of excessive transcendentalism, which was unable to evolve in a positive way. In the meantime, the individual has stepped back; a realisation of the transcendental has been revealed to him, and he has given up his active position in the face of the Absolute. At this time artistic creation has, in a remarkable way, been freed from the need for personal expression, in that it is conditioned by an almost completely objective system of proportion and balance. Music becomes a constellation of notes, intuitively conceived but consciously ordered.

Can one then wonder that the elements of vocal and instrumental music, which gave rise to their own intrinsic structure, appear to us as being unsuited to a world of totally organised sound? The greater the complexity within the isolated tone, the less it is suited for the realising of a precise sound structure, and the more must its particular constitution be taken into account. Suffice it to compare analytically a simple bowed with a simple struck note, to perceive the variety within their components. We have seen how, in earlier times, a current sound material would prove inadequate. In the same way, today, we seek to replace traditional instruments by a simplified means of sound production. Electronic sound provides the required elements, in the purity, regularity and variable intensity of its vibrations made audible by loudspeaker amplification. In a manner particular to themselves, these elements demand a musical organisation in which all dimensions are subjected to the most precise control.

It would be incorrect to evaluate electronically generated sound as anything more than the undefined, unorganised elements which we see in the traditional instrumental world. As I have tried to show, the nature of these instruments was perfectly suited to earlier musical forms. Today, we are doing nothing new. There is in fact nothing particularly revolutionary in our relationship to our means, as is shown by the nature of experimental works in which the material uncovers relationships which could hardly be predetermined. Today, once more, we are concerned with the creation of a new apparatus which will be suited to the realisation of a new way of musical construction. Such a process is constantly bound up with the necessity of experimentation similar to that which Haydn must have undertaken with the orchestra of Count Esterhazy, which for the first time led to an arrangement of the orchestra which not only was retained throughout the Classical period, but which served as the basis of the orchestra until our own times.

Long before the first experiments with sinus tone composition, it had occurred to me, in the search for a greater purification of sound material, to utilize absolute unaltered electronic sounds to realise a structure in duration which excluded all other at that time unmastered dimensions of sound. My second experiment further developed these ideas. Here I restricted myself to proportions of frequencies and dynamic intensities, without altering the durations. Being at that time unable to exercise any control over the notes or note complexes (this being impossible before the first sinus tone experiments), I created a series of simple proportions limited at either end by zero. It was impossible to proceed further in the dehumanisation of music.

The position has changed; ideas thought out in terms of an infinite material, tend to eschew extremes. Equally, certain aspects of music which I had thought to be able to eliminate, have again become active considerations. All this bears evidence to the degree in which electronic music is bound to tradition. So we reach the point of departure for my latest, as yet uncompleted, compositions of the phenomena of combined perception of a group of sinus tones ordered in certain proportions. Variations of tone quality result from small alterations of frequency.

No longer is the truth of logical ordering of any importance. The only valid musical truth: the acoustical perception. This sums up my present position towards electronic music. In the beginning, I sought after a greater musical purity; today, I am confronted by an *other* sound material. I do not consider its basic qualities except in so far as they are suited to the requirements of the composer. If electronic music influences the composer's imagination, his integrity is in no way challenged and the perception of so profound a truth can only be a great joy for him.



## SERIAL TECHNIQUE

PAUL GREDINGER

I begin at the point at which historical study must end, with Webern and the contemporary twelve-note composers. In our times, every new aspect, idea and potentiality is freely developed and at the same time most precisely measured. I cannot attempt to give a general picture of the period nor to show it as a whole. Only by giving some description of my own ideas and experience and the experience of those with whom I am in principle agreed, can I present a single valid viewpoint. I can demonstrate the origins of a musical development and trace its growth, and can bear witness to the extraordinary conclusions reached at the various stages of its zig-zag path. Where others may pass by, unobserving, let us pause and see more. Let us endeavour to see the position of our often very specialised idea within the infinite organism of time. We will see the coordinates, the small in the great and the great in the small; more precisely, see the general in the particular, as that is our special interest.

With envy do visual artists, architects and engineers look at the ordered world of sound. The fixed relationships, an octave regularly divided, are lacking in the measurement of visual proportions. To remedy this deficiency, Le Corbusier in 1948 proposed the 'Modulor'. He described it as 'A Harmonious Measure to the Human Scale Universally Applicable to Architecture and Mechanics'. I quote from his introduction to the description of the way in which he thought out his method, a method similar in purpose to our own, which attempts to discover a formal principle in the existence of a *standard*; this not so much for the purpose of providing a statistical mean, as an attempt to find a balanced and measured proportion of absolute beauty. Le Corbusier writes:

'Sound is a continuous phenomenon, an uninterrupted transition from low to high. The voice can produce and modulate it; certain instruments can do the same, the fiddle for example, but others are incapable of it because they are based on an order of artificial intervals invented by man: the piano, the flute, etc.

For thousands of years men used sound to sing, or play, or dance. That was the first music, transmitted by the voice, no more. But one day – someone first thought of making music permanently transmissible in another way than from mouth to ear: that is, to write it down. No method or tool was available for this. Sound had to be registered at certain determined points, its perfect continuity being destroyed in the process. It was necessary to represent sound by elements which could be grasped, breaking up a continuous whole in accordance with a certain convention and making from it a series of progressions. These progressions would then constitute the rungs of a scale – an artificial scale – of sound. How could one divide into sections the continuous phenomenon of sound? . . . Pythagoras solved the problem by taking two points of support capable of giving both certainty and diversity: on the one hand, the human ear, the hearing of

human beings (as opposed to the hearing of wolves, lions or dogs); on the other, numbers, that is to say mathematics in all its forms: Mathematica, herself the daughter of the Universe.

Thus the first musical script was created, capable of encompassing sound compositions and transmitting them through time and space: the Doric and Ionic modes, which later became the source of Gregorian music, and so also of the practice of the Christian cult for all nations and languages. Apart from a somewhat unsuccessful attempt during the Renaissance, this practice was continued until the 19th century. Then the Bach family, and especially Johann Sebastian himself, created a new system of musical notation: the 'tempered scale', a new and more perfect tool, which gave a tremendous fresh impulse to musical composition. This tool has been in use for three centuries, and it has proved itself able to express the subtlest of things . . . It may well be – I take it upon myself to predict it – that the apotheosis of the machine age will demand a subtler tool, capable of setting down arrangements of sounds hitherto neglected or unheard, not sensed or not liked . . .'<sup>1</sup>

I have quoted this section not so much for the detail of the argument, but for its general substance, its significance in light of the importance attached to it by Le Corbusier in his research in proportion. I would like to emphasise the importance of the Modulor. It is, as Le Corbusier originally intended to call it, a proportioning grid. I quote the remarks of the great architect, on the nature of music, with reverence. He continues: 'Nothing that is built, constructed, divided into lengths, widths or volumes, has yet enjoyed the advantage of a measure equivalent to that possessed by music, a working tool in the service of musical thought. Has this absence of a tool made the spirit of man any the poorer? It does not seem so, for the Parthenon and the Indian temples, the cathedrals, and all the refinements of recent human achievement, the incredible triumphs of the last hundred years, are there to mark man's progress along the path of time'.

So, we may ask whether man would not have been the poorer without the tonal system, without the *Wohltemperierte Clavier*? As the reality of the Indian temple answered the first question, so the reality of the music of the last centuries is adequate answer to our own. The composer requires an appropriate scale to reproduce his work, whereas the visual produces his own. Today, electronically, the composer himself can produce.

We cannot discuss these many new, literally unheard and unimagined possibilities. From its origins music has always been dependent on a standard which changed as it changed. The standard has moved within certain fixed limits, limits imposed by its physical nature. Today, it is in no way our purpose to exceed the natural limits imposed by the ear. Rather is it to the point to attempt an examination of what lies between these limits and to attempt to unravel the tangles of technical misunderstandings. When the time for comprehension comes, the paths of art and technology meet; then, a contact is established, the spark is ignited, the light burns and a new discovery is made. I do not claim the discovery of a new world; at best I can claim a fresh point of view in relation

<sup>1</sup> All the quotations from THE MODULOR by Le Corbusier are made by kind permission of the publishers and are taken from the translation by Peter de Francia and Anna Bostock, published by Faber and Faber Ltd., London and Harvard University Press.

to music. It is our task to describe a fundamental attitude; a principle, we may call it the *Series*.

