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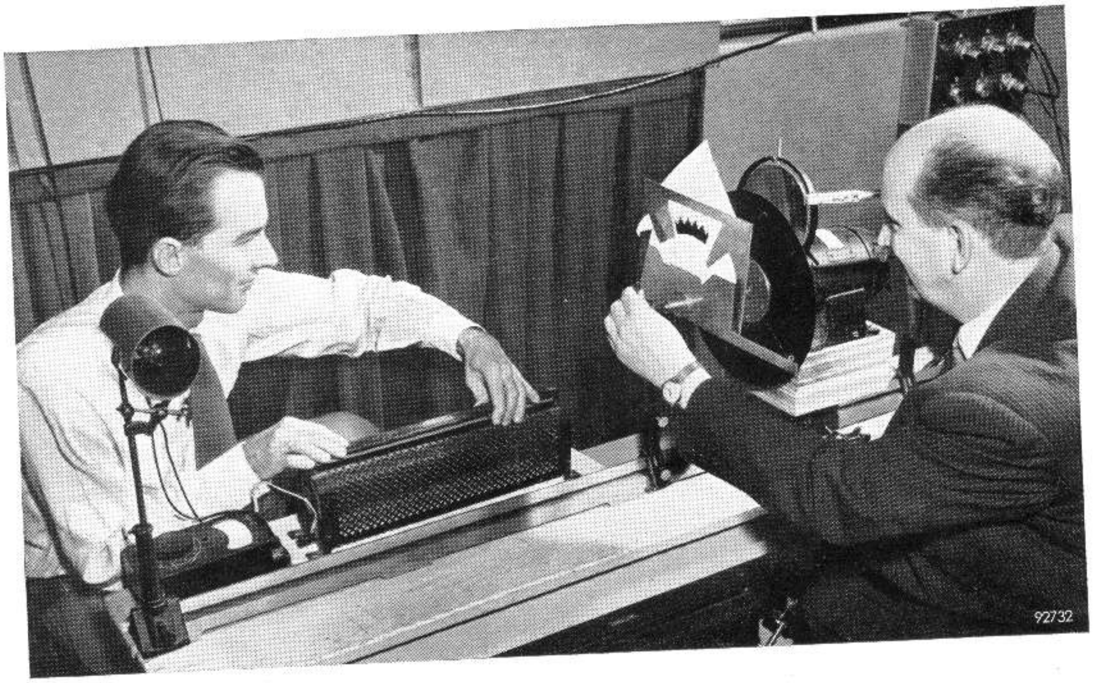

ELECTRONIC MUSIC

by H. BADINGS *) and J. W. de BRUYN.

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*The term "electronic music" is sometimes used when compositions, written for conventional musical instruments, are performed with the aid of electronic devices such as the Hammond organ, the "Ondes Martenot" or electronic music synthesizers **). In recent years, however, the term has come to mean something quite different, being applied to music whose actual composition is based on the use of electronic aids, especially of magnetic recording. These aids can be so employed as to produce entirely new sounds, of which neither the Hammond organ nor any conventional instrument would be capable.*

One of the leading figures in this new field of electronic music is the Dutch composer Henk Badings. His radiophonic opera "Orestes", in which electronic aids play a substantial part, was awarded the Prix Italia in 1954 and has since received more than 200 performances. In his ballet music "Cain and Abel" — which had its first public performance in May 1956 at The Hague — he makes almost exclusive use of electronic aids. Badings' decision to undertake such an experiment evidently owes much to the fact that, having studied engineering at Delft, he has always been keenly interested in technological problems, particularly in those of an acoustical nature.

The fairly extensive range of electronic instruments required to produce "Cain and Abel" was placed at Badings' disposal by Philips Research Laboratories in Eindhoven. It washere that the score was realized jointly by the composer and the co-author of the present article and recorded for performance on magnetic tape. This article gives a description of the electronic aids employed. By way of illustration to the text, a gramophone record giving a selection of the sounds produced is included in this number of the Review. The record also gives a shortened version of the ballet music itself.

In view of the aversion to dogma and the passion for "development" and innovation that characterize Western civilization in our century, no one will be surprised to hear new notes being struck in contemporary music — literally and figuratively. The element of novelty in this connection has two aspects. There is in modern music, just as in modern poetry and art, a perceptible tendency to break with tradition and to shun classical forms of expression and aesthetic laws. On the other hand — and in this respect music might be likened to architecture, with which it has, in fact, frequently been compared — the work of contemporary composers reveals a direct connection with the most conspicuous element of our civilization — technological development. Several composers are at present making use of modern technical equipment in an endeavour to widen the scope of musical expression.

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) For the Hammond organ and similar electronic musical instruments, see: A. Douglas, The electronic musical instrument manual, Pitman & Sons, London 1957 (3rd ed.). For music synthesis, see H. F. Olson and H. Belar, Electronic music synthesizer, J. Acoust. Soc. Amer. **27, 595-612, 1955.

Fig. 1. Part of the equipment employed in the Philips Research Laboratories for making the electronic ballet music "Cain and Abel". On the table are some of the seven magnetic tape recorders used (sometimes five at a time). Also to be seen are a number of amplifiers, a mixing desk, filters, metronomes, various electronic sound-sources, loudspeakers, etc.

