ELECTRONIC MUSIC TECHNIQUES

What is electronic music? Why not just "music"?— Or at least music produced by means of electronics. But this immediately suggests music produced by electronic musical instruments such as organs or guitars

THE term "electronic music" was probably used in the first instance by musicians who weren't perhaps quite so well informed about electronics, but it really has nothing to do with music produced by electronic or electrical musical instruments. And yet, as you will soon discover, the modern conception of electronic music is in fact music produced by hybrid electronic musical instruments. It is fairly essential therefore to deal first with some of the earlier techniques for producing electronic music.

Some years ago, even before the Second World War, musicians began to investigate the possibilities of electronics in music. Much of this stemmed from the development of audio amplifiers, loudspeakers, audio frequency tone generators and electronic circuits and devices for controlling production and reproduction. With a variable frequency audio oscillator one could quite literally "play tunes".

This soon led to the provision of a keying system so that a number of such oscillators could be used as the basis of a playable musical instrument—the electronic organ. This particular development is of course well known and the electronic organ is now one of the most popular of electronic musical instruments.

Serious music composers, however, saw other musical potentialities in the audio tone generator and in many other devices that could electrically or electronically generate or process sound within the audible frequency spectrum. Noise generators, for example, and electrical filters. They also realised that the frequency, amplitude, and dynamic ranges that could be obtained electronically were far greater than those of conventional musical instruments. The only real problem was in being able to reproduce the sounds exactly as and when required in a composition.

Then magnetic tape recording became popular, an almost perfect medium for storing sounds and editing a composition. At this point it would be as well to summarise with a quotation from Herbert Eimert one of the original team of the Cologne Studio of Electronic Music, one of the first studios ever set up for the exclusive production of electronic music.

In a technical paper, Eimert wrote: "Electronic music opens the door to acoustical phenomena of a kind still unknown in contemporary music. It demands new principles of artistic production which cannot be derived from playing an electronic musical instrument but only from the sound itself which is its raw material".

TERMINOLOGY OF ELECTRONIC MUSIC

This comment by Eimert clearly indicates that electronic music is something quite different from natural music, which it is. It involves creation, composition, and production using a terminology of its own.

Until recently such music was produced only from electronic tone sources, for example, tone generators and noise generators, whereby all the required sounds were recorded on magnetic tape and afterwards assembled in the order required by the composer. This "assembly" was done by actually cutting the required pieces from the tape, these being laboriously joined together again in accordance with the score.

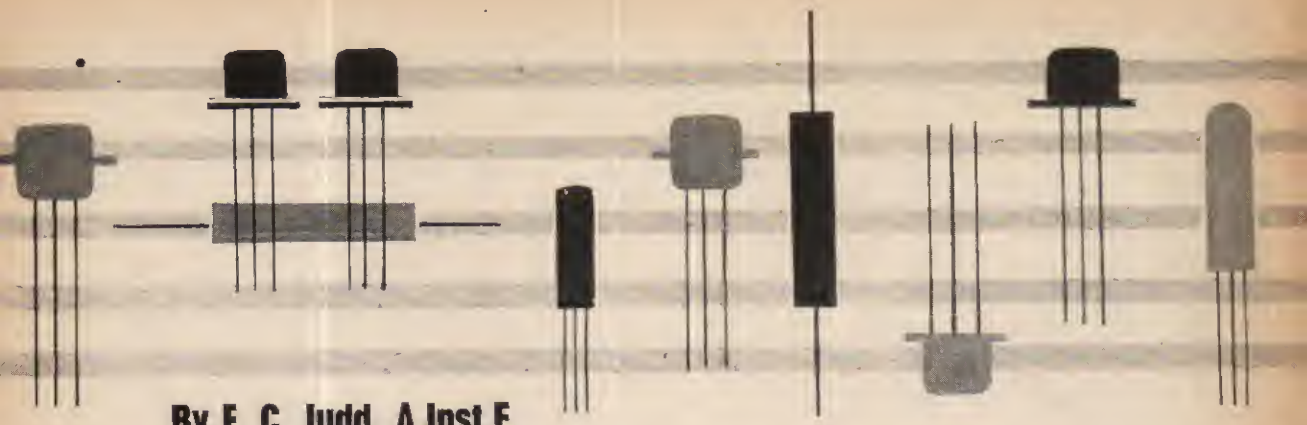
There are existing scores for electronic music using a special notation; an example is given in Fig. 1. The trend in many studios now is to use the keyboard which does away with the arduous job of splicing hundreds of pieces of recording tape. Magnetic tape is, however, still the only practicable medium for reproducing the composition. Electronic music is never played directly from a keyboard system over a loudspeaker as one might play an electronic organ.