A development in art covers a certain span of time, engages and serves the eyes, ears, hearts and minds of a certain number of people. It is our good fortune to be of these people. A description of our experiences is a description of the development of the *Series*. It is a gradual development. We do not search, for in Art experience must find itself. Our efforts are neither revolutionary nor reactionary, nor do they guarantee a certain predictable result. 'The piano teacher is unaware of the fact that he is handling logarithms' (Henri Martin). Today, we are aware of it and our knowledge of acoustics helps us to develop ways of comprehending the as yet uncalculated. Our aim is an art, in which proportion is everything; a *Serial Art*. We have not come to this decision theoretically, but are convinced that it derives from a network of co-ordinated experiences common to all of us.

My greatest musical experience was my meeting with the music of Webern. Today it may seem snobbish or even naïve to say so. But it must be remembered that a few years ago Webern was so little performed that one might well have come upon his music by chance, without any previous knowledge of it. Later when, in all good faith, I spoke of so remarkable a discovery, there were already many who were able to testify to its importance. In fact, I only got to know my Webern in recent years, and it is only recently that I have been able to study, analyse and discuss his music. In Webern's work we realise for the first time the necessity of a system of proportion, in fact, for what I have called a *standard*. Webern's music is not serial, but it is on the way to being so in its limitation of itself to a single system of proportion in a composition. Webern is a twelve-note composer, but that is only of secondary importance. For him the important thing was the relationship of intervals. Fundamentally there is no great difference in the manner of composition between those of his works written before 1912 and his later twelve-note compositions.

I came to the electronic studio in Cologne with a knowledge of Webern's music, and when I had my first opportunity to work with magnetic tape, it suddenly occurred to me that the measurement of time and intensity could be taken for granted; it was the natural solution to a physical problem, a solution which is obvious at the right time and in the right place.

Stockhausen seemed the best acquainted with the inherent problems of serial instrumental music. Though it is possible to compose and hear precise interval relationships between pitches, durations and intensities, one fundamental element remains unaffected. The timbre, a fundamental property of music, is neither integrally composed nor heard in the atonal structure of a serial composition. Here the composer has little choice. In their physical nature and artistic functions, the instruments are so different that they cannot be related on the basis of any common denominator. And no Serial conception can exist without a common denominator.

A certain number and selection of overtones at certain intensities result in certain timbres. The ear is effectively equipped for the perception of the relative pitches and intensities of these partials but is not trained to do so. There is a simple reason why, until today, so little attention has been paid to timbre as an independent phenomenon. The outward (heard) harmony of tonal music and the interior harmony of its partials were identical; they both derived from the same principle: tonality.

Only today when serial structure has been extended to all dimensions, do we realise the disparity of the instrumental means and see its fundamental unsuitability for our ideas.

A disparity of means must always be eliminated. Thus the traditional instruments must be eliminated, and in our electronic music we do so. We work only with the smallest basic element in sound, the sinus tone. As I speak of 'our' electronic music, my mind goes back to the first times in Cologne, when Stockhausen was working on the first serial electronic piece. At this time he discovered the principles which today we call our own and which really are our own. Today, there are already several compositions by various composers and by continued experiment and discovery on our parts, our basic views are now generally accepted as valid.

The use of the sinus tone is a synthetic process derived from the sinus tone itself. It leads to a new tone spectrum, which may be included in our general structure, and so to all new spectra which may be derived from this structure. Physics tell us that all natural acoustical phenomena, from the most dissonant noise (*geräusch*) to the most euphonious instrumental note, are composed of combinations of overtone partials. Non-natural phenomena are produced in the same way. There has been much misguided propaganda for electronic music which has promised new previously unheard aspects of sound. Naïve people have been transported to the world of flying saucers. Unfortunately, we will be unable to fulfill such expectations. On the contrary, we should like to stress the self-evidence of much of the sound world into which we have been initiated. The impact of the obvious is always greater than that of the improbable and fantastic. Reality precludes thoughts of creating a music consisting only of the most radical innovations in sound effects. Let someone attempt this! Our experiences with electronic music prove that there is no barrier between it and the world of traditional music. There is only one world of music, and the young composers are aware of it. Is it a paradox that it is exactly this realisation that attracts us the more to electronic music?

We have demonstrated the artistic justification for electronic music, and have attempted to show it from a new angle, which originated in instrumental music. It is derived from the compositions of Webern, based on an idea of proportion derived from Schoenberg's twelve-note technique and its aim is serial continuity. Interest, if not scepticism, may be aroused by the names of our tools: machine, studio, generator, decibels, tape speed, modulator, frequency, etc. These names only testify to the actuality, to the severity and multiplicity, the involuntary necessity of a proportional system. A further paradox: we conform to general principles and procedures so that we may the more freely select the conditions of our work. Conditions of work here refer to the transformation of every quality into a quantity; the establishment of a proportion between these elements; the introduction of a dimensional ordering; the strictest regularity in the alternation of parameters, etc. The idea, the general principles of procedure to be derived from these conditions give us an idea of proportion, of texture. It is formulated as a musical form or structure; a form, a textural continuity. Its most obvious manifestation is the *Series*.

We cannot yet claim to have defined the nature of the *Series*. Its inner constitution is regulated and we may conceive the idea of a serial continuity of texture as a third

aspect of the serial process. I distinguish between texture and structure. Both represent complements, the one aesthetic, conceptual; the other a dynamic, empirical quality; the idea and its realisation.

Our ears have been the best tools for the examination of acoustical phenomena. Our observations have been realistic, our logic has been a musical logic. The desire for formulation, for the creation of form, for form itself, has come from the material. This well-worn argument has all too frequently been used in defending or attacking a new development in art. Nevertheless, we must admit that the basic materials are the only limits of our work. In this respect we learnt much from the first electronic composition. We were faced with totally new experiences in the creating of a conceived texture in space and time. We discovered that the basic inner truth of a compositional idea is no guarantee of beauty in the external structure. Truth and Beauty stood opposed. This situation belied Schoenberg's conception of the force of truth alone, and caused us no little concern. The idea of musical texture was further complicated. It was demonstrated that a texture derived only from functional proportion was not necessarily aesthetically beautiful. The incompatibility in the reactions of ear and mind and the realisation of the disparity of truth and beauty often forced us back to a revision of some of our calculations. We learned to assess a musical composition actively rather than passively. A fourth principle of the serial process is demonstrated: a serial conception of *Gestalt* must be a generating principle together with the idea of textural continuity, the one being measured by the other. Beauty is measured by Truth.

I have attempted to describe our most important experiences, to make some theoretical synthesis and have given the general principle the name by which it has come to be known: *the Series*.

The *Series* or *Row* was originally a term which referred to the twelve-note row and was extended to rhythm and dynamics. At the same time (here the writer refers in particular to France and the French term, *la Série*) the *Series* is used to notate what in new sound experiment is a freely selected number of sound complexes. Certainly experiment of this kind can lead to good aesthetic results, but it also endangers the dignity of an art in that it can ultimately become an infinite, limitless bluffing. For us the *Series* means a principle, a generating law of proportion, of duration, the essential principle of our music. A specific approach to all musical problems is conceived. Our series is a system of regulating a conception of order; is the method by which simple quantities (smaller or greater sections of the static area ranging from the sinus note to blank noise) are systematically deduced and extended; is the fundamental principle of relationship which generates the structure of a work. The serial principle creates forms in which the whole as well as the parts depend on a single characteristic of the *Series*. It took a great deal of preparatory work to reach this conclusion; we have indicated certain ideas which act as stepping stones to an understanding of it. The work itself is the study of the principles of measurement, of proportion, the principles of the *Series*. Unfortunately not everything can be determined in this way. Each only gives a sequence of momentary pictures or cross sections. We are still far from the integration and a more profound understanding of them.

