THE CONCEPT OF UNITY IN ELECTRONIC MUSIC

(Die Einheit der musikalischen Zeit)

KARLHEINZ STOCKHAUSEN

ON SEVERAL previous occasions, when I have been asked to explain the composition of electronic music, I have described four characteristics that seem important to me for electronic composition as distinguished from the composition of instrumental music:

1) the correlation of the coloristic, harmonic-melodic, and metric-rhythmic aspects of composition
2) the composition and de-composition of timbres
3) the characteristic differentiation among degrees of intensity
4) the ordered relationships between sound and noise

Here, I would like to discuss only the correlation of timbre, pitch, intensity, and duration. In the past, it has been customary to regard these correlative properties of sound as mutually independent, as belonging to fundamentally distinct spheres. They have appeared increasingly separate as our acoustical perception developed along such lines.

Similarly, the means employed for the production of sound, as well as the compositional process itself, were consequent upon this conceptual separation. To generate sound-events having single perceptible pitches, we used the so-called sine tone, square-wave, or saw-tooth generators, which produce periodic oscillations. Sound-events of indeterminate pitch, those that are more or less noise-like, were produced by means of noise generators.

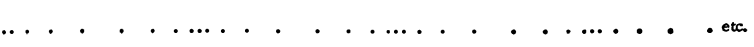
We varied such sound- or noise-colors by means of electrical filters, with which one can strengthen, attenuate, or suppress entirely individual partials or whole frequency-bands—the so-called formants, or bands of noise—of the spectra.

Intensity was controlled by regulating, with the aid of a voltmeter, the voltages recorded on tape (whereby the spectrum itself automati-

cally varied with the variations in intensity), whereas duration was determined simply by the length of tape on which a sound was recorded.

Compositionally, in terms of the production and manipulation of sound, these individual sound-properties had to be dealt with separately. But, on the other hand, we perceive a sound-event as a homogeneous phenomenon rather than as a composite of four separate properties. At a relatively early stage of my work in electronic composition, I had already considered the possibility of equating this unity of perception with an analogous unity in composition itself. In the preparatory work for my composition *Kontakte*, I found, for the first time, ways to bring all properties under a single control. I deduced that all differences of acoustic perception can be traced to differences in the temporal structure of sound waves. These temporal relations enable us to distinguish the many different manifestations of pitch, timbre, simultaneity, sound-mixture, and noise: their speed of oscillation, their particular intervals—either equal and regular or more or less irregular—their density, and the frequency with which pulsations reach the ear. It seemed to me that the differences in intensity among sounds ultimately derive from the latter property: when pulsations of equal value follow one another in closer temporal succession, the over-all intensity increases; to effect this, the density would, in fact, have to be so great that the individual pulses were no longer conveyed as a succession of equal perturbations of the atmosphere but rather as mutually interfering sound-waves: the particles of air agitated by the initial pulses would thus be reactivated by further pulses before they have become quiescent and are, so to speak, "shaken up," so that the impression given is of an increase in over-all intensity. The total complex thus appears as a *single* greater wave rather than *several* smaller ones. The faster the succession of pulses, the stronger will be the appearance of the resultant wave.

A periodic sound wave, such as a simple tone, fluctuating regularly in intensity, would thus be the result of a succession of pulses that alternately accelerate and decelerate within each period. The difference between the fastest and slowest rates of speed of the pulses in each period would define the direction of its intensity (its "intensity envelope") and its amplitude. The distance between periodically recurring equal rates of speed would determine the pitch.



Ex. 1

If a succession of pulses of this kind were to be accelerated so that between the periodic recurrences of the highest speed there were a time interval of, say, 1/440 sec., one would hear a simple tone with the pitch of A-440.

If the rate of speed of the pulse-succession did not fluctuate regularly ( ) but consisted instead of periods of several unequal parts within each equal time-span (as, for example,), the so-called "color" of a steady sound would vary according to the wave crests. A "period" divided into two parts would be represented as follows:

Ex. 2

In a more or less noiselike sound-event the periods would no longer be regular; i.e. the time intervals between recurrences of equal rates of speed would not remain constant but would vary irregularly between a given fastest and slowest speed. These extremes determine the limits of a frequency band, a so-called "colored noise" band. If the rate of speed of the pulse succession were so widely varied that the smallest interval between pulses were ca. 1/16,000 sec., and the longest ca. 1/20 sec., occurring at regular time-intervals, and everything between these extremes occurred in a highly aperiodic fashion (in a manner that one might term "aleatoric") the result would be "white noise."