COMPOSING PROCESSES

The classification of electronic music composing processes embraces all instruments, apparatus, and processes not used for concert or solo performance, but only for the production of a composition with the aid of sound storage devices, such as tape recording, disc, or film recording.

Such apparatus also includes the use of distorting or sound shaping devices connected between the sound sources and the sound storage or recording system. There are linear and non-linear distorting systems, convertors, modulators, phase delay systems, filters, attack and decay control systems, amplitude control methods, and so on.

The results of some of these processes can be heard on the record given free with this issue of PRACTICAL



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ELECTRONICS. Notes on the sounds recorded are given in the display panel on the next page.

When sound recording techniques are added, the processes become even more complex because apart from storage of the sounds other modifications can be carried out, such as time and frequency compression and expansion, reversal, rhythmic repetition, reverberation and so on.

It is not possible on one record to provide an example of every one of the hundreds of different ways in which sounds can be treated or modified. Those that have been included are those most used and which can be produced with fairly simple equipment. The recording also includes an example of rhythmic electronic music employing some of the more simple techniques outlined in this article. Details of the music on the record are given elsewhere in this article.

SOUND SOURCES AND TREATMENT

The basic sound sources used in electronic music composition are pure tone (sine wave) audio frequency generators, the noise generator which produces "white noise" (a sound having random fundamental frequency, amplitude, and phase and which can cover the entire audio spectrum), pulse generators which include square and other shaped waves other than sine wave within the audio frequency spectrum.

The first recording on the demonstration record contains examples of the following sounds: 400Hz pure tone, 100Hz square wave, 10Hz pulse, and unfiltered white noise. Any of these basic sounds can now be treated in various ways, mixed together, given artificial reverberation, filtered, modulated, given specific attack (beginning of sound) and decay (end of sound) and so on.