This is not the place to go into the evolution of the latter type of music. Those who wish to know more about the subject can find information in various books and published articles [1]). It will be enough to note here that the different trends of composition that can at present be distinguished all agree on one essential point: they invariably employ *electronic* means, and in particular *magnetic recording*, for transforming the sounds and moulding them into something entirely new and unique. All these trends will be referred to by the collective term "Electronic Music" [2]). The differences of view between the protagonists of the various trends, some of whom, curiously enough, have brought a new dogma into being, we can only touch upon in passing. Schaeffer in France wants the composer's material to be derived from "concrete" sounds, as for example a steam whistle, a clap of thunder, a dripping gutter, and so on, and he declares all traditional musical conventions taboo ("Musique Concrète"). The "Studio des Kölner Rundfunks", where Eimert and Stockhausen are at work, wants to admit only synthetic sounds produced electronically; this school of thought also seeks to avoid traditional musical elements such as melody, rhythm and harmony, and favours the twelve-note technique introduced by Schönberg in about 1924. Among the composers active in this field in other countries may be mentioned Varèse, Luening and Ussachewsky in the United States, Maderna and Berio in Italy, and in the Netherlands Badings (radiophonic opera "Orestes", Prix Italia 1954; ballet music "Cain and Abel"; film music "The Flying Dutchman") and De Leeuw (radiophonic oratorium "Job", Prix Italia 1956). The less dogmatic attitude of these composers appears from the fact that they sometimes, as in the radiophonic works mentioned, use electronic means in combination with, or only as complementary to, traditional musical instruments.

In this article we shall be chiefly concerned with the technical aspects of Electronic Music. It is evident that the wider the range of electronic resources on which the composer can draw, the richer can be the creative development of this music. For the composition (and "performance") of the ballet music "Cain and Abel", which had its première in 1956, the composer drew on the equipment and cooperation of the Acoustics Group of the Philips Research Laboratories in Eindhoven. The principal apparatus (see *fig. 1*) employed in "Cain and Abel" are described in the following pages.

Examples of the sounds produced are given on the gramophone record appended to this article.

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[1]) P. Schaeffer, A la recherche d'une musique concrète, Ed. du Seuil, Paris 1952.
W. Meyer-Eppler, Elektrische Klangerzeugung, Dümmlers Verlag, Bonn 1949.
H. Badings and A. Brandon, Concrete, electronische en radiofonische muziek, Radio Electronica 4, 144-147 and 152, 1956 (No. 3). (In Dutch.)
F. K. Prieberg, Musik des technischen Zeitalters, Atlantis Verlag, Freiburg 1956.

[2]) The reader should be reminded that the term has been given various other definitions.

The index figures [..] in the text refer to these examples. The reader is recommended to read the article first and then to listen to the record while referring to the condensed explanatory notes given at the end of the article.

Technical aids to Electronic Music

Electronic engineering enters into the creation of Electronic Music in three ways: it provides new sources of sound, it makes it possible to manipulate and transform sounds, and finally it governs the reproduction of the music. For our purposes it will be convenient to begin at the end, that is to discuss the reproduction first.

Reproduction

The term "electronic reproduction" implies the re-creation via amplifiers and loudspeakers of sound originally created at another place or at another time. The appreciation of every type of "reproduction" is primarily determined by the criterion of its fidelity to the original. The familiar shortcomings of electronic reproduction in this respect (noise, distortion and the hole-in-the-wall effect[3])) have been eliminated to such an extent by improvements, for example, in electronic tubes and in recording methods (magnetic recording) and by the introduction of stereophonic techniques, that electronic reproduction can now be made almost indistinguishable from the original. Now that the odium of being a mere substitute need no longer attach to electronic reproduction via loudspeakers, more stress can be laid on the fact that such reproduction offers possibilities which are denied to the original (in this sense it would really be more appropriate to speak of electronic "production" than of "reproduction").

One such possibility resides in the unprecedented freedom with which the position of the sound source or sources can be arranged in a given space. This has been exploited — to give one example — by disposing loudspeakers around an auditorium and by feeding these loudspeakers with electronically delayed music in such a way as to improve the acoustics of the auditorium. This has been done both for "live" music[4]) and for the reproduction of recorded music (stereo reverberation). The composer might go a step further along these lines by not only arranging for different parts of the overall tonal pattern of his score to reach the listeners from different directions and distances — a generalization on the idea of the trumpeter behind the wings in "Fidelio" — but by also giving these parts a different spatial character. It is possible in this way to produce all transitions between the clear and dry directional sound of a trumpet in the open air and the diffuse, non-directional sound of choral music in a church. Something of the kind was in fact done in the performances of "Cain and Abel" at The Hague and Hannover.

Electronic reproduction offers another possibility of the utmost practical importance: in the electronic circuits of the apparatus, the music — or its component sound signals — is available in a form in which its strength (volume) can be controlled by the extremely simple expedient of turning a potentiometer knob. Volume control, and with it the mixing of different parts of a tonal pattern in any desired proportions, is a long-established practice in broadcasting studios. In the early days of broadcasting there was indeed some concern in the artistic world about the power given to the man at the mixing desk to alter the balance of a piece of music. If the mixing engineer has had a good musical training there need be no fear that he will misuse his powers, but from concern about a possible misuse it is only a small step to realize that in the hands of the composer these powers can be turned to useful account. With the volume control he can introduce dynamic figures in notes or combinations of notes where this would otherwise be impossible, as for example in a dying piano chord [1]. By a rapid movement of the volume control, he can deprive a note struck on a percussion instrument of its "attack", and in so doing give a pianoforte passage, for example, a quite unique character [2]. Moreover, there is now no longer a fixed relation between timbre and intensity, as was hitherto the case with many instruments: a whispered passage of a song can be made to sound above an orchestral tutti, although it still retains its "whispered" characteristics.

In the ballet music "Cain and Abel" repeated use is made of a dynamic figure in which the sound intensity is given a bell-shaped variation in time, i.e. it swells rapidly and immediately dies away again. This figure is produced by automatically varying the volume with a device referred to as a tone gate, the circuit of which is given in *fig. 2*; the duration of the bell-shaped variation it produces can be selected in five steps.

The electronic treatment and transformation of sounds

We have seen that in electronic reproduction the sound is at hand in a form in which it can easily be controlled in volume. When the sound is repro-

[3]) See e.g. R. Vermeulen, A comparison between reproduced and "live" music, Philips tech. Rev. **17**, 171-177, 1955/56.