We do wait for *the* discovery, *the* final choice of *the* absolute fool-proof system of black and white. Our aim is to create serial music, not a branch of arithmetic. Nevertheless, the basis of our work remains within the domain of physics and the numbers

inherent in music have their significance. 'The numbers play together' (Klee). But beware he who becomes the servant of these numbers. In the infinite possibilities of composing with fundamental notes or noises, our first object is to give quantitative definition to these elements and to consider them in the light of their later realisation and derivation and to relate them with reference to their inherent properties. We discover laws for the arrangement of quantities and, by quantitative regulation (in the strictest technical sense), attempt to create an autogeneous quality. For this, system and principle must be matched by a complete freedom of action within the overall necessities of the order. Thus we enter the domain of mathematics, and figures. Where I say order, I mean proportion; specifically: cycles per second, decibels, which are only abstract notations, nomenclatures for specific arrangements. Within this arrangement the principle of proportion generates relationships, as it were, families of related and organised qualities: a selection from the infinite possible number of values, derived not by the statistics of probability but in the anticipation of finite forms. These selected values must still be expressed as numbers, and only the music derived from them imparts importance to them. It is preferable to hear rather than to think the proportions we choose. C.p.s. represents pitch levels; decibels, loudness levels; tape length, durations. The actual means of electronic music enable us to practise the hearing and recognition of these quantities. We believe that actual contact with sound is augmented rather than diminished by the change from traditional to electronic music. The first stages of creation are inherent in the proportioning of the material and must mean a breathing of life into the dead numbers, an 'awakening' of proportions into live forms. They become music when they sound – previously I said that they were part of mathematics. Once more I repeat that the ultimate aim is the creation of quality out of quantity.

Let us return once more to the three separate quantitative conditions which determine an acoustical phenomenon: the pitch level, the intensity, and the duration of its partials. I do not wish to go over the ABC of electronic music again, but I must draw attention to fundamental divergences of opinion on this question. I purposely avoid defining them as three dimensions, as it seems questionable to me whether time can be considered as a third dimension. New conceptions have it that time may possibly be considered as the only general dimension, and refer to it as the only conceivable reality. The question is of the greatest importance to us; if time is the matrix, our idea of proportion will be considerably altered. We will be enabled to control an ideal *texture in time*, control pitch levels and their spatial realisation through dynamic intensity. The time structure is created. What the basic series, the ideal texture is for the foundations of the compositional process, the manner of the permutational transformations of the texture is for the technical structure, the evolution of the piece.

I wish thus to demonstrate that it is the regular permutation of structural elements that differentiates our conception of form from that of rhythm and tempo in the 19th century. Our idea of structure, a genuine structure in time, is formed of the continually varying movement of events in time, their acceleration, their slowing down. In this way we are enabled to compare our conception with that of *space-time* in the Renaissance, which derived its symmetrical forms from similar criteria of space distribution. The impression of space in Electronic music, on the other hand, is caused by the differentiation of intensities. About fifty values of the logarithmic scale of intensities can be discerned by the ear. From this scale we derived a measure of distance from the

source of the sound to the ear receiving it, and so can characterise movement of notes or tone mixtures as 'towards' or 'away from' the point of aural perception. One movement succeeds another; nothing is perceived as stationary; the measure is only partially apparent in that one acoustical phenomenon overlaps another. 'The rule will still make itself felt in the form of a subjective experience.' The movement of frequencies, the actual pitch levels, are the *objective reality* which determine the character.

While the somewhat schematic definition of pitch and intensity as subjectively intellectual and objectively real, to a great extent approaches the truth of the matter, we are unable to define time and duration as being either the one, the other, a mixture of the two or even within or without the scope of either. I would call it rather, *organic*, a word on the one hand too limiting, on the other too general, to ensure certain comprehension. Making a virtue of necessity, I am led to realise its unique nature, in that it is impossible to find any comparison or effective definition for the idea of duration. The *form-in-time* is expressed within the duration of a piece by the movement of pitch and intensity *standards*, and so may justly be conceived as an organism; at the same time it is the *resultant* of the systematic application of a single proportional principle, a singular aggregate, a structure. The result is *Serial* music. In truth everything in it: 'to the smallest detail, is regulated by proportion, and all designs, and consequently all experiences of it are unified. Procedures of this type seem to bring one closer to the ways of Nature, in that they, as it were, blossom outwards. All elements, all acceptable patterns, are harmonised and unified within the three proportions.'

So we return to our quotation from Le Corbusier at the beginning. It is no accident that every quotation we have chosen can be taken as referring to music. Of all the graphic arts, architecture is the one which has most in common with music. 'Architecture is not a synchronizing phenomenon, but a gradual unfolding. It consists of a sequence of tableaux, associated in time and space.'

Like music, it is a means of conceiving in time.

With his Modulor, Le Corbusier has produced a measure based on human proportion, a series of harmonic quantities based on the Golden Mean. This measure has had the greatest influence on his practical work, though it is only partially connected with serial principles. Nevertheless its part in the work is sufficiently important to enable us to conceive of an architecture based on serially permuted proportions. Unfortunately this must remain a theoretical idea. In practice the architect is concerned not with the demands of a permutational series but with the conditions of life, which differ from those of art. It would not be of any practical advantage if a door were permuted so as to be situated in the ceiling of a room. To this extent architecture can never be serial in all its elements; the limitations in what cannot be claimed as a pure art, have been obvious for some time. Serialism has a certain place in the plastic arts, though I can cite no examples of it. There are, however, indications that it may come about. It is not surprising that there are as yet no examples, when one remembers that music has only been concerned with the serial idea for a short time and that even here there are as yet very few examples. Similar is the situation in the world of painting. Here the serial idea is the youngest and has hardly yet taken route. We see great possibilities for it, when we remember that in the new music we utilise colour as an aid to the understanding of our quantities and proportions. Let us stand and watch. As we wait, the work goes on.

## ACTUALIA

KARLHEINZ STOCKHAUSEN

Over the course of two years the elementary conditions necessary for composition with electronic means have been worked out. We have created prototypes in sound; we have grasped the essence of what is to be learned from these prototypes. Now we can give some account of the new composition on which we are engaged.<sup>1</sup>

Up to this time our basic material has consisted solely of sinus tones.

In the new composition, sung language is combined with electronic sound. Sung speech phones<sup>2</sup> are, in part of their structure, more differentiated than any sound utilised in composition up to this time. The combination of the given phones and the composed electronic sounds should be quite natural.

Only by 'objectivising' the sung speech phones, *i.e.* subjecting them to an artificial process and thus bringing them within the sphere of electronic sound, can this be achieved. We are in no way concerned with simple antithesis or contrast, which would be crude.

The phones are introduced into the continuous range of timbres which exists from sinus tones to 'blank noise'.

Every phone is characterised by a fixed number of acoustical properties. Together they constitute its form.

A certain number of phones go to make up the text we have selected for our composition. Some of them are closely related in the structure of their timbres, others have only certain characteristics in common; yet others have hardly any or no elements in common. The degrees of relationship in sound between all the phones in the text are quite incidental and arbitrary in their proximity to each other. This, of course, is obvious. Language has its own phonetic laws.

Where the text does not supply degrees of relationship which are necessary for the composition, they are supplied by electronically generated sound. Or, alternatively, the phones are organically included in the rows of electronic timbres.

Thus we may consider every sung phone as one permutational resultant of the elements contained within it.

This is valid for the overall structure. The combination of phones into words and of words into sentences provides the sense of the text.

Similarly to the electronic sounds, all sung phones in this composition are submitted to procedures of musical structuring.

Where the phones of a word are permuted, at least one of the rows utilised includes the phones in their original order as they appear in the text. The purely musical sense of phone permutation is in a more or less surprising manner transformed into word-or phrase-sense: (telbju, lebtuj, jubelt, blujet, etc.).

The gap between musical sense and word sense is continually variable in the same

<sup>1</sup> The composition referred to throughout this article is Stockhausen's *Gesang der Jünglinge*.—Trans.

<sup>2</sup> Phone = an elementary sound of spoken language; a single vowel or consonant sound (O.E.D.).

way as is the relationship between sound and phones; certain permutations allow the sense of the words to come through, even though certain phones be interchanged and so not in their 'most meaningful' positions. There are various levels of normal comprehensibility.

Whatever we may compose the transformation remains immanent.

This simple idea makes necessary adequate methods for the selection and composition of material.

All individual phones or permutations of phones which are required, among them the words of the original text, are executed by a boy's voice. Similarly to the electronic sounds, they are recorded on tape for later use. Where possible the pitch level, duration and dynamic intensity desired for the singing of the phones or sequences of them are executed by the boy at the recording. Otherwise, the sung sounds are transposed to their final pitch levels, durations and dynamics during the montage. The timbre is, as far as possible, determined during the recording.

The basic elements of the electronic sounds must be differentiated in a way similar to the elements of the various speech phones – and *vice versa*. Only if this is so can we consider real permutation and only then can a continuum of timbre be perceived.

