

# ANALYTICAL DESCRIPTIONS

## KLANGFIGUREN

The Material in *Klangfiguren* consists of long sequences ("structures"), which can be distinguished in two parameters: speed and timbre. The timbre is formed from pitch and spectrum.

Alterations in speed and pitch follow 5 patterns:



This results in combinations such as

- rising/falling – getting faster
- falling – slower/faster
- rising – getting slower
- falling/rising – no tempo change
- etc.

Alteration of the spectrum is serial, i.e. there is no clear "tendency". Each sound consists from 1 to 8 partials, the interval between which are  $(\sqrt[36]{2})^1$  to  $(\sqrt[36]{2})^8$ ; each of the 8 intervals can on principle only occur once in the spectrum, deviations resulting from the combination of independent permutations of frequency and octave register.

According to this, a structure is defined – apart from its duration and the number of individual sounds – by serial distribution of spectra and by unambiguous tendencies in alteration of pitch and speed. I call these characteristics the constant complexity of a structure.

As well as receiving constant complexity, each structure is also given a variable complexity by means of transformations. These transformations are:

- A ring modulation
- B group formation
- C insertion of pauses
- D transposition
- E superposition
- F reverberation
- G envelope

A Ring modulation provides the structure with a particular timbre. When the sounds in a structure are being recorded, only intervals are realised, timbre not being fixed. For this purpose sinus tones were used whose frequencies were subtracted from 10,000 (example: for sound 160-352-198-462-244-560-302, the following were recorded: 9840-9648-9802-9538-9756-9440-9698). After ring modulation with a sinus tone of 10,000 cps, the differences have the required frequencies and the sums are above 10,000 cps and can be easily filtered out.

For ring modulation I used:

- (a) sinus tone of 10,000 cps,
- (b) very narrow noise band of 10,000 cps,
- (c) impulses filtered at 10,000 cps.

I recorded:

$\alpha$ )	approx.	3	impulses per second,		
$\beta$ )	"	4	"	"	
$\gamma$ )	"	5	"	"	
$\delta$ )	"	7	"	"	
$\epsilon$ )	"	11	"	"	

Recordings ( $\alpha$ ) – ( $\epsilon$ ) were combined in various ways, resulting in rhythms of varying complexity.

B The individual sounds of a structure were assembled to form groups; the groups were placed in a sequence. The first structure, for instance, consists of 30 sounds, each of which, in the original sequence (1, 2, 3, ..., 30), show clear tendencies for pitch and speed. For example, 5 groups were formed for the fifth form-section containing the sounds 9-16, 25-28, 1-8, 17-24, 29-30. But this fifth form-section also belongs to the first large part (there are 5 parts altogether), in which other groupings of the same structure occur too, such as 25-30, 1-24 or 1-30.

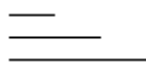
C After the sequence of the sound-groups in a structure had been fixed, they were separated by pauses. The pauses occasionally have the value 0, so that the sounds flow without pauses. – Further examples: groups 1-6, 7-8, 9-15, 16, 17-20, 21-22, 23-27, 28-30 are separated by pauses; all sounds separated by pauses (single sounds).

D Entire structures or individual groups were subjected to transposition. These transpositions shift the sound-groups by small intervals within an octave.

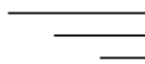
Example: 3 transpositions of a group: (1) 50:60  
 (2) 50:55  
 (3) 50:46

The numerator determines recording speed, the denominator playback speed.

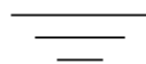
E The results of transposition are synchronised according to one of the following patterns to form superpositions:



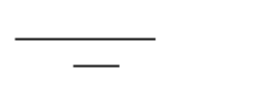
sounds begin simultaneously



sounds stop simultaneously






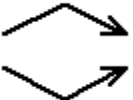
symmetric superposition






serial distribution of points of entry

In the first 3 cases the small transposing intervals cause the original pitch/time tendency to become blurred.

F Sound-groups receive an additional characteristic by means of reverberation. The transition from the unreverberated state to the reverberated one (motion of the sound in spatial depth) and vice versa are in accordance with the motion

-  (1) uniform reverberation
-  (2) increasing reverberation
-  (3) decreasing reverberation
-  (4) combinations of (2) and (3)

G Finally each sound-group (or structure) is given a characteristic envelope:

-  (constant volume)
-  (crescendo) or
-  (decrescendo)

### ESSAY

As in *Klangfiguren*, the material in *Essay* consists of long sound sequences which are defined in three parameters: time-flow, frequency-flow and "elementary" timbre. By elementary timbre we mean here sinus tones, filtered noise and filtered impulses. The "time-flow" is "directionally undefined" by means of the serial distribution of time values in the respective sound sequence. The frequency-flow and the distribution of the elementary timbres are "directionally defined". The frequency curve follows one of 8 forms (fig. 1). The distribution of the elementary timbres is either of "one colour" (only sinus tones, noise or impulses), or "mixed" (double or triple combinations), or it forms a transition between two or three of the elementary timbres. By means of transformation of the material, the elementary timbres become complex.