[4]) R. Vermeulen, Stereo reverberation, Philips tech. Rev. **17**, 258-266, 1955/56.

duced via the medium of magnetic tape, an even greater measure of control is possible. Originally intended as a means of recording speech and music, for playback as and when required, magnetic tape provides the conductor or composer with remarkable possibilities: they now have the music literally at hand from second to second and can do with it whatever they wish. A good illustration and one that is of considerable practical importance, is the ability to cut out of the tape an unsuccessful passage of a recorded work and to insert in its place a better executed version. In recent years this

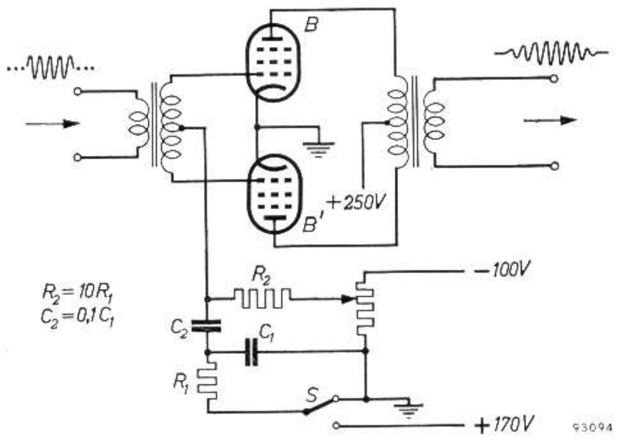

Fig. 2. Basic circuit diagram of the "tone gate". A signal, e.g. an alternating voltage of constant amplitude (constant sound intensity) is applied to the input of a push-pull amplifier with tubes B and B'. In the position of switch S as shown, the tubes are biased below cut-off by a voltage of about -90 V on the grid and no signal appears at the output. When switch S is thrown over, the grid bias, rapidly at first, goes more positive and rises above cut-off potential, whereupon (depending upon the charging of capacitors C_1 and C_2) it returns again to -90 V. During that time the amplifier gain rises gradually from zero to a certain value from which it at once gradually returns to zero, so that the input signal arrives at the output with its amplitude modulated in the shape of a bell. The width of this tone pulse (i.e. the duration of the tone or note) can be regulated in five steps by switching over to other values of capacitors C_1 and C_2. After returning the switch to its original position (whereupon the capacitors discharge very rapidly via diodes, not shown) the same process can be repeated.

practice (editing) has brought about a veritable revolution in the gramophone record industry [5]). But the composer can also exploit the same procedure in order to create new musical sounds: for instance, with each note of a percussion instrument he can remove the piece of tape on which the attack is recorded, thereby producing an effect which, though of the same nature as that described in the last paragraph, is yet quite different [3]. A very striking transformation is obtained by playing a piece of tape at a speed different from the recording speed [4]. The pitch, of course, changes proportionately, but at the same time an unusual tonal pattern is produced owing to the fact that the relative strength of all harmonics remains exactly the same, which is not generally the case when playing different notes on an instrument. Accelerating the tape also makes it possible to play extremely fast runs with a perfection that is quite beyond the reach of a flesh and blood instrumentalist. Continuously varying the tape speed results in a glissando which, when applied for example to notes played on a pianoforte, produces a most remarkable effect [5]. (This was done by using a tape recorder with a variable frequency power supply for the motor.) The tape can also be played in reverse: the notes of a pianoforte passage then swell up successively, each ending on the "attack" [6]. Another possibility with magnetic recording is to conserve the sound for a very short time on, for example, a rotating magnetic wheel, the sound being taken from the wheel by a number of playback heads and added in variable intensity to the signal being recorded or reproduced (*fig. 3a*). In this way a reverberation [7] is introduced, on the same principle as the method of stereo reverberation employed for improving the acoustics of an auditorium [4]). If the signal taken up by a playback head is fed back to the recording head with a longer delay and greater loop gain (fig. 3*b*), the result is a sound something like the familiar "motorboating" of an oscillator [8].

Magnetic tape is undoubtedly the most important aid to the creation of Electronic Music, not only because of the wide scope it offers for the transformation of sounds, but also because it was with this medium that it first became possible to register individual sounds, to transform them and then to put them together to form a unified whole — in other words, to "compose" them in the musical sense. We shall return presently to this procedure of composition and discuss its consequences from the artistic point of view.

The manipulation of magnetic tape is not the only method of transforming sounds. An obvious method is to use electrical networks, with which variable linear distortions can be effected ("shaping" of the frequency characteristic). A special case in point are *electrical filters* with passbands characterized by sharp or gradual cut-off, beyond which the sound is attenuated or even suppressed [9]. By this means a particular narrow range of frequencies in each note can be given a dominant significance (creation of formants).

Another sound-transforming device which was also used in the production of "Cain and Abel",

[5]) See e.g. J. L. Ooms, The recording and production of gramophone records, Philips tech. Rev. **17**, 101-109, 1955/56.

is the *modulator*, in the form familiar for example, in carrier-wave telephony [6]). This modulator has two equivalent pairs of input terminals; if two musical tones are applied to these terminals, both tones appear at the output together with all their combination tones (intermodulation products). Of these the difference tone (beat frequency) is the most prominent. If the one input signal is a musical chord and the other a purely sinusoidal vibration, the chord will appear at the output accompanied by a kind of shadow chord which is a constant frequency lower [10].