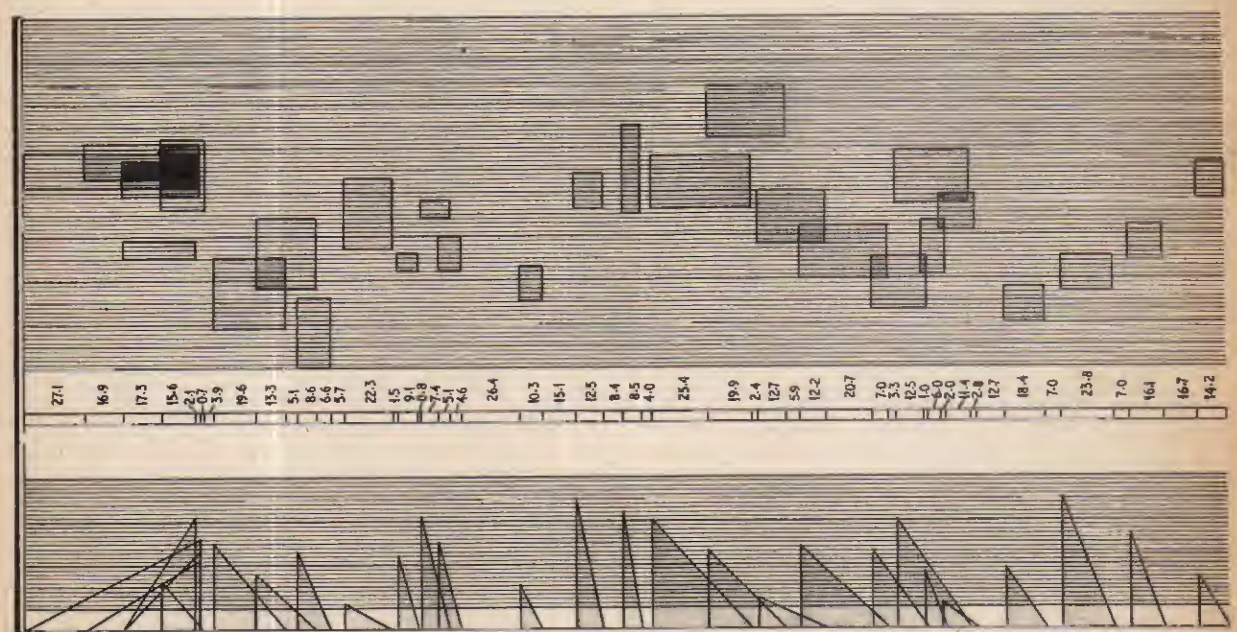

Fig. 1. Part of a score for electronic music (Universal Editions). This is one page taken from the 30-odd page score of STUDIE 2 by KARLHEINZ STOCKHAUSEN (DEUTCHE GRAMMOPHON LP 16133A), a classic piece of electronic music. The upper half of the score which contains 80 lines is used to indicate the frequencies contained within the "blocks" and according to the composer's instructions at the beginning of the score book. The duration of each frequency block is indicated by the middle scale which gives the respective length of tape in centimetres for recording at a tape speed of 30in/sec. The lower half contains the instructions for the amplitude of the frequency blocks rising or falling according to the duration of the recording. The 30 lines represent the level in decibels, the top line being 0dB or maximum record level

One of the most used treatments is the modulation of one sound by another by means of a ring modulator. When two pure (sine) tones of different frequency are fed into the modulator they are reproduced at the output together with two more tones at the sum and difference frequencies of the originals. The sound produced is a kind of chord with unusual timbre and an example is included on the record.

Audio frequency filters are also used extensively in the studios, but can be costly devices and difficult to make if sharp response is required. Simple forms of RC filter will cater for many amateur experiments; these and other electronic circuits for sound treatment will be given in the second part of this article. Examples of filtered white noise are given on the demonstration record.

Treatment and mixtures can go on almost *ad infinitum*. For example ring modulated tones can be pulsed or further modulated with noise. Pure tones can be mixed or modulated with square waves or other wave shapes and any of these combinations, can be given controlled degrees of attack, decay and reverberation. Practically all of the various "electronic" treatments and mixtures can be carried out before recording.

REVERBERATION

Reverberation is a very popular effect. It can be produced by a tape recorder with two heads, or a plate or spring line reverberation unit. The "spring line" reverberation unit is the most effective and could be built by a knowledgable amateur. The reverberation produced by such a device is quite different from that produced by a feedback system employing magnetic tape. Spring line and plate reverberators produce an echo which closely approximates natural room echo but which can be extended to provide a "sound-in-a-large-empty-hall" effect.

Echo produced by the magnetic tape feedback method is hard and abrupt, but it is a very distinctive form of echo. Both kinds of reverberation (echo) are demonstrated on the record. The tape feedback system can

P.E. SOUNDS AND EFFECTS RECORD

THE examples contained on the record are typical of the sounds and treatments employed in a studio for producing electronic music. Most of them can, however, be produced with amateur equipment such as a sine wave generator, an ordinary multivibrator (square wave generator), a ring modulator, and various simple electronic circuits that will be described in Part 2 of this article.

Voice announcements precede each recorded example. Some notes on the equipment and treatment employed are included. Details of the individual recordings are given below.

BASIC SOUND SOURCES

1. Pure sine wave from an ordinary audio signal generator (400Hz).
2. Square wave from an audio signal generator (square wave output).
3. Pulse wave from a multivibrator.
4. Unfiltered white noise from a white noise generator.