*Essay* consists of eight form-sections, each of which is based on different material. The complexity of material is characterised by the combination of a frequency curve with a distribution of the elementary timbres. Since only the material itself together with its transformations occurs in one form-section, the complexity of the form-section results from the kind and number of transformations used.

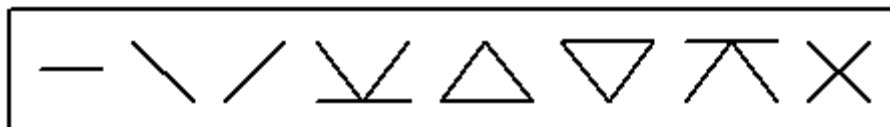


Fig. 1

The tapes of material in *Klangfiguren* consisted of tone sequences of similar timbre in which not only the flow of the pitches but also that of the time was directed (compare *Klangfiguren*). This caused the individual sound to preserve the character of a monochrome, limited sound-object, comparable to instrumental sounds: all sounds have the same timbre, all sounds have a directed flow of pitch and time so that even if the duration of individual sounds (or their pitches) cannot always be perceived, they can be observed to be in duration und pitch proportions.

In *Essay*, however, entire pitch or duration "ranges" are divided into a large number of steps, so that, especially in rapid sections, it is not only difficult to distinguish the individual sounds, but they are intentionally "preserved" in the larger frame. It is no longer the monochrome, limited, individual sound that functions as a the SOUND, but the "sound space", divided into small steps.

This technique can be best demonstrated by the pitch-flow. The frequency range between 50 and 12,800 Hz was divided into 8 octaves. Each tape of material was given a different number of octaves, from 1 to 8. The first three pitch-flow forms (compare fig. 1) traverse their pitch-space completely. Forms 4 to 7 consist of two parts: one horizontal one and one with two directions. For these forms the "pitch-space" is divided into two parts: one for the horizontal flow and one for the directed ones. (Form 8 is treated in a different manner.) Some of the eight forms are, as it were, "contained" in the pitch-space of a horizontal flow (in forms 1, 3-7); in other words, the pitch-space reserved for the horizontal flow is once more subdivided.

As well as the subdivision of the pitch-space, the time-space, i.e. the duration of each tape of material, is also divided up into sections. The number of sections per material varies between 3 and 10. The number of sections corresponds to the number of flow-forms, which – where necessary – are inserted in the horizontal part.

Example of this compositional technique:

Material B: total length 256.5 cm (all cm indications refer to a tape-speed of 76.2 cm/s = 30 ips),  
 number of sections: 6  
 quotient: 3/2  
 durations of sections in the horizontal part (see fig. 2):

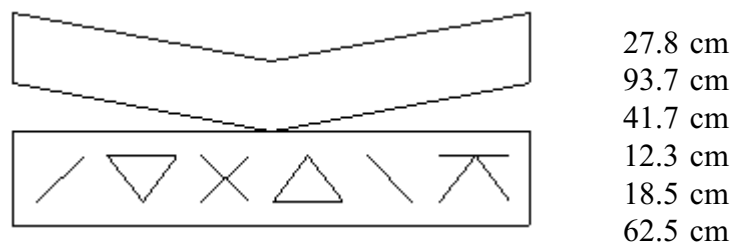


Fig. 2

number of octaves: 7 (50-6400 Hz),  
 division of pitch-space: horizontal: 3 octaves (50-400 Hz),  
 directed: 4 octaves (400-6400 Hz),

subdivision of horizontal part: 8 parts (quotient:  $\sqrt[8]{8}$ ):

- (1) 50 - 65 Hz
- (2) 65 - 84 Hz
- (3) 84 - 109 Hz
- (4) 109 - 141 Hz
- (5) 141 - 183 Hz
- (6) 183 - 238 Hz
- (7) 238 - 309 Hz
- (8) 309 - 400 Hz

subdivision of the sections: section 1: 6 ranges (3-8)

section 2: 2 ranges (4-5)

section 3: 8 ranges (1-8)

section 4: 3 ranges (3-5)

section 5: 5 ranges (2-6)

section 6: 4 ranges (3-6)

number of sounds per section: 8

The given frequency ranges for the sections are always subdivided again if we have a compound form.