For most musicians, these considerations may seem specifically related to acoustics rather than to music. Actually, however, a musical composition is no more than a temporal ordering of sound events, just as each sound event in a composition is a temporal ordering of pulses. It is only a question of the point at which composition begins: in composing for instruments whose sounds are predetermined, a composer need not be concerned with these problems. On the other hand, in electronic music, one can either compose each sound directly in terms of its wave succession, or, finally, each individual sound wave may be determined in terms of its actual vibration, by an ordering of the succession of pulses.

If, in fact, all of the experiential properties of sound could be traced to a single principle of ordering—such temporally composed successions of pulses—compositional thought would have to be radi-

cally reoriented. The distinction between the "acoustical prearrangement" *within* the material and "musical ordering" *using* this material would now have to be discarded. The prevailing additive, or "synthetic" compositional procedure, in which the different properties are bound together, would now be expanded through a protogenerative and more unified approach. One would not proceed from sound properties that had already been experienced and then allow these to determine temporal variations; instead, one would compose the temporal arrangements of pulses themselves, and discover their resultant sound properties experimentally.

After my first, relatively simple, attempt at such a procedure, I was able to predict roughly the particular temporal orderings of the pulses. I then proceeded to record fixed successions of pulses on tape within a relatively low speed range (using pulsation intervals of between 1/16 and 16 secs.) and then increased the speed until I arrived at the "field" of frequencies and color that I desired. This was done by means of a pulse generator with which the speed of the pulse succession was regulated by hand. Thus, for example, if I wished to generate a periodic wave—that is, a sound of constant pitch—from a succession of pulses lasting eight seconds whose speed variations are fixed, I would have to accelerate the rhythmized eight-second succession 1,024 times, that is, transpose it ten octaves upwards, reducing its duration from eight to 1/128 sec. In order to sustain this pitch of 128 cps. for 10 sec., I would have to re-record the original succession 128 $\times$ 10, or 1,280 times, which can easily be done by means of a tape loop. The "color" of the resulting sound would be determined by the variations of speed among the pulses of the original succession, which are now determined by the periodic duplications and accelerations of the wave form within each time span—i.e. the "intensity envelope."

With such a compositional procedure, then, one must proceed from a basic concept of a *single, unified musical time*; and the different perceptual categories, such as color, harmony and melody, meter and rhythm, dynamics, and "form," must be regarded as corresponding to the different *components* of this unified time, as follows:

1. Harmony and melody correspond to periodic waves (that is, to sound-events of constant pitch) whose individual periods should not be greater than ca. 1/16 or less than ca. 1/6,000 sec. because beyond these limits they are no longer audible as "pitches."

2. The color of harmonic spectra corresponds to the whole number fractions which, as "fundamentals," refer to periods of between ca. 1/13,000 and ca. 1/16 sec.; the color of nonharmonic or noiselike spectra corresponds to more or less aperiodic successions of periods.

3. Between ca. 1/30 and 1/16 sec. our perception of duration gradually changes into perception of meter and rhythm; i.e., *periodic* periods may then be considered as *meters*, and the *internal intervallic relationships* of the distances between pulses within any given meter—that which determines the tone color for periods shorter than ca. 1/16 sec.—may here be considered as "rhythm."

Aperiodic relationships of periods, which are considered "*noises*" in the sphere of color, correspond, when the periods are longer than ca. 1/16 sec., to *aperiodic rhythms* having no recognizable meters—i.e. no recognizable periodicity (just as a deviation from simple periodicity in the sphere of frequency—"*dissonance*"—corresponds, in the sphere of duration, to *syncopation*).

Although many of the new compositions have been criticized for their alleged "lack of rhythm," they may actually be considered to have "pure rhythm" without meter. This objection, moreover, is exactly analogous to that directed against the use of aperiodic sound waves, i.e. against "noises."

4. Meter and rhythm correspond to the time intervals whose order of magnitude is between ca. 1/8 and ca. 8 secs. At about 8 secs. our ability to distinguish durational relationships gradually breaks down. With values of greater length we are no longer able to remember the exact lengths of durations or perceive their proportions as accurately as we can those that lie between ca. 1/8 and ca. 8 secs.

"Form" in a special sense—the time relationships of longer events—corresponds to durations of the order of magnitude of from several seconds to about 15-60 minutes (for "movements" or whole "compositions").