ELECTRONIC TREATMENT

1. *Ring Modulated Tones.* Simple ring modulator and two pure tone sources (audio signal generators).
2. *Filtered White Noise.* Noise generator and one-third octave filters.
3. *Pulsed Tones.* Previously recorded ring modulated tones fed into a ring modulator (one input) with impulse generator (multivibrator) fed to the other input.
4. *Attack and Decay.* Use of volume control and/or electronic circuit.

REVERBERATION EFFECTS

1. *Mechanical Reverberation.* Obtained with a spring line reverberator.
2. *Tape Echo.* By feedback from a tape recorder replay head immediately following the record head. Signals returned via recording amplifier.
3. *Excessive Echo.* By allowing tape head feedback to build up followed by cut-off with volume control. Noise sound from noise generator.
4. *Pre-echo.* Sound echoed during reverse recording and then replayed in the original direction.

TAPE RECORDING TECHNIQUES

1. *Replay Speed.* Sound recorded and replayed at same speed.
2. *Replay Speed Doubled.* Sound replayed at twice recording speed.
3. *Reversed Recording.* First part as recorded; second part in reverse.
4. *Tape Loops.* Used for effective repetitive rhythms. Recorded basic sound cut from length of tape. Joined into a continuous loop.

Note: Reverse replay of a tape recording may only normally be carried out with a full track recorder or a twin track stereo recorder, in which case the recording is first made on the lower track and replayed, in reverse, on the upper track, or vice versa. If the recorder is made to play in either direction, this does not apply; the reverse play effect then becomes straightforward.

RHYTHMIC ELECTRONIC MUSIC EXAMPLE

The final track on this record is a piece of electronic music using the loop rhythm example described above, except that the tempo is slower. The melody is the theme of a complete electronic music composition for which the author was awarded first prize in the 1965 British Recording Contest (professional section).

The rhythm was first recorded on a continuous loop of tape. This tape was then cut to exactly 44 bars (in 2/4 time) thus providing a four bar introduction followed by 40 bars for the melody.

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be produced quite easily with any tape recorder having an extra tape head, i.e. a replay head after the normal record head.

During recording, signals on the tape are picked up by the replay head and returned to the tape via the recording amplifier so that the sounds are re-recorded a fraction of a second later. The returned signals must be under control (via a volume control) otherwise the feedback will build up to a vicious roar. This effect is, however, sometimes used deliberately to produce dynamic sounds as illustrated on the record.

One other reverberation technique should be included and this is called pre-echo. Here the sounds are recorded in the normal way on tape. The tape is then played in reverse on one machine and re-recorded and simultaneously echoed on another. When this recording is replayed in the reverse direction the echoes of the sounds will precede the sound itself.

TAPE RECORDING TECHNIQUES

Any two or more of the sounds so far described can be combined to form a complex composite sound. The possibilities begin to become almost unlimited and we have not yet dealt with keyboard sound systems, rhythm machines, and the endless variety of pure recording techniques such as reversed playing, speed changing, frequency compression, tape loops, multi-track recording, superimposing, tape cutting and the re-assembly of recorded items.

With the help of the record included in this issue it is now possible to give actual examples of some of the effects that can be produced. Also at the end of this article will be found a list of recorded works containing examples of all kinds of electronic music and sounds.

However, before going on to describe some of the recording techniques used on the record, the following is a brief resumé of the author's equipment used to make the various sounds, although a more modest range can be used.

Sound sources include sine and square wave generators, a pulse generator (1·5 to 6,000Hz), white noise generators, electrical filters, double beam oscilloscope, stereophonic amplifiers and loudspeakers, spring line reverberation unit, sound mixers for up to six channels, ring modulator, microphones for non-electronic sounds, an electronic organ as a keyboard system (melody in tempered scale) and finally three tape recorders, two of which are half-track stereo machines, one full-track tape recorder (mono) and a replay deck with full-track and half-track heads.

THE BRITISH AMATEUR TAPE RECORDING CONTEST 1967

The above contest, held annually, is open to amateurs only. There are seven different categories for entry. Readers inspired by this article on Electronic Music Techniques may like to know that their own original work can be entered in Class 5 TECHNICAL EXPERIMENT, which embraces sound compositions, electronic music, musique concrête, multi-track music and trick recording. The maximum playing time for a tape is 4 minutes.