Two more examples for the realisation of the horizontal part:

(1) section 1: frequency curve time curve timbre curve

84 Hz	3.2 cm	sinus
102 Hz	2.9 cm	impulse
124 Hz	4.9 cm	sinus
151 Hz	3.9 cm	impulse
183 Hz	3.6 cm	sinus
223 Hz	2.3 cm	impulse
271 Hz	4.4 cm	sinus
329 Hz	2.6 cm	impulse

(2) section 6: frequency curve time curve timbre curve

horizontal:	183 Hz	4.7 cm	sinus
	172 Hz	11.9 cm	sinus
	141 Hz	8.0 cm	sinus
	209 Hz	6.1 cm	sinus
	196 Hz	5.3 cm	sinus
	151 Hz	9.1 cm	sinus
	223 Hz	7.0 cm	sinus
	161 Hz	10.4 cm	sinus
directed:	84 Hz	10.4 cm	impulse
	96 Hz	7.0 cm	impulse
(simultaneous	109 Hz	9.1 cm	impulse
to horizontal	124 Hz	5.3 cm	impulse
part)	133 Hz	6.1 cm	impulse
	116 Hz	8.0 cm	impulse
	102 Hz	11.9 cm	impulse
	90 Hz	4.7 cm	impulse

The tapes of material are transposed in their entirety, the transformations being put together to make a form-section. The form-sections are distinguished by the various numbers and combinations of transformations. The transformations are:

- (1) ring modulation (with sinus, noise or impulse)
- (2) transposition
- (3) filtering
- (4) reverberation
- (5) envelope
- (6) others (distortion by overloading; cutting up the result, putting tape pieces together in different order; transposition using tempophone)

The application of the transformations can be seen in the following table:

form-section	number of transformations	ringm.	transp.	filt.	reverb.	env.	other
1	7	S	x	x	x	x	-
2	6	-	x	-	(x)	x	(dist.)
3	3	-	x	-	x	x	-
4	9	N+S	x	x	x	x	(cutting)
5	16	S+N+I	x	-	(x)	x	-
6	4	-	x	-	x	-	-
7	20	(S)	x	-	(x)	(x)	-
8	5	(N+S)	x	-	x	x	tempophone

Indications in parentheses mean that only in relatively few cases was the relevant transformation performed.

## TERMINUS

### Frequency characteristic

Production of the material for *Terminus* starts with a long sound consisting of five sine wave glissandi. Each sine wave has to start its glissando from a prescribed basic frequency. No sine wave is allowed to become higher than the highest one or lower than the lowest one, so that the spectrum is unambiguously defined in the pitch range.

The five frequencies are: 331, 443, 592, 793, 1062 Hz.

The speed of the motion may change between 4 octaves/sec and 1/4 oct/sec. The motion may only cease on the relevant basic frequency, and only for 4 seconds.

These conditions result in a basic sound exhibiting certain characteristics:

- construction from sine waves,
- certain frequency band width,
- average change in speed of the spectral construction (continuous alteration by means of glissando).

### Volume characteristic

All sine waves were recorded at equal intensity, so that the basic sound has a constant volume. In order to alter the volume, periodic amplitude modulation is employed. In order to obtain more complex alteration of volume, three different periods are superposed, mostly 1/3 Hz, 1 Hz and 4 Hz approx.

### Transformations

Since the idea was to derive all the sounds in the piece from the above-mentioned basic sound, a number of different kinds of transformations had to be carried out. The basic sound's characteristics were not allowed to be neglected. The following list shows the way in which the individual transformations change the "original" which is to be transformed in its structure.

- Transposition: Spectral construction is unchanged.  
Frequency band width (as ratio of upper limit to lower one) is unchanged.  
Average pitch changes according to the transformation interval; the same applies to the average speed of alteration.
- Filtering: Spectral construction, band width and average pitch are changed.  
Speed of alteration is practically unchanged apart from very narrow filtering.
- Reverberation: All characteristics are unchanged except for a general blurring effect (depending on the reverberation system).
- Ring modulation: Spectral construction, band width and pitch are changed.  
Speed of alteration is preserved as long as no glissando sounds are used for modulation.
- Chopping: In the rhythmic range (to about 16 Hz), continuous pitch alteration is replaced by leaps in pitch.  
Spectral construction, band width and speed of alteration are preserved apart from spectral alterations caused by short rise times of impulses and a superposition of the original speed of alteration with the chopping frequency.  
In rapid chopping operations (above 16 Hz) continuous pitch alteration asserts itself again; the quick impulse series is audible as a rough sound.
- Cutting and permutation: Here I mean that short pieces are cut out of transformed (for instance, transposed) sounds and stuck together in a particular order.  
Dominating characteristics of the resulting "structure" are determined by the order and duration of the pieces of tape; the characteristics of the basic sound recede.
- Synchronisation: If several transformations are superposed, their characteristics coalesce to give a new total impression whose complexity is above that of the individual layers, but which still depends on the characteristics of the basic sound and its transformations.