The vowel is thus a single element in the series of spectra of harmonic formants; the simple voiceless consonant a single element in the series of 'noises'. The various groups of mixtures and combinations occur between these two series.

Each timbre, like the phone family, must be available to composition in forms of regular 'periodic' elementary structures. All perceptible properties of 'periodic' and 'statistic' structures must be accessible to the composer's complete control and must be sufficiently variable according to his ideas.

For our composition the choice of eleven basic elements ensures a sufficient number of sound relationships between all utilized electronic sounds and phones.

These eleven forms are considered as non-identical in their basis and are used like the sinus tones which had previously been our only element. A basic element is one which cannot be reduced to further varied spectral components, either by direct hearing or by means of any methods of practical acoustical analysis, and which may be utilized at any pitch level, duration and dynamic.

In fact, out of the sound world of the entire utilized sound continuum, each of these eleven elements defines an area which, essentially, is of its own nature. Overlapping areas merely substantiate our idea of the timbre continuum. Each element determines its own appropriate functional application and its own limited sphere of functional activity. It is possible with some difficulty to produce a 'coloured noise' from sinus tones. This, however, is not a functional procedure.

The eleven elements are 1. Sinus tones; 2. Sinus tones in which the frequency modulates 'periodically' or 3. 'Statistically'; 4. Sinus tones in which the amplitude modulates 'periodically' or, 5. 'Statistically'; 6. 'Periodic' or, 7. 'Statistic' combinations of both sinus tone modulations; 8. Coloured noise with constant density or, 9. With 'statistically' varied density; 10. 'Periodic' or, 11. 'Statistic' sequences of filtered 'beats' (*Knacke* – clicks).<sup>1</sup>

These basic elements are controllable in all three parameters and may be freely varied within the limitations of our compositional methods.

<sup>1</sup> Translator's Note: 'clicks' and 'beats' (cf. page 4) may be regarded as identical.

The ranges of modulation and filtered band widths are limited by the intervals of resolution of pitch levels and duration sequences.

So, all elements are heard as 'simple' tones of similar colour. They are differentiated only in the detail of their micro-time-structure.

The various ranges or line- and band-spectra of sounds, tone mixtures and noises as well as the limits of timbre permutation, as they are conceived for this work, are only defined by the simultaneous composition of these elements.

The selection and composition of material is one indivisible conception. Six scales were selected for the pitch level system. As in earlier works they represent the 'interval' relationships between elements, whether they be harmonic or melodic ratios, or those between sound and phones, sound groups or pitch 'regions'.

Harmonic, sub-harmonic and chromatic pitch scales and the combination of all three are used.

Thus we may understand why sung sequences of phones, in which the basic pitch levels have been varied according to their contexts, cannot be definitively registered by the singer on tape.

The system of pitch levels which is used requires mixture-scales which combine harmonic, sub-harmonic and chromatic pitch intervals and in which the steps of the scale must be clearly differentiated. These intervals cannot be sung precisely. The singer sings an approximation of the required pitch which is rectified only in the course of the actual montage work.

In *Studie II*, tempered pitch scales were used to delineate the area between tone mixtures and noises. The closeness of steps varied the degree of 'brightness', but not of course of 'colour', which results from the nature of the elements and the proportion of partials and intensities. This may be seen in the illustration of one page of the score of *Studie II*.

In the present composition the three scales of pitch-level and the three types of their combinations ensure, with regard not only to the spectral composition but also to harmony and melody, an adequate variety of line- and band-spectra. The interval ratio of harmonic, sub-harmonic, chromatic and combined interval scales are largely varied by the series of scales.

Additionally, the partial-tone structures of the sung phones are organically arranged within this interval continuum.

To ensure sufficient variability of the regions using elements simultaneously or in groups, up to six of these 'regions', each an octave in span, are utilized.

Differentiation of the intended permutation of timbres is obtained from the complexity resulting from the simultaneous combination of the six formant regions within one sound process, from the varying of the elements or groups of elements, in all their components, according to the series and of coordinating a special intervallic scale of partials or of medium frequency width ratios in each formant octave.

The methods by which we differentiate and select elements lead us to the following conclusions: our point of departure is always the structure of duration; all other functions of sound are derived from it. To illustrate this we will describe elements numbers 10 and 11: filtered periodic and statistic sequences of beats.

A sequence of 'clicks' at a periodic rate is determined by the number of clicks per second. The clicks are produced by a special generator. If a sequence at 20 Hertz in width is filtered at any pitch level – let us take for example 980/1,000 Hertz at a constant rate of for example every 1/10 second – we get a clear note of medium pitch between 980 and 1,000 Hertz with regular beats ten times a second.

If the rate of beat is gradually increased to exceed the 'time-constant' (*Einschwingzeit*) of the filter in use (this depends on the frequency) and the limits beyond which the ear can no longer differentiate, what started as a rhythmically repeated note becomes continuous. If, on the other hand, the rate of beat is reduced towards zero, the regular structure of the tones becomes increasingly more apparent. Single, isolated beats are better heard; the note is resolved into a sequence of individual tones of identical pitch and duration. In the present work, 20 beats per second is taken as the fastest speed.

These limits are selected for a good reason: if the beats become any faster, the frequency of beat is heard as a second pitch level rising up out of the bottom besides the filtered pitch. The element would then no longer be a 'simple' tone and, therefore, no longer an 'element' according to our basic premise.

The relationship between pitch and time structure, which has always been of particular interest to us, is here emphasised.

Similarly, we see a continuous transition between what may be called durational intervals which are characterised as rhythmic intervals, and durational intervals characterised as pitch levels. On the average, the transition from one to the other occurs at ca. 20 beats (or oscillations) per second and is continuous.

A spectrum is composed of rhythmically periodic tones of varying pitch levels, determined on the basis of the filtering mentioned above. Differentiated variants of it are effected by the various polyphonic microstructures of the chosen regularly pulsating elements. A further factor of the permutation is the variation of dynamic intensity.

In addition to these periodic tone forms we have the second, the 'statistic' type. Contrary to 'statistic' amplitude and frequency modulations, in which we are at present unable to determine technically the rate of phase of modulated or modulating frequency, we can here come nearer to the determining of the statistic interval rate in 'statistic' clicks. Individual clicks are isolated and ordered one next to the other according to the quantities assigned to them by the statistic permutation of rows. Every interval is exactly calculated. When the sequence of beats is filtered as previously, we obtain non-periodic, seemingly haphazard beats at the selected pitch levels. We may perceive the differentiations in these 'statistic' rhythmic element-structures only when further variants and average speed (obtained by the alteration of the smallest interval of the series of durations) are permuted. The spectra resulting from the combinations of these elements are once more characteristic.

If, as in the previous example, these 'statistic' sequences of intervallic beats pass the threshold for the differentiation of pitch levels (by the average speed of the clicks' exceeding 20 per second) we hear a noise outside the filtered pitch level. The noise becomes proportionally lighter as the average speed of the clicks is increased. But the determination of its pitch levels must be approximate and is only possible in the form of a 'statistical' average.

Thus we define 'noises' in general as resulting from 'statistic' polyphonic time structures of sounding elements:

*Tones:* resulting from periodic polyphonic time structures.

*Elements:* 'simple tones' as periodic linear time structures.

*Sounds:* is taken as a collective term; electronic sounds, instrumental sounds, speech sound (phones), sounds in general.

'Tones' and 'noises' are *spectra*. They may be harmonic, non-harmonic, sub-harmonic, chromatic, combined, statistic, etc.

Each of these basic elements is structured in the way shown above.

Six different types of scale are used for the intensities as for the pitch levels.

At this time it might be better to discuss in some detail the problem of loudness levels without demonstrating the way in which the conclusions have been utilised in the composition in progress.

By loudness levels we mean the perception of quanta of sound energy. If the quanta are increased we say it is louder and *vice versa*.

We do not regard loudness level as an independent dimension: intervals of duration between sound perceptions can surely not be effected if they are not 'loud'. We perceive time in the intervals between the registering of sound quanta.

We have found out empirically the relationships between durations and intensities. If two tones of equal duration have different loudness levels, the 'louder' is perceived as 'longer', the 'softer' as 'shorter'. Every musician knows this intuitively, when he quite unconsciously allows a shorter duration for louder than for softer notes, in order to obtain the effect of regularity. Is the reason for this that the louder ones are retained by the memory longer? Or do the air columns vibrate for a longer period when the intensity is increased? The musician is not concerned with 'why': he measures with a perception, not with a ruler – as long as he plays and listens. If the quanta he perceives are not borne out by the watch or the rule, then the technical measurements are wrong; this only proves that an abstract idea of quantities has been formed, and watches and metronomes have been set according to it.