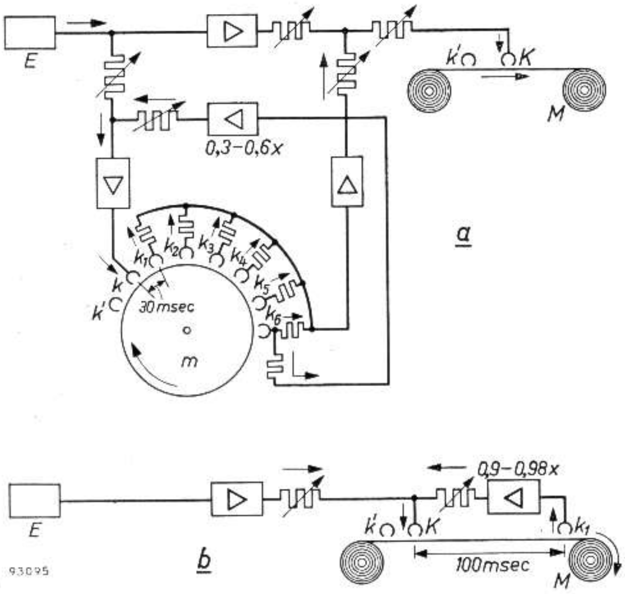

Fig. 3. Arrangements for introducing reverberation (*a*) and excessive feedback (*b*). *E* sound-source (this may be an amplifier if the sound-source is not electronic itself); *M* magnetic tape on which the result of the treatment is registered by recording-head *K*.
a) The signal is also registered by recording-head *k* on a magnetic layer around the rim of a drum *m* with erasing head *k'*; the signal on this layer is then picked up successively by a number of playback heads k_1-k_6, situated at progressively increasing distances from *k*. These signal components, delayed by 30 up to 180 milliseconds, and which are not separately distinguishable but together create the impression of reverberation, are fed, with the original signal, to *K*. In general, reverberation times much longer than 180 milliseconds are needed; to avoid using a very large number of heads for this purpose, the signal picked up by the last playback head k_6 is passed back to recording head *k* (loop gain 0.3 to 0.6×), resulting in six weaker components with delays up to 360 msec, followed by six more even weaker components with delays up to 540 msec, and so on.
b) A feedback loop is formed on the magnetic tape itself between playback head k_1 and recording head *K*, with a delay time of at least 100 msec, and an appreciably larger loop gain (0.9 to 0.98×); in this case the fed-back signal can be heard separately and sounds rather like the "motor-boating" of an oscillator.
With the reverberation equipment in (*a*) one feedback head is not enough, since the overall frequency response is not completely flat and hence the signal cannot be fed back too many times.

Electronic sound-sources

By the manipulation of magnetic tape quite new "sounds" (or rather, vibrations) are produced which can be made audible via a loudspeaker; they are effectively "original" sounds although they were never picked up by a microphone. Once we are familiar with this idea, it soon becomes obvious that we can dispense entirely with the primary sound that can be picked up by a microphone and, instead, apply directly to the loudspeaker such vibrations as can be produced by various electronic devices. A number of electronic sound-sources were used in the composition of "Cain and Abel", some of which have long been known and widely used, although chiefly for other purposes.

In this sense the Hammond organ and kindred instruments are also electronic sound-sources and the composer of "Electronic Music" could, if he wished, use them just as well as conventional musical instruments. When seeking for new tonal possibilities, with the aid (*inter alia*) of sound transformations, there is little point, however, in starting with a rather intricate instrument on which a great deal of effort has already been spent with the object — again by electronic means — of producing or imitating certain timbres of musical sounds. The sound-sources which we have used are therefore of a more elementary and less specialized nature.

From the physical point of view the simplest electronic sound-source conceivable is the *sine-wave generator* (commonly known as an audio signal generator). A loudspeaker connected to such an apparatus delivers an almost purely sinusoidal sound pressure, that is to say a tone practically devoid of harmonics, which strikes the ear as strange and ethereal [11]. The pitch of the tone can be continuously varied by simply turning the frequency control knob. By this method glissandi [12] can be produced at will, but its greatest virtue is that it offers a simple means of obtaining with great accuracy notes with various intervals, i.e. any desired scale. One can therefore deliberately depart from the narrow paths of the conventional equal temperament scale, which divides the octave into twelve equal intervals. In "Cain and Abel" repeated use is made of "pure" (harmonic) intervals, that is to say intervals exactly equal to the whole-numbered frequency ratios of the harmonic series. Although some of these intervals, used melodically, sound somewhat unusual, they are soon accepted by the ear as "good". We mention specially the use of intervals with ratios in which the numbers 7 and 11 appear, which have no counterpart in European music: they have hitherto been rejected since, although they blend perfectly in a chord of harmonically tuned notes, they are strongly dissonant with

[6]) See e.g. F. A. de Groot and P. J. den Haan, Modulators for carrier-telephony, Philips tech. Rev. 7, 83-91, 1942.

certain notes in the equal temperament scale (e.g. the seventh). (For this reason a pianoforte is designed so as to suppress as far as possible the "dissonant" seventh harmonic of the fundamental of each string.)

To achieve harmonic tuning — as, indeed, for many other purposes of checking — we made use of a cathode-ray oscilloscope. A harmonic interval produces on the oscilloscope screen a typical stationary Lissajous figure. This method does away with all the intonation difficulties that arise if an instrumentalist is asked to play, by ear, unusual intervals with the traditional continuously tunable sound-sources (the singing-voice, violin, etc.).

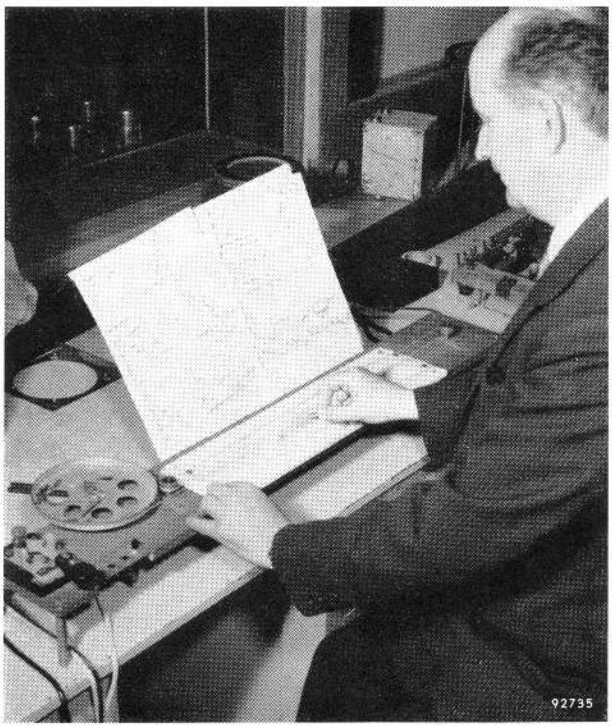

Fig. 4. The composer playing a multivibrator.