Form

The formal construction of *Terminus* was based on the fact that transformations of sound material which in its turn is already transformed keep on moving further away from the initial material. It was to be expected that the sound material would first differ because of transformation, but would later forfeit these differences because common characteristics caused by transformations dominate the original characteristics of the "Urklänge". The generation diagram can be seen in fig. 3. The results of columns A to D and results E7 and E8 form the first form-section of *Terminus*, the results of columns F to H the second. The results of lines 1 to 3 do not occur in the piece.

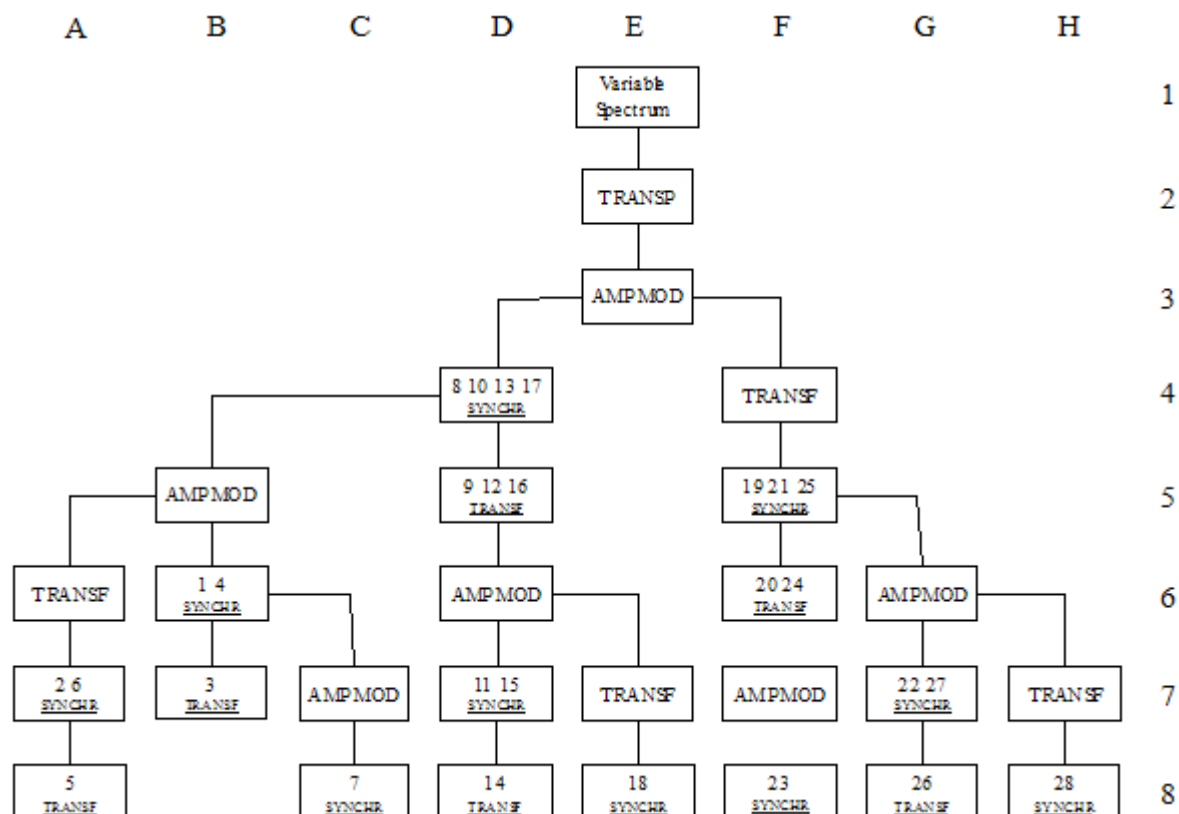


Fig. 3

Amplitude modulation means that each final result was amplitude-modulated three times with three different modulation frequencies, resulting in an irregular modulation after superposition. The results of amplitude modulation are always regarded as intermediate ones, and do not occur in the piece.