The transitions and overlappings between all the time spheres are quite flexible, but this is especially so with reference to "form," which is most obviously an approximation (in the literature of music, of course, the durations of "movements" or *continuous* works vary from several minutes to ca. one hour).

Perhaps I should mention here that each of the three large musical time-spheres—*frequency duration*, *rhythm duration*, and *form duration*—are of approximately equal size: each has a compass of about seven "octaves" (where "octave" signifies a relation of 1:2). Between the highest note on the piano, whose fundamental wavelength is ca. 1/4,200 sec. and the lowest, whose wavelength is ca. 1/27 sec., there are just over seven octaves. Below this point sound waves gradually become audible as rhythms (a good illustration of this is the audible effect of the lowest notes on the organ), and from ca. 1/16 sec. to ca.

8 sec.—the span of rhythm durations—there are again seven octaves, as follows:

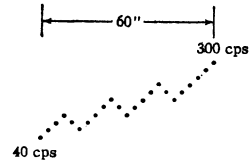
$$(2^1 - 2^2 - 2^3 - 2^4 - 2^5 - 2^6 - 2^7 - .)$$
$$1/16'' - 1/8'' - 1/4'' - 1/2'' - 1'' - 2'' - 4'' - 8''.$$

The sphere of form duration, from ca. 8 sec. to between ca. 900 secs. (15 minutes, the approximate traditional duration of single movements of a work) and ca. 3,600 secs. also includes seven-nine octaves, as follows:

$$(- 2^1 - 2^2 - 2^3 - 2^4 - 2^5 - 2^6 - 2^7 \ldots)$$
$$8'' - 16'' - 32'' - 64'' - 128'' - 256'' - 512'' - 1{,}024'' \ldots$$

Thus, the total musical time sphere encompasses the durations between ca. 1/4,200 sec. and ca. 900 secs., that is, 22(-24) "octaves," or 22-24 progressions of 1:2.

At this point I would like to demonstrate, with an example from my composition *Kontakte*, a continuous overlapping between the time sphere of "frequencies" ("sounds" and their "colors") and the sphere of "rhythms" (individually audible pulses within given time intervals). This overlapping will take place in the zone between ca. 30 and ca. 6 pulses/sec. To begin with, I fed a periodic succession of 16.6 pulses/sec. into a very narrow-band filter. This succession emerged as a sound wave of clear, recognizable pitch. Then, within one minute's duration, I continuously varied the frequency position of this filter from 40 cps to 300 cps—that is, over a span, from low to high, of about 3 octaves—in an ascending zigzag glissando pattern:

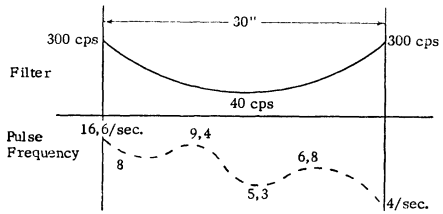


Ex. 3

These variations in filtering are heard as variations in the pitch resulting from the pulse-succession.

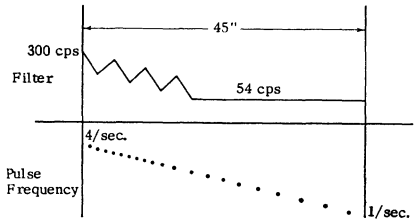
Next, I subjected this result to a tenfold acceleration, until 166 pulses/sec. sounded instead of 16.6 pulses/sec.; that is, one heard a steady pitch having a frequency of 166 cps (between $E\flat_3$ and E_3). The *pitch* variation between 40 and 300 cps, heard at the first stage, now appears as an intensification of the tone color of the 166-cps tone (now 6 secs. in duration). Because of the high speed, this pattern is no longer heard as an ascending "melodic line."

For the continuation of this sound, I generated a thirty-second succession of pulses whose speed decreased from 16.6 pulses/sec. to 4 pulses/sec. according to a zigzag pattern. Simultaneously, the filter was continuously varied downwards from 300 cps to 40 cps and then upwards again to 300 cps.



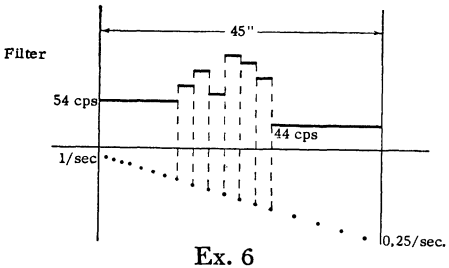
Ex. 4

During the next 45 secs., the speed was lessened from 4 pulses/sec. to 1 pulse/sec. according to a pattern of 4 zigzag alterations of the filter in the range between 300 and 54 cps. After 27 secs., the filter remained level at 54 cps.