The counterpart of the sine-wave generator is another familiar electronic device, which is widely used, for example, in counter circuits — the *multivibrator*. This produces a sound which contains all harmonics of the fundamental up to the audio limit, the successive harmonics differing in intensity according to some slowly varying function. (The resulting signal, which may have a square or a sawtooth waveform, can also, of course, be modified by passing it through an electrical filter or shaper circuit.) Two versions of this sound-source were used in the composition of "Cain and Abel". The first, which has been given the name "baritone clavier", supplies a signal having an almost square waveform, the fundamental of which can be adjusted in pitch to a series of discrete frequencies by means of push-buttons [13]. With the second instrument the pitch of the fundamental can be varied continuously (making glissandi possible): in the low register the vibration approaches a square waveform, but in the high register it gradually assumes a sawtooth form [14].

A photograph and the circuit diagram of this multivibrator can be seen in *fig. 4* and 5.

For various parts of "Cain and Abel" use was also made of a *noise generator*. As a sound-source this device differs from all other known sources in that the sound it produces has a continuous instead of a line spectrum. Noise having a constant energy distribution over the entire spectrum of audible frequencies ("white noise") is musically not particularly interesting since there is nothing that can be varied except its intensity; nevertheless, with the aid of filters, it is possible to impose on the noise a somewhat vague impression of pitch. To do this we employed filters passing a frequency band of one or several octaves [15], or a third [16], these bands being capable of displacement in certain fixed steps.

In the electronic sound-sources mentioned above, the frequencies of the vibrations, with all their components, are determined by *electrical* elements. In another, rather hydrid, group of electronic sound-sources the frequencies (pitch and tone colour) are determined by *mechanical* means, although the vibrations only become acoustically effective through the medium of a loudspeaker. To this group belong two kinds of "electronic drums" and an "electronic clavichord", which were used for "Cain and Abel". The first drum was essentially just a large condenser microphone, the vibrations

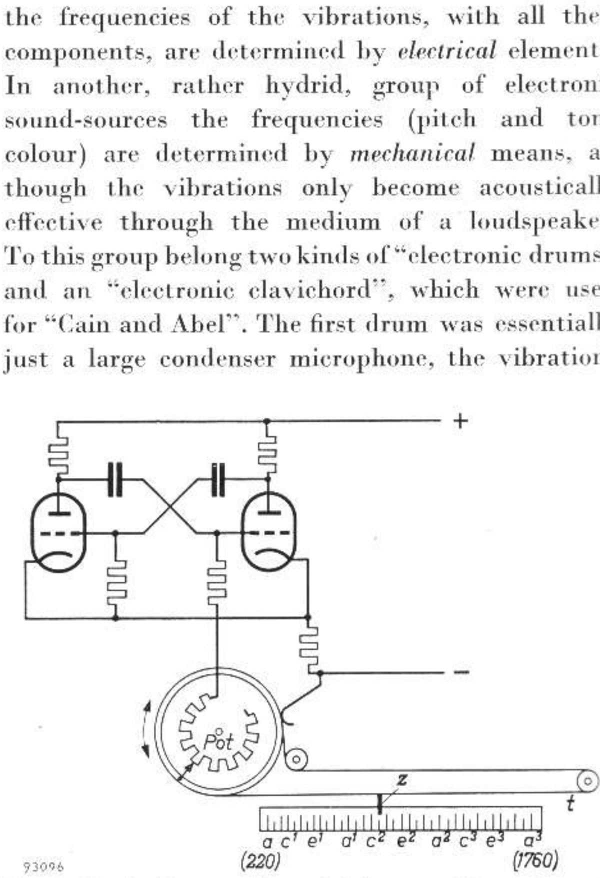

Fig. 5. Circuit diagram of a multivibrator with continuously variable pitch. The pitch is controlled by a potentiometer *Pot* whose sliding arm is fixed to a wheel; a cord and pulley system enables the musician to turn the wheel by moving a clip *z* along a scale calibrated in notes from *a* to a^3. By moving *z* rapidly to and fro a natural vibrato can be produced.

Fig. 6. The electronic clavichord.

being produced by taps or drum rolls on the diaphragm. The second consisted of a steel sheet whose vibrations were picked up at a specific position by a piezo-crystal; according to the part struck and the manner of damping the vibrations, a considerable variety of sounds could be produced [17]. A photograph of the "electronic clavichord" [18] is shown in *fig. 6* and a description of the device is given in the caption to *fig. 7*, which shows the circuit diagram.

The last to be mentioned of our range of electronic sound-sources is a particularly remarkable instrument which we call an *optical siren* [7]). In this device the pitch is determined mechanically, namely by the speed of a motor-driven disc, but the tone colour is produced by optical means, a pattern cut out in a sheet of paper being successively scanned by slits in the revolving disc placed in a beam of light, and the light-variations so produced being converted into electrical variations by a photo-electric cell (*fig. 8*). "Tone-colour melodies" created with this instrument are to be heard in several parts of "Cain and Abel" [19].

[7]) J. F. Schouten, Synthetic sound, Philips tech. Rev. 4, 167-173, 1939.