Transformation means transposition, filtering, reverberation, ring modulation or chopping (in various combinations, too). The transformations chiefly apply to superpositions of amplitude modulations (B7, D5, D8, G8), but also to synchronisations of several transformations (A8, F6). –

A secondary aspect was first to transform the amplitude modulations and then to synchronise them (A6, E7, F4, H7). In these four cases the transformations were only evaluated as intermediate results (which do therefore not appear in the piece). Occasionally



several transformations were performed for the same square of the plan in order to have variants (see Order).

Synchronisation means the combination of several results of the preceding stage (one line higher in the generation diagram), primarily of several amplitude modulations (B6, C8, F8, G7), but also of several transformations (A7, E8, H8). Here, too, several variants were occasionally produced. –

Results D4 and F5 play a special part, for in these cases it was not merely amplitude modulation or transformations that were superposed. The available material, rather (E3 in the former case, F4 in the latter), was cut up into pieces which were stuck together in layers which were then synchronised. In this way structures occur with structural characteristics which had not been present in the initial material (E3). These structures were then transformed further in their entirety (B5, D5, F6, DF6).

### Order

The final results of sound production should be presented neither in columns reading downwards (progressive distance from the starting-point of each column), nor in lines from left to right (formation of groups of the same degree of transformation), nor in an arbitrary order. In order still to make the distance from the starting-point audible, the following scheme was used, the material of the first form-section having first to be divided into two sub-sections: columns A to C and columns D to E. (Altogether three sub-sections result in this manner; the third one is formed from columns F to H.)

Scheme: start in each sub-section with the lowest line index and use the "permitted" material (underlined in the generation diagram), paying no attention to the columns. Then find the next line containing "permitted" material and use it, if it consists of several parts, from left to right. If more "permitted" items of material should be found "above" some material (same column, lower line index), they are added immediately (in decreasing line index order).

According to this scheme the following sound sequences result for both form-sections (three sub-sections). The lines refer to the generation diagram.

Sub-section 1	line 6: B6
	line 7: A7 – B7, B6
	line 8: A8, A7 – C8
Sub-section 2	line 4: D4
	line 5: D5, D4
	line 6: –
	line 7: D7, D5, D4
	line 8: D8, D7, D5, D4 – E8
Sub-section 3	line 5: F5
	line 6: F6, F5
	line 7: G7
	line 8: F8, F6, F5 – G8, G7 – H8

This demonstrates the meaning of the variants; if according to this scheme a square of the plan is repeatedly arrived at, the relevant material should not be repeated literally.

## FUNKTIONEN

For the production of the experimental series of works called *Funktionen* use was made of the studio's voltage-controlled equipment.

The source of all control voltages was the "variable function generator" (VFG), at which two voltage curves were set:

- (a) a "serial" curve (see fig. 4),
- (b) a 01-curve consisting of impulses of maximum amplitude (1) and the amplitude 0. Both voltage values alternate (010101...), which results in a comb-like curve.

to (a) The "serial" curve was used in both its original square impulses form (fig. 4) and in a filtered form. The 50 samples of a period of the VFG were used either periodically or aperiodically.

to (b) The 01-curve was only used in its unfiltered form and used aperiodically.