Closing date for receipt of tapes is December 30, 1967.

Rules of the Contest and entry forms can be obtained from The British Amateur Tape Recording Contest, c/o The Secretary, 33 Fairlawnes, Maldon Road, Wallington, Surrey.

Despite this fairly comprehensive range of equipment, it is all set up in a very small studio and does not begin to compare with studios such as the BBC Radiophonic Workshop which occupies two large recording studios and features an enormous range of electronic and recording equipment.

Returning to recording techniques, magnetic tape is now the accepted recording medium and in itself provides various possibilities in the treatment of sounds. Of these, the change of speed is very frequently used; sounds are recorded at one speed and replayed or re-recorded at another.

In electronic music the speed change is used to raise or lower the pitch of recorded sounds. Most tape recorders operate on two or three speeds which are normally related by one octave difference in pitch derived from doubling or halving the tape speed, using $3\frac{3}{4}$, $7\frac{1}{2}$ and 15 inches per second.

In the studio, recorders with small differences in pitch are frequently used and as a rule the speeds are pitch related so that a recording made in, say, the key

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Some of the sound generating and recording equipment used to produce the demonstration record

continued from page 723

of C can be replayed at a semi-tone or whole tone higher but still in "concert" pitch. This can be done with a tape deck or tape recorder with interchangeable capstans which are turned down to a pre-determined diameter, although these are not normal stock items and may have to be made specially.

With a full-track mono tape recorder, or a stereo tape recorder with two half-track heads, it is possible to replay recordings in reverse. When this technique is used the attack or beginning of a sound comes at the end. An example of this is included on the demonstration record.

TAPE EDITING

Tape editing is one of the primary techniques used in electronic music composition and was at one time used almost exclusively. The splicing of individual musical notes recorded on tape is, to say the least, laborious. This method is now being short-circuited by using keyboard systems so that the sounds or melodies can be actually "played" in the required order. The output from these keyboard systems can be connected directly to a tape recorder.

A simple keyed oscillator system can be extended to rhythm machines employing electronic and mechanical/electronic methods of producing percussion sounds in various rhythms and at different speeds. A device of this kind is, however, somewhat complex and here we may return to the technique of recording sounds individually, and re-assembling these into a loop.

Each required percussive sound is first recorded on magnetic tape. The sounds are then cut from the tape and assembled in the required order. The completed rhythm sequence is then looped and replayed at the desired speed.

It is, of course, essential to provide the correct time values to each sound in order to create a useable rhythm. The illustration included in the record gives a better idea of the possibilities than any form of diagram. The tape loop technique can also be used for the repetition of long rhythmic or musical sequences, for example, several bars of rhythm may be looped. Looped rhythms can also be recorded and these recordings joined together so as to form the complete rhythmic background to a melody and harmony.

Part 2 of this article will deal with simple electronic circuits for sound production and treatment and the use of a domestic class tape recorder in the creation of electronic music.

Records of Electronic Music available in the UK—

1. *The Fascinating World of Electronic Music.* Kid Baltan and Tom Dissavelt. Eight recordings on an l.p. disc containing some very fine examples of rhythmic electronic music. Philips P.08168L (Mono only).
2. *Fantasy in Orbit.* Tom Dissavelt. Fourteen recordings on an l.p. disc. Fine examples of etherial music. Philips 633.302.BL Mono (also available in stereo).
3. *Poeme Electronique.* Edgar Varese. A good example of the dynamic effect of electronic music. Philips ALB.3392.
4. *Music from Mathematics.* Electronic music (?) by an IBM7090 computer. Interesting for its technical achievement. Brunswick STA.8523.
5. *Electronic Sounds and Music.* Various examples of electronically derived sounds and one composition.
   Electronic Music and Musique Concrête. Four compositions employing tape assembly techniques.
   Rhythmic Electronic Music. Four compositions of electronics in rhythm. These three records are produced by the author of this article on Castle EFX1, 2, and 3.