In electronic music, however, we no longer 'play' the music according to our perception. Technical ways of measurement stand between us and our musical material. We have to give a decibel or cm. p.s. measurement in order to determine the loudness and length of a required note. We must indicate the number of oscillations per second, in order to determine how 'high' the note is to sound.

Thus a conscious realisation is forced upon us of what previously has been practised as being obvious. Our invention has to be expressed in terms of technical quantities and there are good motives for this being so.

As we have said above, two notes of equal duration (according to the stop-watch) are only perceived as being of 'equal length' when they are of 'equal loudness'. Our experiments with elements 10 and 11 have done much to clarify this. If we gradually reduce the amplitude of tones pulsating periodically at say, 10 Hertz (filtered clicks, not, of course, sinus tones of 10 Hertz) we perceive it as becoming increasingly more 'continuous': the individually perceived quanta are gradually mingled one with another and they, as it were, dissolve into each other; finally, its character is so vague that it can no longer be differentiated at all and the feeling of duration of the individual beat is levelled out and disappears. The same happens with amplitude-modulated tones. On the other hand, if we make the pulsating notes louder, our time perception becomes more distinct.



It is simpler to differentiate the single element: each separate one seems 'shorter'; the durational intervals may be exactly perceived.

This has always been apparent in musical practice, but until now there has been no need for an explanation of it. If a piece of music is played at a fixed tempo and if sequences of equal values are to be executed softly and loudly, the soft one becomes less clear and its shape is lost. The perception of time disappears in the individual interval and only a vague 'fluctuating' movement remains.

This is, of course, obvious; let the reader imagine a piece of shadowy character where the feeling for articulated detail is lost; 'time is forgotten'; and it is to be played forte; misterioso in fortissimo . . .

We do not maintain that pitch levels or intensities are illusory and that everything is time. That would be a levelling out of qualities of perception which have been developed and formulated from the sea of quantities. We are, however, concerned with compositional consequences resulting from a realisation of certain relationships: the realisation that rhythm may be projected into a perception of pitch or timbre, that the perception of time is dependent on intensities, that technically measured durations do not correspond to perceptions of them where various intensities are juxtaposed, that a timbre does not remain the same if its intensity or the frequency of a partial is altered, that . . . that . . .

We aim not at an equating but at a further differentiation.

Some human beings have the remarkable faculty of being able to co-ordinate time quanta with perceptual qualities and being able to say, 'that is an  $a^1$ ' without having to think or make a calculation in time: 440 periodic vibrations per second equals pitch  $a^1$ . Nor need anybody think, when the pitch is altered, that the procedure must be altered in time, that 660 vibrations instead of 440 per second must be generated in order to make an  $e^2$ .

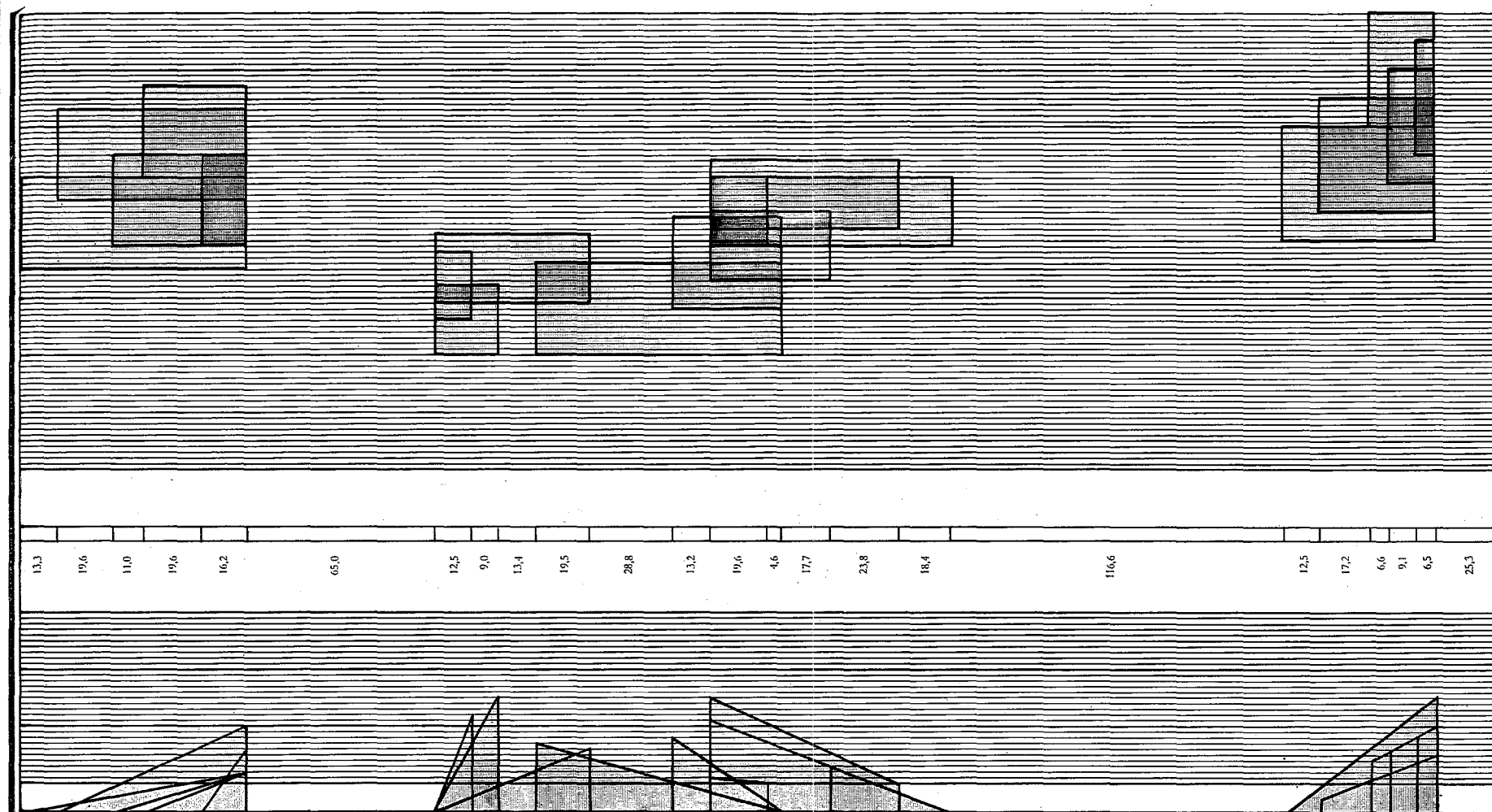
Is it not equally surprising when somebody says: 'That car is going at 50 m.p.h., that other one at 70'? Is not the same faculty called for here of associating individual variations of time with general conceptions of speed, tone, colour and in the film, frame?

Some of this cannot be found in books. More than ever before we have to listen, every day of our lives. We draw conclusions by making tests on ourselves. Whether they are valid for others only our music can show.

A further principle, the most important of all, is revealed to us when we consider the way in which all properties of sound procedure are to be extracted from the structure in time.

Explanation of illustration on facing page:

The frequencies are drawn along the top of the score. The line spacing corresponds to the interval  $\sqrt[25]{5}$  from 100 to 17,200 c.p.s. As each note mixture contains five frequencies with constant intervals, only the highest and lowest intervals are indicated by horizontal lines joined at the beginning and end by vertical lines, the enclosed space being shaded. (Only three appear on this page.) The three remaining frequencies between the highest and lowest are ascertained by dividing the enclosed space into 4 equal intervals following the vertical lines. In the lower system, envelopes varying between a constant step height from -30 dB to 0 dB are notated. Each tone mixture has its corresponding envelope. The duration is indicated in cm, at 76.2 cm. per second on lengths of tape. If the relationships of partials are closer, the tone mixtures are perceived as darker and *vice versa*. This cannot be seen on the notation as this would involve shading wider regions lighter and narrower regions darker. But a further variation of the density by overlapping of tone mixtures can be seen in the notation of the various degrees of shading.



KARLHEINZ STOCKHAUSEN,

Studie II: a page from the score published by Universal Edition (for details see facing page).