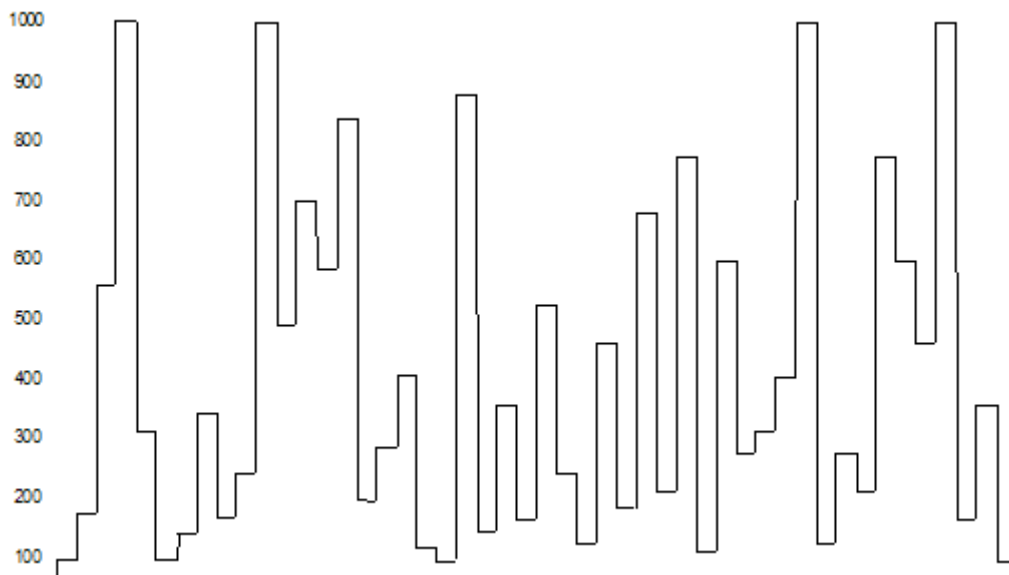


Fig. 4

The idea of the experiment was to produce the entire sound material for several versions (*Funktion Grün*, *Funktion Gelb*, *Funktion Orange*, *Funktion Rot*) exclusively by means of the two curves a and b. If the curve set at the VFG is used rapidly enough, a sound rich in harmonics results, which can be used as basic sound material. Otherwise a low-frequency signal results (a direct voltage with slowly altering amplitude), which can be used to control other equipment. For these purposes tapes of material were recorded bearing the names BASIS, MEL, RING, MOD, and which will be explained in the following.

**BASIS**

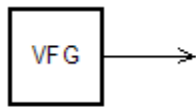


Fig. 5

The serial curve is rapidly used, unfiltered, at various speeds, so that sounds which are rich in harmonics and which have various fundamental frequencies result (13 sounds between 32 and 784 Hz). Fig. 5 shows the block diagram. The arrow indicates recording and loudspeaker playback.

**MEL**

The serial curve is used, unfiltered, at various speeds (10 frequencies between 32 and 724 Hz). The resulting voltage curves control a sinewave oscillator set so that the highest amplitude corresponds to 1000 Hz, the lowest to 100 Hz.

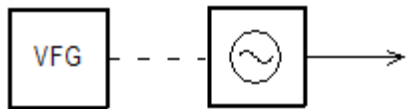


Fig. 6

This results in an extremely rapidly recurring "melody" (at least 32 times per second, not more than 724 times per second), which is, however, heard as a complex sound. The broken line in fig. 6 indicates that the signal from the VFG is used as control voltage for the oscillator.

**PULS**

The serial curve is again used in its unfiltered form. But in contrast to BASIS and MEL, the individual samples of a period do not succeed each other regularly, but irregularly. For this a noise signal is used; the peaks of the noise signal trigger the individual samples (see fig. 7; trigger impulses are indicated by a dotted line). In this manner impulses of various amplitudes result. The average impulse frequency was between 1.2 and 10.2 impulses per second.



Fig. 7

These three sorts of material (BASIS, MEL and PULS) serve as sound material which can then be subjected to further transformations. The transformations consist of ring modulation, filtering and reverberation. For ring modulation an audio signal is necessary, for filtering and reverberation a control signal for an amplitude modulator, which regulates the proportion of filtering and reverberation.

Since both the audio and control signals should be structured aperiodically, the samples of the VFG must be triggered by a noise signal. This results in the following circuits:

**RING MODULATION (fig. 8)**

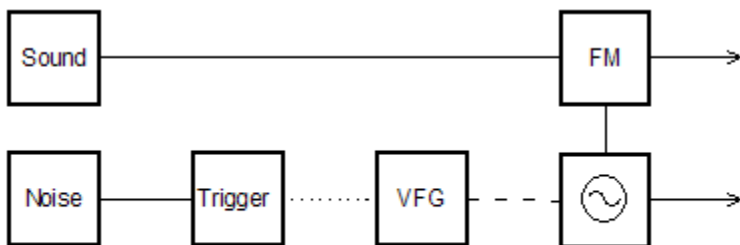


Fig. 8

The amplitude peaks of a noise signal are used as start impulses for the VFG which in its turn supplies the direct voltage set per sample to an oscillator. The oscillator frequency controls the ring-modulator.

FILTERING / REVERBERATION (fig. 9)

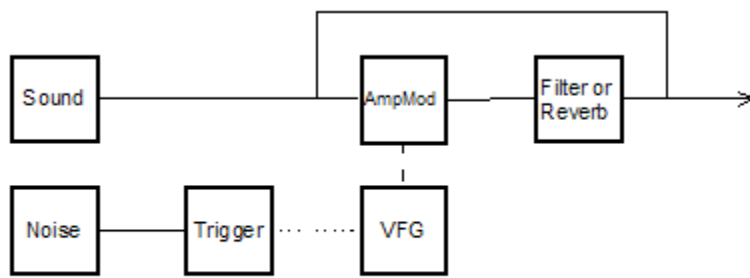


Fig. 9

The amplitude peaks of a noise signal are used as start impulses for the VFG which in its turn supplies the direct voltage set per sample to an amplitude modulator. The amplitude modulator regulates the intensity proportion for the filter or reverberation device.



