

UTRECHT STATE UNIVERSITY
INSTITUTE OF SONOLOGY

**VOLTAGE CONTROL:
DIAGRAMS AND CIRCUITRY**

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V o l t a g e C o n t r o l :

D i a g r a m s a n d C i r c u i t r y

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C O N T E N T S

5	Introduction
6	PERIODIC AUDIO SIGNALS APERIODIC AUDIO SIGNALS
7	CONTROL SIGNALS
8	Variable Voltage Source (Ex.1)
	PERIODIC CONTROL SIGNALS
10	Frequency alteration by constant waveform (Ex. 2-4)
16	Amplitude alteration by constant waveform (Ex. 5)
22	Combined frequency and amplitude alteration (Ex. 6-7)
32	Frequency alteration by complex waveform (Ex. 8)
36	Percussive sounds (Ex. 9-10)
	APERIODIC CONTROL SIGNALS
40	Amplitude alteration by variable waveform (Ex. 11)
42	Combined frequency and amplitude alteration by variable waveforms (Ex. 12-17)
56	Chopped and percussive sounds (Ex. 18-22)
71	THE LEVEL SWITCH (Variable Voltage Comparator) (Ex. 23)
78	THE FLIPFLOP (Ex. 24)
81	THE SAMPLE AND HOLD CIRCUIT (Ex. 25)
86	THE VARIABLE FUNCTION GENERATOR (Ex. 26-28)
90	THE VOLTAGE-CONTROLLED FILTER (Ex. 29-33)

The complete text is stored on DECTape 'DIDAC 1' under the following file names:

VOLCON 001	(Introduction - Variable Voltage Source)
VOLCON 002	(PERIODIC CONTROL SIGNALS)
VOLCON 003	(APERIODIC CONTROL SIGNALS)
VOLCON 004	(LEVEL SWITCH - SAMPLE & HOLD)
VOLCON 005	(VFG and VCF)

This summary contains no information about how studio apparatus is built or how it works, and there are no recipes for sound production. The aim is a more or less systematic survey of the available apparatus and some possibilities of its application.

There are two chief tendencies in the development of electronic studios:

- (a) the tendency towards the "construction kit" system: one special piece of apparatus is built for each function; complex functions can be obtained by connecting individual pieces of apparatus (e.g. Utrecht);
- (b) the tendency towards the electronic music instrument: each individual piece of apparatus serves a complex purpose; the electronic music instrument thus represents a premeditated selection of all conceivable complex functions (e.g. Synthesizer).

This summary will be limited to the first of these tendencies.

In this summary a distinction is made between audio signals and control signals. Audio signals are audible alternating oscillations in the range between 16 and 16.000 Hz. Control signals are variable direct voltages, the fluctuations usually occurring below 16 Hz. Both types of signals can be stored on tape, audio signals directly, control signals after frequency modulation.

Another distinction can be made between periodic and aperiodic signals. In periodic signals a simple or complex waveform is repeated at regular intervals; aperiodic signals contain no repetitions at all. Although in the production of sounds for electronic music use is frequently made of hybrid forms (waveforms whose complexity makes it either just possible or impossible for symmetries to be recognized), this summary is limited to examples of periodic oscillations (e.g. sinewaves, simple superpositions) and aperiodic oscillations (noises).

This results in a classification into audio signals and control signals on the one hand, and periodic and aperiodic signals on the other. The categories of periodic and aperiodic audio signals are merely mentioned, since the practical exercises provide sufficient opportunity for the production of illustrative material. For the categories of periodic and aperiodic control signals there are not only block diagrams but also illustrations of waveforms recorded on an ultra-violet recorder.

This text originally summarized a series of lectures and apart from certain modifications is reprinted here in its original form. This accounts for the rough distinction as to periodic and aperiodic signals, which might be useful for the composer's preliminary orientation.