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The elements which we have chosen do not amount to more than neutral material; they are differentiated only because of the different ways in which they have been selected. It is, however, possible for the composer to make structures as he wishes or imagines them, from these elements, which may be related to the overall structure, the plan of the whole work.

Thus one comprehensive idea of working suffices to provide the elementary micro-structure as well as the macrostructure of a composition. The meaninglessness of the elements themselves is dispelled and they gather a specific musical importance. A sound which results from a certain mode of structure has therefore no relevance outside the particular composition for which it has been intended. For this reason the same 'prepared' element, the same sound or the same 'object' can never be utilised in different compositions, and all sounds which have been created according to the structural pattern of one composition are destroyed when the composition is completed.

A prototype is created and, in the actual assembling of the composition, is copied wherever the original sound or a further variant of it is required. When the work is completed these prototypes become useless and are destroyed.

We are of the opinion that the basic conception of our work can become the central idea of electronic composition. Against doubt and hostility we will hold fast to the idea 'that the structure of a work and its material are one and the same thing'.

The polyphonic idea of structure in our present work demands a corresponding spatial projection.

Sextuple stereophonic sound is used. There are six loudspeakers or groups of loudspeakers (according to the dimensions of the auditorium). They are placed around and above the listeners; in this way the listeners are, as it were, enclosed within the sound polyphony of the composition.

The original purpose of electronic music was for radio transmission. In this we have anticipated the technique of stereophonic radio sound. For the time being a version has been arranged for transmission on single channel radio.

Up to now all electronic compositions have been composed for transmission over a single loudspeaker. For this reason concert performance in large auditoria has been quite necessarily unsatisfactory whereas transmission has been adequate.

In our present work we have to show whether this, the first stereophonically conceived work in total structure, will lead to a new, active art form of musical composition and listening.

By regulating the positions of the sources of sound it will be possible for the first time to appreciate aesthetically the universal realisation of our integral serial technique.



## STUDIO TECHNIQUE

GOTTFRIED MICHAEL KOENIG

Electronic music comes into existence at the intersecting point of two tendencies: a technical and a musical. Even 50 years ago experiments were made to produce music by electrical means and later electronic concert instruments were invented. Of course, as long as the limits of traditional instruments presented no prohibitive resistance to the intentions of composition, it was impossible that the experiments in electronic sound production should have any influence on musical development.

Were it not in the nature of technique, taken independently of artistic considerations, to produce quantitatively, it would not concern itself with the exploration of possibilities for their own sake. Art, on the other hand, is qualitatively designed, aiming not at universal application, simplification or efficiency but at the most precise, most unique expression. The more differentiated this expression becomes, and the more it departs from traditional formal categories, the more it falls back on the language of the material itself. From this, music obtains a control principle which reflects our compositional situation, a principle of systems and statistics. The analyzed single event is understood as part of a group which is generated according to the same principle, in order to project this group structure into the totality of a finite form. Simultaneously, music discovers the developments of electro-acoustics, and technique, meanwhile improved, once again crosses the path of music whose structural propositions are scarcely any longer to be realised by traditional instruments. The sound material that compositional tendencies now have makes possible differentiation to the limits of audibility.

The progressive separation of partial events, the isolation of the single tone, the colour, and the rhythmic value, would reduce it to a unit of pitch, duration, and loudness, were not other composed relationships of this data available. If proportion is the structural principle it is limited by the musical instrument: the continuous traversing of the area between the extremes should be possible. Also it is necessary to compose the colour, and to continuously alter it. This is possible with electrical measuring instruments. A colour can be created from its elements, the overtones; dynamic values can be varied according to the requirements of the composer by means of volume control and level-indicator. Durations correspond to lengths of tape; the tape is cut with scissors. Because these manipulations follow a score and the measurements are so combined that they integrate the structural idea, obligatory for the complete piece, they lose their technical character, which is irrelevant compared with the formal intention.

Although the basic equipment of a studio, namely two tape-recorders, a control-panel, and a tone-generator already present the composer with a great number of possibilities, every score calls for a particular work plan for its realisation. The statistical nature of serial composition requires a rationalisation of production. The manifold quality of the music requires a corresponding complexity of electrical and recording technique. Since the diverse musical demands require corresponding technical

procedures, these procedures are not yet universal enough to be valid for the most extreme demands imaginable.

Rationalisation is not only the technical consequence of the artistic construction, but a matter of technical quality. The more the sound is subjected, once produced, to further processing, the worse its quality becomes. Accumulating a sound from several sinus tones already demands repeated copying; further processing makes it difficult to keep the copying noise within tolerable bounds. One solution for this problem can be provided by a thought-out plan of realisation, which translates the musical structure into a technical one. In doing so the necessity for simplification should not be enforced at the expense of the score. Appropriately the composer makes thorough inquiries in the studio in advance as to the working of the different instruments. Since he is used to taking into consideration the technical possibilities of the orchestral instruments, he will be able to organise an electronic score according to the given technical facilities. Technical quality could also be achieved by further improvement of the studio. If there are a sufficient number of frequency generators to hand it becomes possible to produce the component parts of a sound simultaneously, *i.e.* without copying. Apart from these, research should be made into mechanical or photo-electric automation, which could be controlled by some adequate notation. Then the composer could constantly give his ideas a supervisory hearing without wasting work or time. Directly, without any electromagnetic processing and storage, the final composition would be converted into sound that is technically immaculate.

A critical attitude to the working methods develops studio technique, quite apart from the musical demand. This results in either improved or entirely new methods. Some of these are used for processes for which they were not conceived. The continuous tape loop, for example, originally designed for controlling or repeating shorter events, was later used for the production of sounds. Now it is used for accumulating whole sections of the score. The fact that the drive motors of the tape recorders run at a regular speed can be utilized in a rational manner. The irregularities of this speed, which can produce noticeable inaccuracies, can be automatically adjusted. In principle any unanticipated deviation can be used consciously as a new means.

Many of these means, which were either thought up, tried out, or suddenly perceived, remain unexploited until they collide with a compositional idea. The realisation of electronic music is entirely conditioned by this dual musico-technical character. To consider both the realisation of a given score and the artistic application of technical structural methods pushes ahead both music and working methods. Thus the need to accumulate a sound from partial tones led to the invention of the tape loop, which then gave the idea of constructing complete structures with its aid. This loop moreover makes it possible to provide each partial tone with its own dynamic curve within a sound, the length of which is already fixed. In this way the electronic sound achieves a flexibility which the instrumental sound could never achieve. The buzzer (a difference-tone generator) is used to produce either single frequencies or glissandi, but is also used to control the drive motor of a transposing machine. An especially practical synchronisation device is to apparently shorten the tape loop in a constant ratio. If this ratio is made variable, entirely new conditions are created for the composition of music, particularly for shaping the precise state (growth, decay or steady state) of the tone, which modifies the colour; the only other procedure for modifying the colour is an electrical one: by

means of the cutting angle of the tape. There exist procedures whose application is limited to certain musical demands, just as it is imaginable to develop a piece of music exclusively within a single working method. Music and technique are so inter-related that only by a united effort can the artistic idea transcend the technical restrictions.

## STATISTIC AND PSYCHOLOGIC PROBLEMS OF SOUND

WERNER MEYER-EPPLER

### 1. *Aleatoric Modulation*

A process is said to be aleatoric (from Lat. *alea*=dice) if its course is determined in general but depends on chance in detail. Calculation of these procedures can be effected by statistical means. Musically, everything which is not 'written in the notes' is within the aleatoric sphere. In traditional music, the significance of statistical questions has been limited to the scientific investigation of the particular instrumental result attained by an individual performer by the almost imperceptible variations of relevant musical parameters, such as pitch, intensity, timbre and the duration of sound elements (16)<sup>1</sup>. It has been correctly pointed out that up to the present all technical endeavours to include these variations as a constructional element in the building of instruments, have gone astray. As an irrefutable example we may cite the case of the cinema organ.