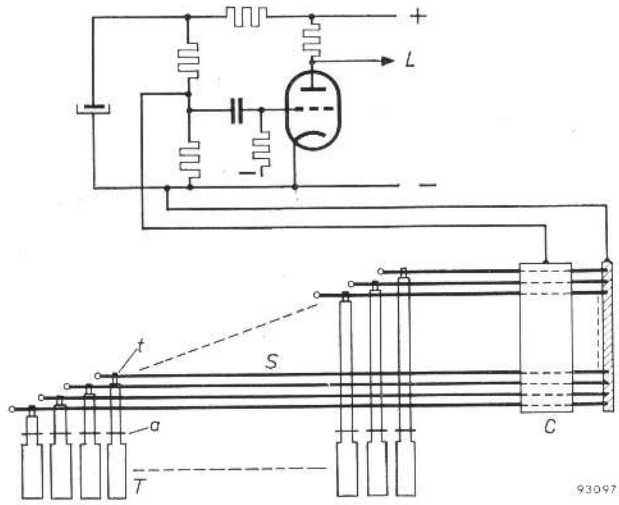

Fig. 7. Schematic representation of the electronic clavichord. The parallel single wires *S* of this instrument are made to vibrate in the same way as in a normal clavichord, i.e. with key-operated tangents (*t*; *T* are the keys and *a* their pivots) which, after being struck, also act as the endpoints of the respective strings. The strings as a whole constitute one electrode of a capacitor, the stiff plate *C* above the strings being the other electrode. This capacitor is incorporated in an amplifier circuit in exactly the same way as a condenser microphone. A loudspeaker can be connected either directly to the amplifier at *L*, or via various electronic devices.

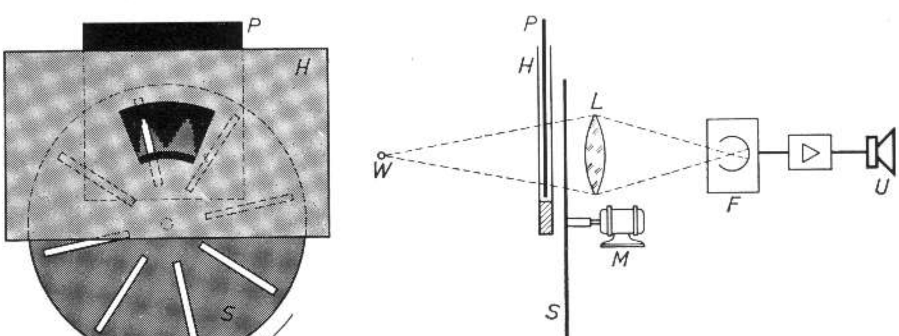

Fig. 8. Schematic representation of the optical siren (see photo on title page). A beam of light emitted by light-source *W* is concentrated on a photomultiplier tube *F* by a lens *L*. Situated in the beam is a holder *H* containing a sheet of paper *P* in which a waveform has been cut out, and behind which rotates a disc *S* driven by a motor *M*. As the disc rotates the pattern is successively scanned by narrow radial slits in the disc, and the light passing through the slit varies in accordance with the ordinate of the pattern. The photoelectric current in *F* varies in the same rhythm and is passed via an amplifier to the loudspeaker *U*.

A natural vibrato effect can be introduced by holding the sheet of paper in the hand instead of fixing it in the holder.

The composing and "performance" of electronic music

Outwardly the most striking difference between an "electronic" and a traditional composition is that the former cannot be performed by musicians in the presence of the public. The process of transforming sounds, for example by cutting and splicing, retarding, accelerating or reversing magnetic tape, excludes this possibility at once and leads to quite a different procedure. The composite sounds which the composer indicates at a given moment in his score — for example, a melody from the signal generator, an accompanying pianoforte figure, on which is to be superimposed rhythmical figures from the clavichord with accenting by an electronic drum — are each produced separately by a musically trained engineer and transformed on instructions given by the composer. The result is a number of "acoustic layers" (in this instance four), each recorded on a separate magnetic tape [20]. Tuning control by means of fixed frequencies, and accurate time measurement ensure that the acoustic layers are properly matched and synchronized (in the composition of "Cain and Abel" the tuning was checked with the aid, among other things, of a set of electrically driven tuning forks which produce tones from c^1 to c^2). The layers are then put together in the correct dynamic relationship either all at once or, if preferred, one by one [21], until at last a single magnetic tape is obtained on which the entire work is recorded. This tape is now ready to be played to the public.

A frequently heard misconception is that this procedure must lead to a rigid, mechanical tonal pattern in which there is no room left for artistic interpretation. It cannot be denied that direct contact between performer and audience is lost owing to the prior performance of the work and its reproduction via magnetic tape, although the same applies to broadcast music and to music played on gramophone records. It is also true that, in the case of "Cain and Abel", for example, the work was largely performed for the first time by the composer himself — partly because there are as yet so few musicians who can "play" electronic apparatus, and partly because the act of composing in this new realm of music sometimes runs parallel with the act of performance [8]). Nevertheless, there is certainly room for interpretative re-creation, as testified by the fact alone that the composers of Electronic Music do not identify their work with a magnetic tape but set down the musical thought they wish to express in the notation of a score (*fig. 9*), even though, in doing so, they must necessarily use many new signs, often inventing them themselves. The scope for interpretative re-creation appears in the fact that in making as well as in putting together the acoustic layers indicated in the score there are innumerable details, for example the question of relative sound intensities, that must be decided by musical feeling. This has already been made plain by the results of making versions of the radiophonic opera "Orestes" in other languages: the individual performances (in Dutch, German and English) reveal very striking differences of interpretation in the electronic sounds, although in none of them were the composer's intentions misrepresented.

The composer of Electronic Music need scarcely offer a justification of his work. From the psychological point of view he can regard his experiments in this unexplored territory as sharing in that passion for innovation and development which, as we remarked at the beginning, is characteristic of Western civilization. He can supply their musical motive by pointing to the charm or the fascination of the new sounds, and in particular:

- the timbres with their rich variations;
- the harmonic tuning;
- the wide scope in the dynamics of the music;
- the tempi and the brilliance of the figures, not subject to human limitations;
- complete freedom to combine independent rhythms (whereby the metrical accents on the average can even cancel each other out, producing a curious, hovering movement [22]).

Having, therefore, regard to the common definition of music — as the art of conveying artistic emotions from man to man by the medium of air vibrations — there can never be any doubt in the mind of the composer of electronic music about the right of his brain-child to exist, but he must leave the decision to the listener — of today or perhaps of tomorrow.

8) As a matter of interest, the process of composing and making the magnetic tape for "Cain and Abel" was completed within one month. In general, however, the realization of an electronic score is a rather time-consuming process, and roughly speaking requires just as many "man hours" as it does to rehearse with an orchestra a traditional concert piece of comparable length and complexity.