PERIODIC AUDIO SIGNALS

Standard functions: (a) sinewave, (b) triangular wave, (c) square wave, (d) sawtooth wave.
Complex functions: (e) additive or multiplicative mixture of several sinewaves, (f) special generators (e.g. Harmonic Tone Generator of Beauchamp, Variable Function Generator of Tempelaars).

In musical terms periodic chopping can also be classified with the periodic signals; the periodicity is restricted to the rhythmic range <16 Hz.

APERIODIC AUDIO SIGNALS

- (a) white noise,
- (b) noise bands with constant bandwidth (Brüel & Kjaer generator),
- (c) filtered noise (octave, third, Allison filter etc.),
- (d) tone mixtures with fundamental <16 Hz,
- (e) additive mixture of aperiodic signals,
- (f) multiplicative mixture and modulation of periodic or aperiodic signals with aperiodic results:
 - (1) ring modulation,
 - (2) reverberation,
 - (3) chopping,
 - (4) splicing,
 - (5) amplitude modulation.

REMARK

The difference between periodic and aperiodic signals is mainly important for composers who organize a composition according to structural ideas which are to be applied to all parameters (regularity, irregularity). But even without this limitation the direct production of audio signals will lead to a final synchronisation based on a score which can be said to be "scored" with these sounds.

On the other hand voltage control makes it possible to produce both the sound and the form in one process, so that the sounds determine the form and vice versa. This method comes into its own in sound production with the computer. In both cases the composer can activate "playing processes", the musical idea not describing the structure of individual sounds or of the entire form, but the structure of the playing processes.

Control signals are an alternative to manual operation and can be stored. This makes it possible for production processes to be determined in advance and to be activated at any desired time. This can be important

- if precise instructions are to be followed, eliminating any form of improvisation; the control signal can be put together from its physical determinants and reproduced in an unchanged fashion. This also applies to random quantities cropping up during tryouts or improvisation and which are to appear unchanged in the final version.
- if several apparatus settings are to be changed simultaneously according to exact instructions; a control signal can be tried out and stored for each process.

Control signals are also important for various kinds of remote control, such as live electronic music and real time data processing (control according to the momentary situation of the sound). Most voltage-controlled equipment can also be operated by hand if desired.

Three questions must be asked and answered about the treatment of control signals:

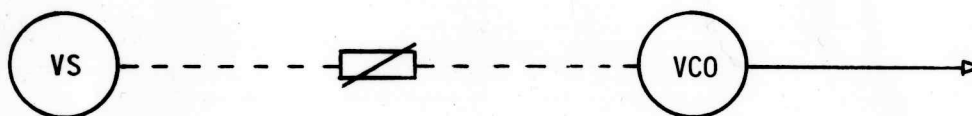
- (1) WHAT IS A CONTROL SIGNAL? A control signal is a direct voltage whose amplitude changes slowly between fixed limits (0 V and +5 V in the Utrecht studio). The amplitude changing between the electrical limits can be compared to the turning of a knob between its mechanical limits. In both cases there is a correspondence between the possible settings and the parameter values of the controlled signal (e.g. pitch or intensity). A control signal is "slow" with respect to the signal that it controls; basically however there are no limits to the fluctuation of the control voltage.
- (2) WHICH APPARATUS CAN BE CONTROLLED?
 - (a) with regard to frequency: oscillators for sine, triangle, square and sawtooth waves. The control of these oscillators only applies to the frequency, not the amplitude. Voltage-controlled oscillators are abbreviated VCO.
 - (b) with regard to amplitude: amplitude modulators. These are amplifiers whose amplification factor depends on the control voltage. The abbreviation is therefore VCA = voltage-controlled amplifier.
 - (c) with regard to the spectrum: voltage-controlled filter (VCF). Filters are known as low-pass (LP), high-pass (HP) and band pass. Low and high-pass only let low or high frequencies through, the cutoff frequency is variable in both cases. Band-pass filters let a frequency band through; if the limit frequencies consist of low and high pass, they are both variable, allowing a band of variable width to be shifted up and down in the frequency range at will. There are also band-pass filters with separate control for bandwidth (BW) and centre frequency (CF). Band-stop filters work like band-pass filters except that they eliminate the set frequency band and let the rest of the