At first appearance the critics seem to have all arguments on their side, but a closer examination persuades us that a general human inadequacy cannot be blamed on to a technical process. Fault is to be found not with the technical process but with the builder of the organ, who could think of nothing more enterprising than mechanical regular vibrato of amplitude or coupling of two pipes to produce beats. With the addition of one more pipe, he would have been able to replace the sweet penetrating sound of the cinema organ by a genuine 'choric effect'.<sup>2</sup>

Certainly the resultant oscillatory modulation which is valid in all three dimensions (pitch, intensity and timbre) is still far from corresponding to the aleatoric modulation resulting from the playing of a string instrument. Some of its characteristics do, however, approach strict aleatoric modulation. This approximation may be considerably extended by appropriate choice of frequency range and amplitude of oscillation in the three pipes. It would nevertheless be misleading to attribute the ugly effect of the regular vibrato to the technical 'perfection' of an instrument, thus attributing the bad taste of the instrument builder to the nature of the technique. The contrary is true: from a technical viewpoint instruments which correspond to an alleged public taste are primitive and it will be seen that real perfection will eventually lead to instruments which at the same time fulfil artistic requirements. The manufacturer is not to be excused on the grounds that a greater degree of creative effort is demanded in order to find better solutions.

Certainly it is in no way a simple task to effect a strict aleatoric modulation on a mechanical basis with mechanical instruments. But it is impossible to discover why the builders of electronic musical instruments insist on retaining the unbearable vibrato of the cinema organ. It would require no additional technical expenditure to replace the

<sup>1</sup> These numbers refer to the Bibliography at the end of the article.

<sup>2</sup> The choric effect (swell on the great organ) may be described in terms of physics as a combined frequency and amplitude modulation of internally independent spectral regions leading to an increased fusion of sounds.

sinusoidal modulation by an aleatoric oscillation. Completely adequate for this would be a noise signal limited by filtering to its aesthetically most effective region around 6 c.p.s. Apart from several patents registered in the Patent Office (*e.g.* 7) I have nowhere found any evidence of this kind of modulation. The composer, however, who wishes to work with electronic means is not bound to look for an instrument manufacturer who is prepared to build an aleatoric amplitude or frequency modulator into his generators. In a studio he can produce these modulations for himself, and is thus enabled to experiment on the dependence of sound effect on the average frequency, the band width and the r.m.s. amplitude of the modulating aleatoric oscillation.

One requires a sound generator operating within a frequency region of up to c.100 c.p.s. (heterodyne generator) (1), together with a band-pass filter whose pass range does not exceed 10 c.p.s. In this way an aleatoric oscillation is obtained where the average instantaneous frequency lies at the centre of the transmission range of the filter, and where the amplitude oscillates aleatorically with an average instantaneous frequency equal to half the band width of the filter. With a band-pass filter with a free transmission range of from 5 to 15 c.p.s., the average instantaneous frequency of the aleatoric oscillation is at 10 c.p.s., the average oscillatory frequency at 5 c.p.s.

The aleatoric oscillation enables us to modulate a periodic carrier oscillation, *e.g.* a sinusoidal oscillation. If  $A(t)$  is the filtered aleatoric oscillation and  $\sin 2\pi \nu t$  is the sinusoidal oscillation, ( $\nu$  is the instantaneous frequency of the oscillation in this formula), the following modulation forms may be distinguished:

- (i) Modulation of amplitude:  $A(t) \cdot \sin 2\pi \nu t$ ;
- (ii) Frequency or phase modulation:  $\sin (2\pi \nu t - A(t))$ .

These two types of modulation may also appear simultaneously.

For the realisation of the modulation we require in (i) a modulator, in (ii) a controllable delay-line in so far as the oscillation generator's frequency cannot be directly affected through a reactance tube (*i.e.* a tube operating electrically as a capacity or self-induction). For example, a stepwise controllable delay-line is to be found in the vibrato arrangement of the Hammond organ. Oscillator controls with reactance tubes are described by Flanagan (4) and Weber (14). They contain a pentode as a controllable frequency selecting element.

A timbre modulation may be obtained by means of a controllable filter, *e.g.* of the RC- or RL-type. E. E. Schneider (10) describes this type of filter and the way in which it works. If a transposing filter is utilised the pass band is controlled in the simplest way by a phase-shift generator (6).

The composer who disposes of the possibilities of aleatoric modulation will be surprised to discover that this kind of modulation leads him directly into a world of phenomena, previously described as 'noises'. By broadening the frequency range of the modulating oscillation and increasing the r.m.s. amplitude the resultant sound becomes more similar to a noise, *i.e.* a sound whose exact pitch cannot be determined.

These few observations clarify the fact that aleatoric sound procedures need not necessarily produce aleatoric (*i.e.* non-predictable) sensations. For this it is essential that the frequency range of the applied aleatoric modulation be selected in such a way

that the oscillation of amplitude and frequency may not be perceived as dynamic or pitch alterations. Gliding up and down of the tone when the frequency is modulated stops for modulating frequencies of above 7 c.p.s. according to examinations made by Stevens and Davis (11). It does not, however, follow from this that a pitch movement is to be observed in all cases of frequency modulation below this level. For this purpose, as G. W. Stewart has shown with reference to the uncertainty relation of the conjugated variables duration and frequency, a frequency swing is required (*i.e.* a variation upwards and downwards of the carrier frequency) of a size as great as that of the modulation frequency. For a frequency modulation with pitch-level oscillation of 3 c.p.s. to become audible, a carrier frequency of *e.g.* 440 c.p.s. (*a'*) must oscillate at a rate of at least three times per sec. between 437 and 443 c.p.s. If for aleatoric modulation of amplitude and frequency a frequency range (defined by the middle of a narrow noise frequency band) of below 7 c.p.s. and for frequency modulation the corresponding frequency swing stipulated by Stewart (half the width of the noise frequency band) is selected, the unsystematic course of the modulating function becomes perceptible, *i.e.* the dynamic or pitch structure of the music becomes to a greater or lesser extent aleatoric. A procedure of this kind can attract the composer, and cases are known where aleatoric characteristics have been introduced (by mathematical, not by technical means) into the structure of the composition (J. Cage).

## 2. Analysis of Compositions by Methods of Information Theory

Apart from the application of statistical methods by composers as described above, other statistical methods are utilised in analysing musical compositions. Here it is a matter of examining musical creations with the mathematical means provided by statistical information theory. One assumes as a premise that music, just as language, is made up of defined or at least definable single elements which can be nominated and described, *i.e.* it does not form a structureless continuum. It is hardly necessary to recall that the sum of these elements does not result in the music, no more than component syllables form a poem. Nevertheless, it seems that by concentrating only on the 'semantic' aspects of music and by the elimination of all the emotional-aesthetic qualities, interesting aspects of musical structure may be discovered which cannot be found out by any other means (13). In this way special criteria of form are added to older ones, which are designed for the examination of latent work methods of the compositional process.

Formal criteria of various orders may be determined. The first order contains all observations concerning the statistical distribution of the sound elements themselves without reference to any mutual relations.<sup>1</sup> The second order ('Markoff chains') and all higher orders take into account, in examination, the frequency of transfer from one element to another or between further distant elements, and their contextual relationships; considerable mathematical problems arise from these examinations. As a characteristic which serves as a form criterion of the first or higher orders, information entropy may be derived from an observation of the rate of appearance of elements or

<sup>1</sup> We consider, for example, in statistical terminology the 'mean' or 'average' pitch level (respectively value, intensity, spectral density, speed, etc.) of the composition and the absolute or relative distribution of the appropriate characteristics around this average value. The adoption of an averaging interval, *i.e.* the time region over which averaging is extended, is essential for the comparison of values; for a piece of music is not strictly stationary in the statistic sense and so not liable to come under the application of the ergodic hypothesis.

groups of elements.<sup>1</sup> Up to the present, mathematical results exist only for literary works (5) but there is no reason why the same procedures should not be applied to musical compositions.

### 3. Structural Characteristics of Valency Regions

Though a specific statistical structure may be ascertained in a musical composition from an examination of the score, it is by no means certain that this structure, conceived at an intellectual level, is automatically transferred into sound. There are no relationships between acoustical stimuli which may be derived from the score and the corresponding sensations of sound which would permit us to consider these sensations as some kind of 'mapping' of stimuli within the physiologico-psychological range. To clarify the details of these fairly complicated relationships we are compelled to adopt a special notation for that property of an acoustical stimulus which determines the similarity or disparity of a sensation. With reference to the terminology customarily used in physiological optics, we will call this quality the valency of the stimulus (9).

These valencies may be represented in a multi-dimensional space. The components of the valencies, *e.g.* frequencies, time- and place-co-ordinates act as 'co-ordinates' of this space. In an abstract valency space of this type every sensation indicates a place of sensation. In opposition to what one might conjecture these places of sensation are not distributed arbitrarily close together but are separated from each other by different limina.<sup>2</sup> The resulting cellular structure is the metric field of the valencies.