Explanatory notes to the acoustical illustrations

Side 1 of the gramophone record appended to this article contains examples of individual sounds touched upon in the text; each example is introduced by a *morse-code signal*, by which it can be identified in these explanatory notes. The index figures [..] refer back to the text. Side 2 contains a much abridged version of the ballet music "Cain and Abel"; it was put

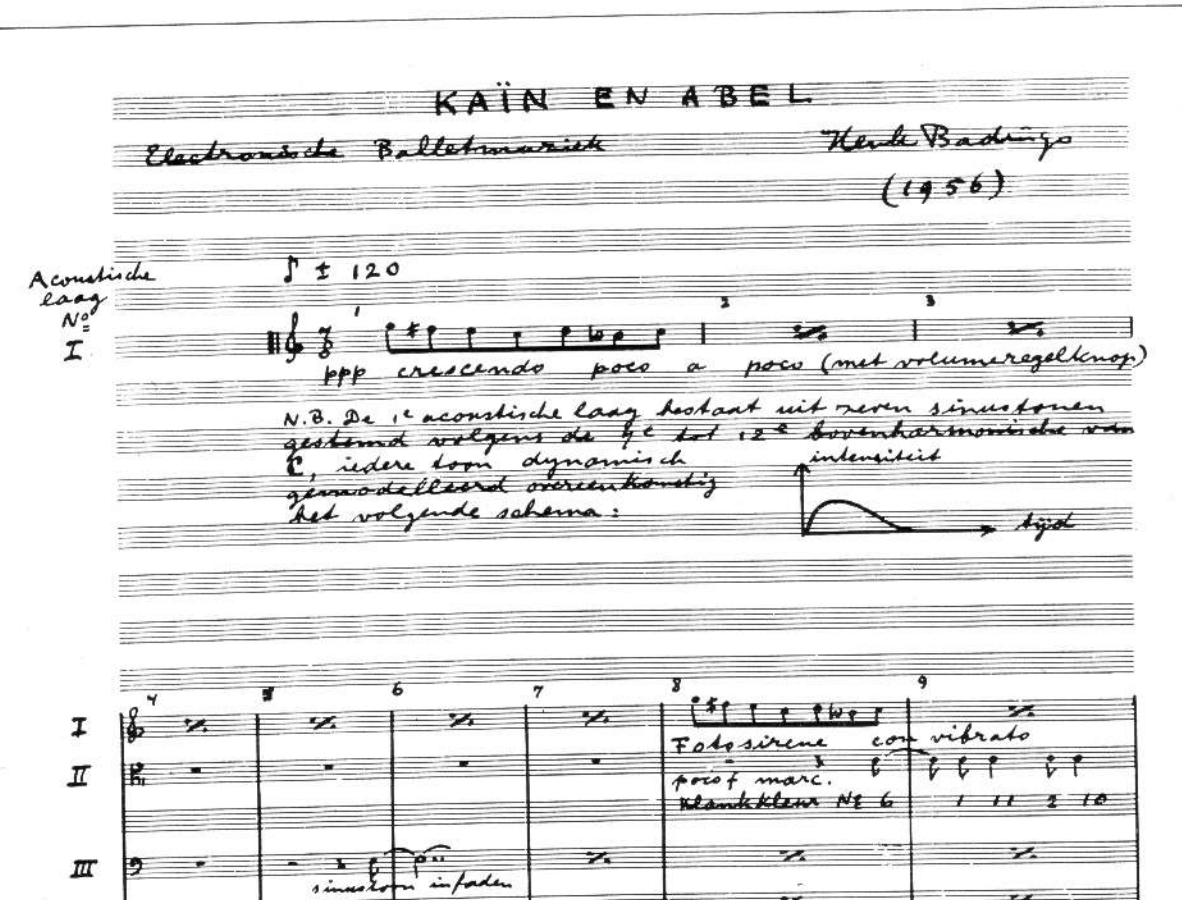

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Fig. 9. Page 1 of the score of the electronic ballet music "Cain and Abel". It can be seen that five "acoustic layers" are used and that the composer of this kind of music is at present obliged to add a lot of written explanation to his score in order to specify his intentions. For the optical siren ("Fotosirene" in the score) twelve vibration patterns (each producing different tone colours — "klankkleur" in the score) were cut out beforehand and numbered, so that it was only necessary to indicate in the score the numbers and the pitch (r.p.m. of the disc).

In other parts of the score other methods of notation are used, including a kind of tablature (a finger-position notation as formerly used for the lute) and a graph in which the required vibration frequencies are directly plotted as a function of time.

together by the composer from the original tape (playing time about 20 minutes) so as to offer in a playing time of 8 minutes a large number of striking passages without doing too much violence to the musical form of the whole.

The examples on side 1 fall into three groups:

I. Illustration of the effect of electronic sound treatments, each applied to the same traditional musical sound, viz. a pianoforte figure, recorded on magnetic tape.

II. Illustration of the sound of several of the electronic sound-sources discussed in the text; some are the original sounds direct from the source, others are treated as under I.

III. Demonstration of the combining of acoustic layers. A passage from "Cain and Abel" is chosen which occurs on side 2 of the record; to make the demonstraton clear, however, the layers are put together anew and some treatments prescribed in the score (including the addition of reverberation) are omitted.

Group I (Various electronic treatments)

First the pianoforte figure itself is heard, consisting of a chord, a run, and the same chord an octave higher.

Then:

—• Tape retarded (speed halved) [4].
Acceleration (tape speed doubled and tape played twice) [4].
Acceleration (tape speed quadrupled and tape played three times) [4].
Glissando of the chord over one complete octave [5].

—•• Dynamic figure introduced in chord by varying the volume control [1].
Attack of each note in the run suppressed by means of the volume control [2].
Attack of the same notes removed by cutting out the pieces of tape at which each attack occurs [3].

—••• Reversal of time by playing the tape in reverse [6].