Ex. 5

In the third part of the pulse succession the speed was decreased regularly from 1 pulse/sec. to 1/4 pulse/sec. (within 45 secs. duration); the position of the filter remained constant at 54 cps for the first 15 secs., and then, suddenly, with each individual pulse, it was varied seven times in a fixed up-down, up-down "melodic" pattern, and then held constant at 44 cps.



Ex. 6

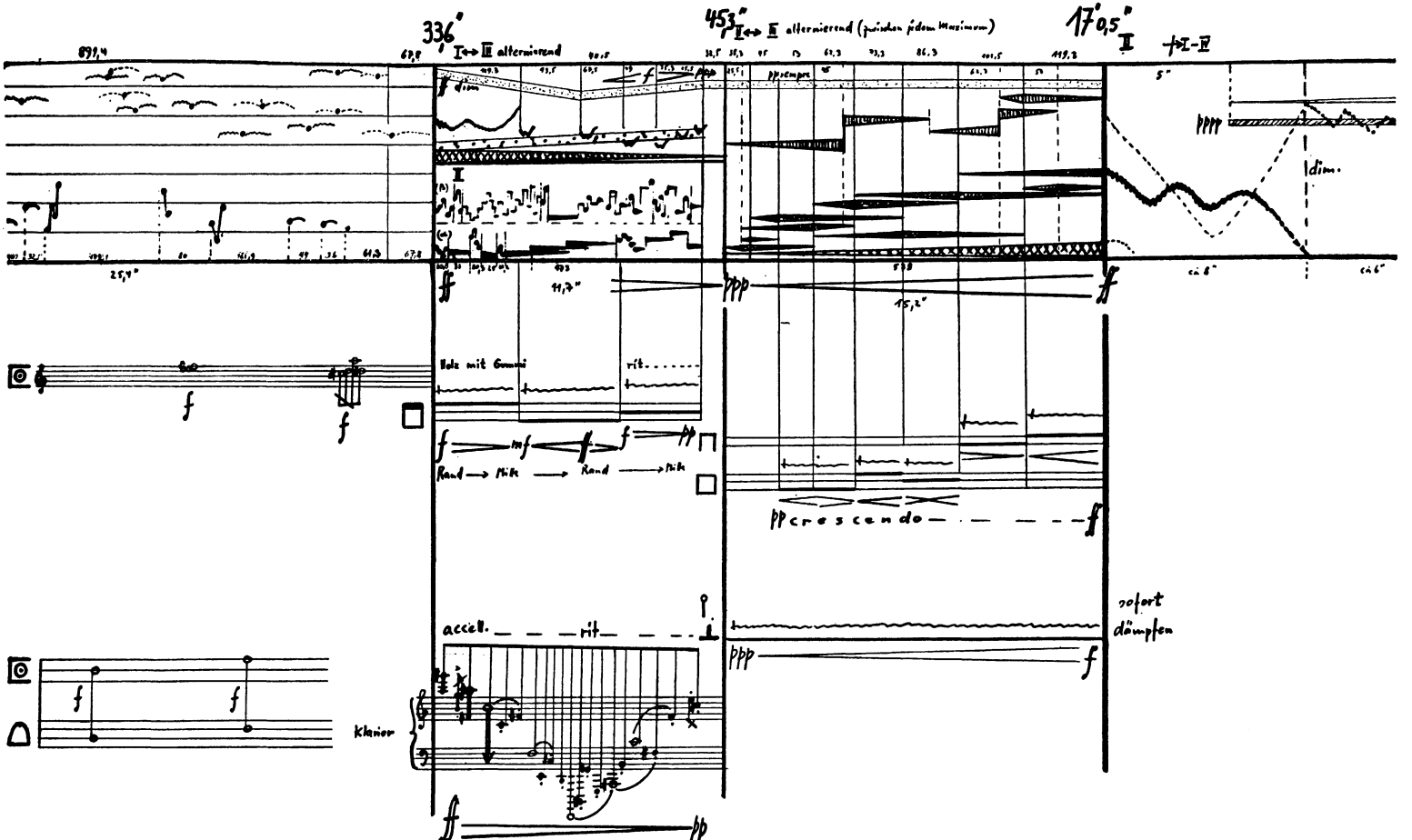
Next, I connected the resultant parts, and the overall diminution of the speed amounted to 6 octaves (from 16.6 pulses/sec. to 1/4 pulse/sec., along with the abovementioned pitch variations between 300 and 44 cps). (60″ + 30″ + 45″ + 45″)