Fig. 10

For technical reasons, however, the control signals were previously recorded on tape (fig. 10), so that during sound production the ring-modulator could be directly

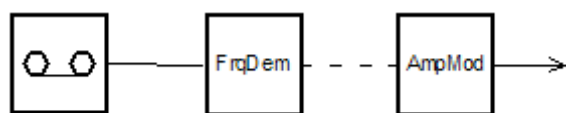


Fig. 11

connected with this tape, and the filter (or reverberation device) via a frequency demodulator. The frequency demodulator is necessary because low-frequent voltage alterations cannot be directly registered on tape. The interspersed oscillator (in fig. 10) is for frequency modulation, which is cancelled by the

demodulator (in fig. 11).

The control signals for sound transformation are called RING and MOD and are defined as follows:

RING

The serial curve is used partly unfiltered, partly filtered (by means of the VFG's own filters for rise and fall-times of the samples). It is used aperiodically (by means of noise signal), the following oscillator produces frequencies between 100 Hz and 1000 Hz. The average speed of the trigger impulses is varied in six ways. The tone-sequences on tape are then transposed in four steps by alteration of the playback speed. The transposition intervals are: 25/50, 40/50, 63/50 and 100/50.

Altogether 28 different control signals for the ring modulator were produced in this manner.

MOD

The serial curve is triggered in its filtered form and aperiodically used (13 variants). Moreover the 01-curve is used for 13 more variants – unfiltered and also aperiodically triggered. The trigger impulses then alternately produce a constant amplitude and a pause. In this manner the material is chopped (after amplitude modulation).

## Sound production

The sounds from categories BASIS, MEL and PULS on the one hand and the control voltages from categories RING and MOD on the other hand were combined to form 36 production models. In the simplest case (model 1), BASIS sounds are used unchanged, later to be accompanied by ring modulation and filtering (models 2 to 12). In the remaining models (13 to 36), one or two control voltages are used for the amplitude modulator (see figs. 12 and 13).

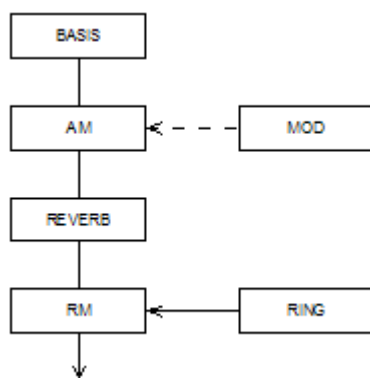


Fig. 12 (left)

The basic material is amplitude-modulated (envelope or chopping), reverberated and then ring-modulated (model 31).

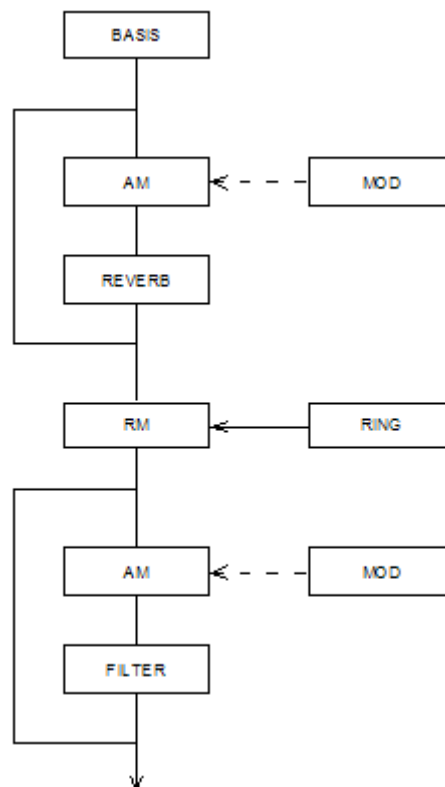


Fig. 13 (right)

The basic material is (as in fig. 12) amplitude-modulated and reverberated, at the same time mixed with its original form. This mixture is ring-modulated, amplitude-modulated and filtered. The filtered part can be mixed with the unfiltered ring-modulator result (model 34).

Such a model merely indicates the circuit, but tells us nothing about the sounds used in the circuit. It would therefore accordingly be possible to produce additional basis-sounds and control voltages for other versions of *Funktionen*. But even with the present restraints a vast number of combinations is possible.