—•••• Excessive feedback applied to the chord (played twice) [8].
Reverberation added to complete piano figure [7].

Group II (Various electronic sound-sources)

——• Sine-wave generator: staccato notes [11], glissando [12], legato notes [11].

——•• Optical siren: "tone-colour melody" [19].

——••• Multivibrator ("baritone clavier") [13].

——•••• Multivibrator (continuously variable) [14].

——••••• Steel sheet, beaten and damped in different ways [17], also in part electronically treated by the introduction of dynamic figures and by accelerated playback (cf. passage near the end of side 2).

——•••••• Noise generator:
Bandwidth 1 octave (successively 8-4, 4-2, 2-1 and 1-0.5 kc/s) [15].
Bandwidth 1 third (mean pitch varying in steps from 100 to 1600 c/s) [16].

——••••••• Electronic clavichord [18]:
The same figure as the pianoforte figure in Group I.
A different figure; magnetic tape played with continuously increasing speed.
Intermodulation of the last figure and a sinusoidal tone of rising frequency.

Group III (Combination of acoustic layers)

— A complete passage, composed of five layers.

—• First layer:

obtained from pianoforte figure played at 224 quavers per minute (♪ = 224); tape played at double speed in reverse [20].

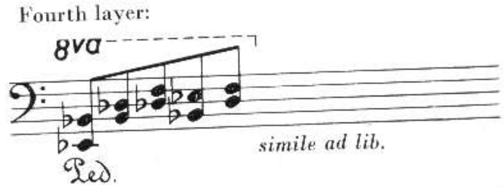
—•• Second layer:

obtained from pianoforte figure produced by depressing the keys of the chord on the keyboard and scraping a hard object over the strings involved, ♪ = 200; tape played at double speed.

—••• Third layer:

obtained from pianoforte figure played at ♪ = 65; tape played at double speed.

—•••• Fourth layer:



pianoforte figure played at ♪ = 105; normal tape speed.

—••••• Fifth layer: sound consisting of notes struck on tubes, similar to the chime of a bell in E flat, followed by the clavichord figure [18] with intermodulation given at the end of Group II, but with tape speed increasing still further.

——• Combination of third and fourth layers [21] [22].

——•• Combination of third, fourth and first layers.

——••• Combination of third, fourth, first and second layers.

———• All five layers combined, same as heard at the beginning of this group.

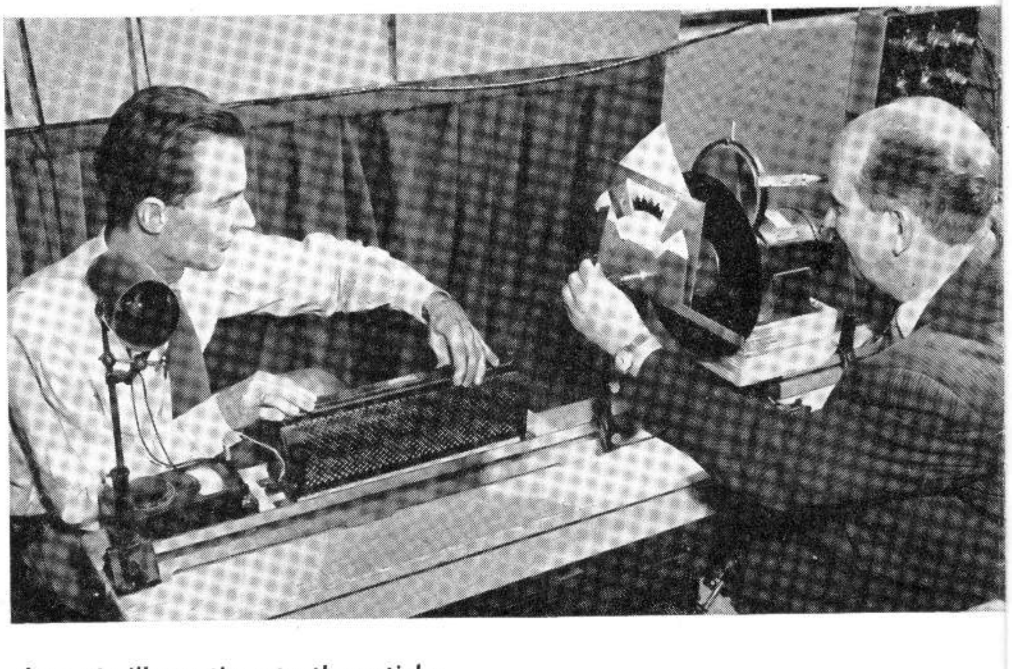
Summary. In contemporary music various trends of composition have evolved which may be described under the general heading of "Electronic Music". A characteristic common to them all is the use of magnetic recording and other electronic aids for the treatment and transformation of sounds into something entirely new. The composers "raw material" may be produced by traditional musical instruments, or derived from "natural" sources or created by electronic means. In this article the electronic instruments are described which the composer, Henk Badings, used in the Philips Research Laboratories, Eindhoven, for creating his electronic ballet music "Cain and Abel". The authors deal in some detail with a number of possible treatments, such as retarding, accelerating and

reversing, making dynamic figures, filtering, intermodulating, producing feedback effects and adding reverberation. They then go on to describe some electronic sound-sources, including the sine-wave generator, multivibrators, noise generators, the "optical siren" and an electronic clavichord. The composer sees the musical significance of using such devices in the wide scope they offer, e.g. for adding innumerable new timbres to traditional musical instruments, for working freely with scales differing from the conventional equal temperament scale, for producing faster and more brilliant figures than would otherwise be humanly possible and for employing extremely complicated rhythms that could scarcely be maintained by even the most skilful ensemble.

The various possibilities are illustrated by acoustic examples given on a gramophone record appended to this article, and which also offers an abridged version of "Cain and Abel".

Record available, upon request, from Secretary's Office.

Philips Technical Review



Acoustic illustrations to the article:

Electronic Music

by **H. Badings** and **J. W. de Bruyn,**

Philips tech. Rev. 19 (1957/58), No. 6

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