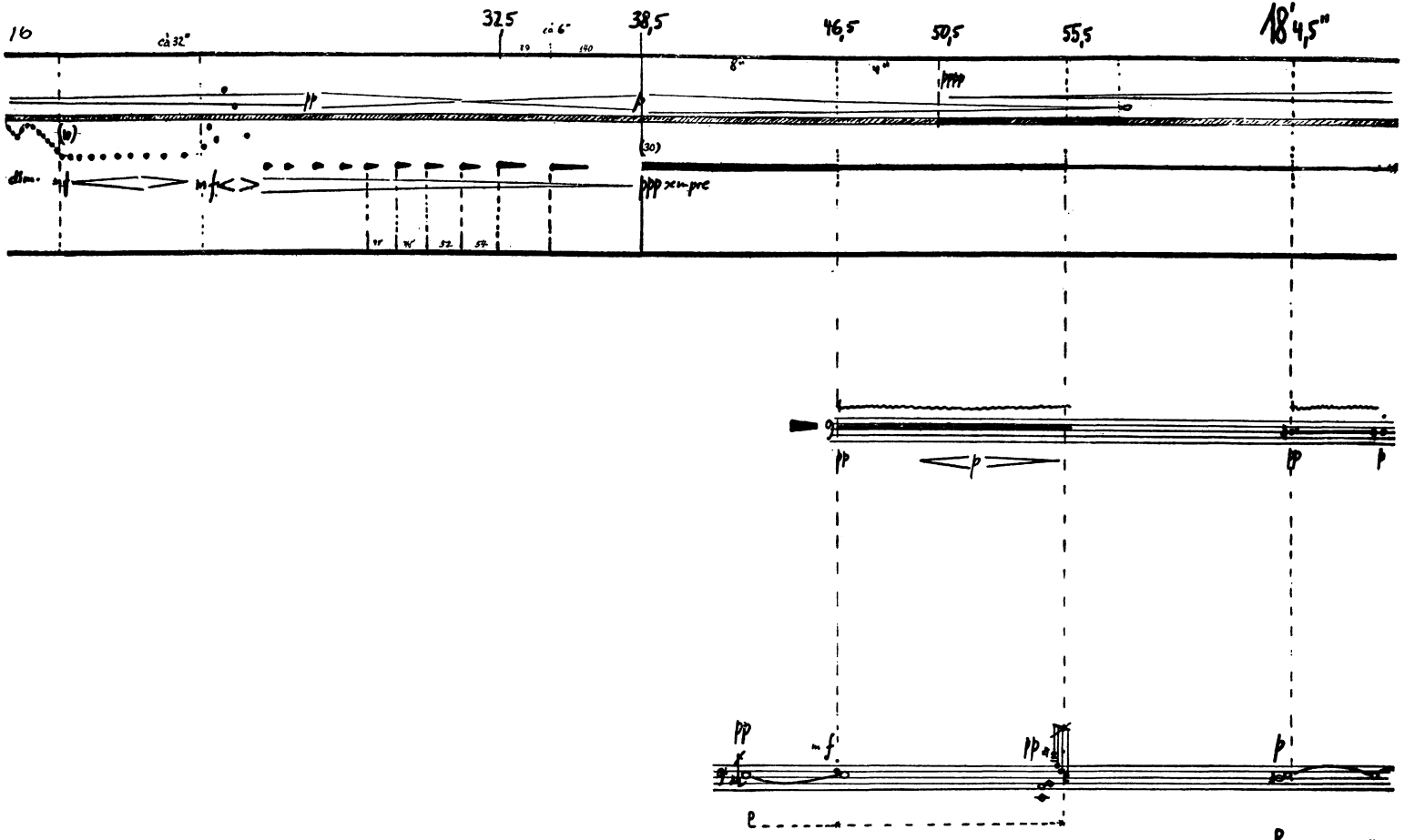
For the last pulses, I gradually altered the filter feedback time so that, at the end, the duration of each individual pulse is increased, and the "color" becomes somewhat "metallic."