Strictly speaking it is not constant but depends on the velocity of alteration of the stimuli. Sounds, for example, carry their metric field over a large area with them. They are only differentiable when they follow each other in close sequence. This phenomenon is known as conversion. Where the stimuli are presented in an isolated form the valency locations can only be roughly differentiated. The network is narrowed, as the number of stimuli per time unit is increased but at the same time it shrinks together.

All alterations of stimuli are rendered ineffective by the cellular structure of the valency-region if they are smaller than the difference limina at the appropriate velocity of alteration of the stimuli. It is not possible to effect an arbitrarily narrow scale either for pitch level or for intensity. Thus, for example, at a volume of 80 phons (*forte*), at a moderately fast rate of succession, we are unable to distinguish more than about 200 pitch levels in the whole sound area. We obtain similar limitations in examining the temporal sequence of compositional elements. Within a time interval of some milli-

<sup>1</sup> If  $p_i$  is the frequency of occurrence of the element 'i' in the work to be analyzed, the first-order information-entropy is defined as:—

$$H_1 = - \sum_i p_i \log_2 p_i$$

which may be applied to the total inventory of different elements. In the second order, the frequencies  $p_i$  are replaced by the joint frequencies  $p(i,j)$  which indicate the occurrence of the pair of elements 'ij'. Thus the second-order information-entropy is

$$H_2 = - \sum_i \sum_j p(i,j) \log_2 p(i,j)$$

<sup>2</sup> The idea of a metric field may be illustrated by an example from phonetics. Vowels are, as is well known, characterised by two formant regions each of a width of 300 c.p.s. Tests enable one to establish how many c.p.s. are equal to shift the middles of the formant regions to effect a noticeable alteration of vowel colour. M. Joos found that frequency alterations of approximately a semi-tone are necessary (8). The metrical field of vowel timbres then resembles honeycombs with diameters of approximately one whole tone.

seconds the sequence of notes may be interchanged without affecting the perception of the sound. The acoustical stimuli in this case associated to the notes are called 'conditionally equal'; the indifferentiable sensations are called 'metameric'.

Metamerism is a phenomenon which may be generally observed in the world of auditory perception.

Filtered noise offers us a simple example of metamerism. Although this noise presents a quite different oscillographic picture at different times (as all aleatoric procedures should) the sound perception is unaffected by these alterations in the oscillation image.

Finally, it is to be emphasised that sound elements which are juxtaposed in time can have the effect that identical physical vibration procedures give rise to totally different sensations. The phenomenon has been particularly observed in the case of synthetic explosive sounds such as 'p', 't', 'k' which may be perceived in a totally different manner, depending on the vowels which are juxtaposed to them (3). To explain this one cannot attribute it to masking which has already been known for a long time because the influencing is effected by the following vowel (regressive dissimilation) as well as by the proceeding. At this point it may be mentioned that practically all statements about timbre have been effected by means of phonetic methods applied to spoken sounds. Contrary to instrumental timbres, vowel timbres have the particular advantage that they may be recognised by untrained hearers thus making it possible to describe precisely even small alterations.

### 4. Pitch Loudness Level

The newcomer to physio-psychological acoustics will be stupefied when the results of experiments show him that a note does not remain a note, and a sound not a sound of unalterable perceptible qualities, if alterations are effected in one of its valency dimensions, which at first glance would appear insignificant. Thus, for example, he cannot fully realise that a pure tone (physically — a sinusoidal sound signal) alters in pitch, if the amplitude is enlarged or diminished, where the frequency is constant. He will be equally amazed to learn that this phenomenon has nothing to do with the sound generating instrument and thus cannot result from a technical inadequacy, but is in fact a property of the human ear (the cochlea). Only after detailed study and experiments of one's own can one realise the fact known to acousticians, that the loudness level of a sinus tone of constant amplitude will alter by many orders of magnitude if the frequency is altered, and that the amount of alteration depends largely on the sound pressure amplitude chosen.

In returning to sounds, complex tones and noises, one will be discouraged by the multitude of occurring events (11). For example, it will be discovered that the loudness level of a complex tone cannot be calculated from the levels or at least the sound-pressure amplitudes of its components by any known mathematical means but that strange physico-psychological relationships intervene in the form of the Sone-curve. If the resultant loudness level is correctly determined, a new difficulty arises: it does not follow from the explanation of the loudness level whether certain components of the complex tone do at all contribute to the compound sound resultant; they sometimes are rendered imperceptible by masking.

### 5. Triple Pitch Quality

Research into electric methods of sound and noise generation has revealed a great number of perceptive phenomena which can only be discovered in traditional instrumental sound, where the ear has been prepared for it by electro-acoustic experiments. This is similar to the impression received from exotic languages; when one hears them for the first time one can hardly observe their phonetic characteristics. Only by concentrated study can one teach one's ear to distinguish the unaccustomed sounds and sound combinations.

One of the most significant discoveries for the composer in the sphere of sound perception is the triple pitch level quality. Every musician is aware of the fact that a note has a double quality, the one – its absolute pitch, running parallel to the frequency, the other – the chroma, a quality which recurs cyclically within each octave (only for frequencies of up to c. 4500 c.p.s.). It sounds obvious if we say that we hear a note *a'* if the fundamental of the frequency is 440 c.p.s. But what happens if we remove this fundamental by electrical means, leaving only the harmonics with frequencies of 880, 1320, 1760 c.p.s., etc.? Or if we take away the fundamental 440 c.p.s. and second harmonic 880 c.p.s.? We learn from experiments that the perceived pitch level remains the same: *a'*. One may take away many of the lower harmonics without altering this. If this 'mutilated' note is interrupted for only an interval of a second, the sensation is completely altered. Instead of the 'residual tone' on *a'* we now hear another pitch which lies approximately in the region of the strongest remaining harmonics and is called 'formant pitch'. With some practice one can hear the residual pitch and the formant pitch simultaneously, recognising their unmistakable varied qualities. Both pitch sensations are independent of one another and so, although it may sound paradoxical, a one-voice sequence of notes takes on the character of a two-voice line through the counter movements of residual and formant pitch. Sequences of notes may be generated in which even the experienced listener will not be able to tell whether the sequence rises or falls. The singular effect of certain carillons depends on this conflict between residual and formant tones.

Without going into the far-reaching consequences of a triple pitch quality of the theory of the mechanics of hearing, I merely wish at this point to emphasise that at this stage of our research the significance of the form of oscillation apart from the spectral structure of the musical sound signal becomes clear. If a stationary sound signal is supplied with a periodic envelope, under certain conditions the frequency of this envelope will become audible as a residual tone. This casts a new light on the problems of rhythmic formation, in that this may without effort be considered as the continuation of the pitch phenomenon in the lowest frequencies.

The timbre of notes with so called 'gliding formants' belongs to this order of problems. That a sound, whose spectrum lacks the even harmonics is known as 'a hollow sound' (e.g. the clarinet), quite independently of the actual pitch of the fundamental, ought to have to do with the form of oscillation rather than with the structure of the spectrum. Similarly with sounds which, for example, lack all harmonics divisible by 3 or 5. They also have properties which remain invariable although the frequency of the fundamental note is altered; we still lack a suitable notation for their sound characteristics. Examination of spectra of this type has been limited to the period in which one has been able to work with electric sound generators.

### 6. The Psychological Effect of Infra Sound

H. Burris-Meyer of the Stevens Institute of Technology in Hoboken has demonstrated that listeners may perceive rhythmically sound oscillations which lie below the lowest frequency threshold (i.e. below 16 c.p.s.). In a play 'The Emperor Jones' infra-acoustical sound beats were generated behind the stage by means of a super-dimensional 'electronic drum' which carried a significant intensity when the rhythm was tense. Despite the fact that the actor could hear nothing of this drum rhythm he soon began to synchronise his spoken part with the acoustically imperceptible drum beats. Thus sound, i.e. vibrations, may generate a physical effect even if they lie outside the perception area. It should not be necessary to demonstrate the consequences of this psychological discovery for electronic music.

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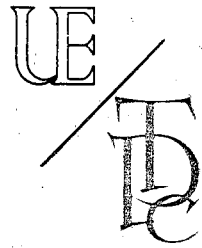
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