In order to produce a version, the following questions have to be answered:

- which models are to be used?
- which sounds (or control voltages) are to be used in each model?
- how long should a sounding result be?
- in which order should the sounding results appear?
- in what fashion should the sounding results be distributed among several tracks?

For *Funktion Grün* each model was used four times (once for each loudspeaker). This means that the 36 combination possibilities are presented completely once per channel. With regard

to the musical form this leads to a single, closed "block" in which the 36 models are presented in an arbitrary sequence, but with various durations. According to this "monolithic" idea, the selection of basis-sounds and control voltages per sound was left to chance, as was also the case with durations and order of the sounds per loudspeaker. This composition process seemed to be justified because chance already played an important part during sound production (combination of basis-sounds and control voltages in the circuit models). The use of such circuit models is based on the assumption that when similar basic sounds and control voltages are used sound variants result, and that the groups of variants are also similar to one another to the same extent to which the individual circuit models vary a basic model.

### **Musical form**

In this manner a complex of relationships within fixed limits results: the circuit models vary a basic scheme, the basic sounds and control voltages to be used in the models are based on the same curve that was set at the function generator and otherwise differ in slight transpositions of pitch and time (density differences in aleatoric control signals). In view of these manifold relationships and the unpredictability of the result when basic sounds and control voltages are combined within the circuit models, the form of the piece is fixed within certain limits before sound results are put into an order – if we wish to understand by "form" the totality of all possible relationships. (Perhaps one should introduce the term "form potential" for this.) If however this form potential becomes actuality (each sound being given a duration and a position in the piece), we have something that exhibits a particular relationship to the form potential. The type of relationship cannot be recognised until the potential has become actuality several times (in variants). The more closely the components of the form potential are woven together, the lesser the extent to which the various actualities differentiate with regard to one another and to the potential; the potential is then in practice the form itself.

The intention was to produce various versions according to the example of *Funktion Grün* (monolithic form, each sound once per channel, variants only by alteration of the sound assembly in the circuit models, the durations and order of the sounds). Lack of time was not the only reason why this plan was not carried out. Another reason arose from the observation that the random mixture of all sounds by no means leads to an amorphous result; the listening ear rather tends to group sounds and to relate such groups of sounds as entireties to each other. If the aleatoric "actual form" provokes perception of grouping, the question might be: to what extent could this grouping be influenced by the fact that the material of the "potential form" is first grouped and then left to chance for the production of the "actual form"?

The versions *Gelb*, *Orange* and *Rot* were produced according to this question. *Funktion Gelb* was given 3 form-sections, *Orange* 4 form-sections and *Rot* 6 form-sections. For this purpose the 36 circuits models were assembled in groups, each form-section being characterised by the use of such a group. This means that most sounds of a form-section were taken from the characterising group, a few more sounds from the other groups. The form-sections were given an additional characteristic by various treatments of the loudness (only loud, only soft, characteristic transitions, etc.).

## Programming

When unalterable basic sounds and control signals are fixed on magnetic tape, a programmatic aspect enters the field. The rule used in the *Funktionen* that the assembly of the sounds and control signals to form circuit models, and the choice of durations and orders, should be left to chance (although with the repetition prohibition which we know from SERIES), accentuates this programmatic aspect. A computer would also have been able to produce all the basic sounds and control voltages according to the data which were set at the variable function generator; further decisions were left to a computer in any case. But during production a problem arose: all basic sounds and control voltages last for 90 seconds; but during production I started these tapes always at different positions in order to obtain sounds that were not all the same. Still, the result is a sound which in most cases is longer than the duration required by the score. For shorter sounds a suitable section was sought in order to avoid a silence resulting instead of a sound. For longer sounds, on the other hand, an arbitrary piece of tape was cut to the required length. This arbitrary choice could also have been left to a computer. I tried during production not to make any decision that a computer could not have made either.

This is actually the experimental aspect of the series of *Funktionen*. If the production of music is to be entrusted to automatic processes, the automata must be programmed; if music is to be programmed, we have to know what can be stated about music in the form of programs. This is why I did not make any form-plans for the *Funktionen*, neither were there any material-plans from which a form could develop more or less compulsorily. The idea of the potential form served rather as a scheme for all decisions which had to be made during composition (including realisation). Music is then no longer primarily conceived as a guide for premeditated emotions, but as the density of the possible relationships which become actuality not before their production under the influence of chance, and which during performance are presented to the listener as material on which he must test his capability of relating to one another sounds beyond any environmental associations, independent of bodily actions required to produce sounds, to relate them to one another and to articulate these relationships as musical language.