At this point, I subjected the total result to an acceleration, which amounted, at the beginning, to a tenfold acceleration from 16.6 to 166 pulses/sec., and, by virtue of the continuous alterations, to a 2.5-fold acceleration at the end, so that the intervals between the final pulses amount to ca. 1.5 secs. The pitch of the final pulses is then steady at 160 cps, which is approximately the same as that with which the event began. Whereas the accelerated form of the original frequency variation is heard chiefly as tone-color variation, we gradually perceive it again as a succession of individual pulses, as pitch, because of the continuous dissolution of the sounds. The initial sound of 166 cps slides (in 6″ + 32″) about 7½ octaves downwards, passing through the zone where perception of pitch modulates into perception of rhythm, where perception of "tone color" merges into that of "melody," and thus the "color" is dissolved into a succession of individual "pitches."

At the conclusion of this pulse succession, the intervals between the individual pulses correspond to 45.5 cm., 48.5 cm., 52 cm., and 57 cm. of the tape (where 38.1 cm. = 1 sec.). I then added three more pulses with a pitch of 160 cps, between which the intervals were 89 cm. and 140 cm. This continued the gradual retardation and lengthening of the pulses. The third and final pulse was protracted into a continuous sound once again (by means of overmodulating the filter feedback). By means of amplification I made this sound increasingly "overtone-rich" and in five stages filtered continuously from the lowest to the highest portions of the sound. As a result, within 48 secs., its color first gradually brightened, then passed out of the range of audibility, "over the top," as it were.

OPPOSITE AND OVERLEAF:
Stockhausen, *Kontakte*, pp. 19 and 20


336"
I↔II alternierend
453"
I↔II alternierend (zwischen jedem Maximum)
17'0,5"
II
+I-II
pp sempre
dim.
Holz mit Gummi
rit.
Rand → Mitte → Rand → Mitte
pp crescendo
accell.
rit.
sofort dämpfen
Klavier


16
cà 32"
32,5
cà 6"
38,5
46,5
50,5
55,5
18'4,5"
8"
4"
pp
(30)
dim.
mf
pppx in pre
pp
p
pp
p
pp
mf
pp
p
e
P

Beginning	200–300 cps
	450–600 cps (after 8″)
	800–1,000 cps (after 17″)
FILTER:	1,500–3,000 cps (after 26″)
	5,000–10,000 cps (after 35″)

The entire process of temporal transformation, as it was applied in *Kontakte*, is schematically represented in the score between the time coordinates 16′56.5″ (highest layer) and 18′26.5″ (pp. 19-20 in the score). Most of the events in *Kontakte*, like the one in the example, were composed by means of many temporal transformations of pulse structures.

I have already affirmed my belief that any drastic separation between acoustics and music is no longer meaningful where composition includes the synthesis of the sound waves themselves. The temporal process by which a sound is transformed into a rhythm can, without doubt, take a musical form. The aesthetic judgment of the listener can determine if the result of this process is successful, if it is significantly congruent with the total work, and if it has been accomplished with originality and imagination.

It is understandable that, in traditional Western music, where the spheres of harmony and melody dominate, only those sound-events were used that have periodic waves and clear, recognizable, constant "pitch." The way in which the laws of harmonic and melodic union of such tones, whose harmonic sound spectra are based on whole-number divisions of the sound waves of the fundamentals, corresponds precisely to the definition of consonant and dissonant intervals and their function, indicates the necessity of excluding noise from this kind of music. Similarly, in the sphere of duration, the *meters*, i.e. periodic time intervals (or measures) were filled in with rhythms—consequently, by whole-number divisions of the meters (tone color is to a fundamental as rhythm is to a meter)—and all of the variations and disruptions of the metrical periodicity were regulated according to the definition of syncopated and regular time intervals and their function. Correspondingly, in the sphere of form, such metrical successions were formed periodically into units of 2, 4, 8, 16 measures with "irregular" (or, better, "syncopated") variants of 3-, 5-, 7-, or 9-measure periods. All of musical time was unified under a common principle, and it was unnecessary to include in this scheme the actual sound wave structure of instrumental tones, since this was guaranteed in advance by the selection and construction of instruments of fixed

pitch. If nowadays, on the other hand, it has become necessary to take into account factors such as those discussed here, to bring all the spheres of electronic music under a unified musical time, and to find one general set of laws to govern every sphere of musical time itself, this is simply a result of the condition imposed by electronic music that each sound in a given work must be individually composed.

(Translated by Elaine Barkin)