- spectrum through.
- (3) HOW CAN CONTROL SIGNALS BE PRODUCED?
- (a) with a variable direct voltage source.
 - (b) with low-frequent oscillators for standard functions.
 - (c) with noise generators. Noise signals are sometimes not suitable for voltage control until they have been filtered or demodulated.
 - (d) with demodulators which detect the amplitude or pitch curve of an audio signal and produce a corresponding direct voltage signal. Any kind of signal can be demodulated: generator sounds, stored sounds (tape), microphone signals.
 - (e) with the variable function generator; any voltage curves can be set and reproduced at any speed.

In block diagrams it is advisable to indicate audio signals by continuous lines, control voltages by dashes and trigger signals for switch functions by dotted lines.

Besides the diagrams there is a tape of the resulting audio signals. The tape also contains sound models recorded as alternatives to the diagrams, but not represented graphically. Students are advised not only to build the given circuits but also to reconstruct the alternatives in the sound models.

The abbreviations used in the circuit plans do not conform to those in use at the institute at present. In the individual commentaries however the abbreviations used at the institute are indicated in square brackets [].



EXAMPLE 1: Variable Voltage Source

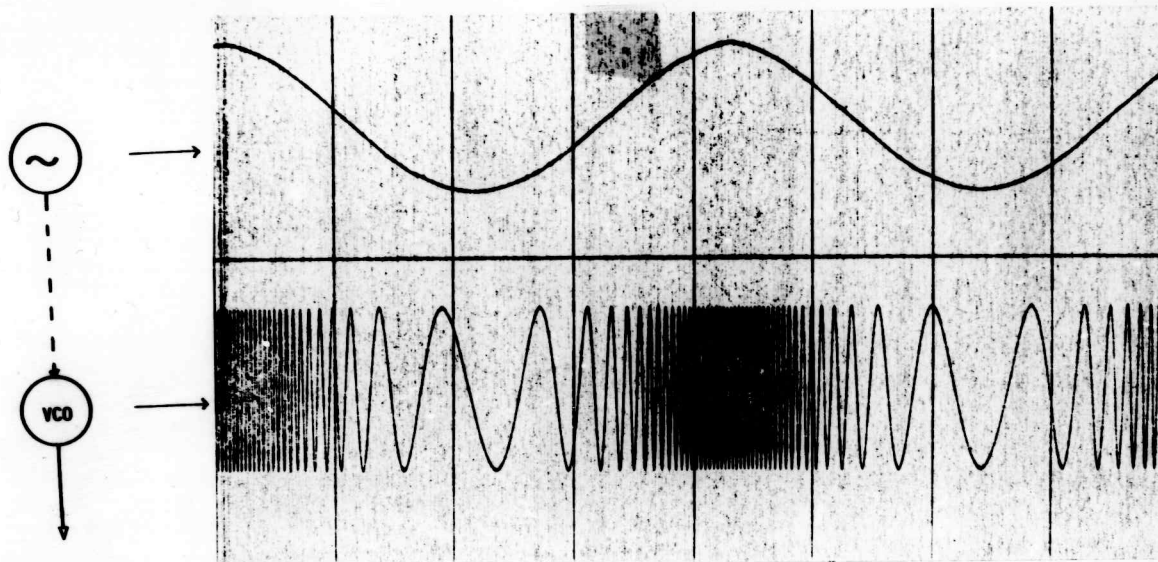
Controlled voltage source (VS) with VCO [V-FUG]. The relationship between the control voltage and the resulting frequency depends on the type of oscillator and its pre-settings.

(Tape examples: (a) HP 100 Hz, (b) EXACT 1000 Hz, (c) PHILIPS 300 Hz, range 3,3 corresponding approximately to 100-1000 Hz)

Commentary:

The voltage source supplies a fixed voltage (+5 V), which is regulated by hand, using a fader.

The generator produces an audio signal, the frequency of which depends on the control voltage.

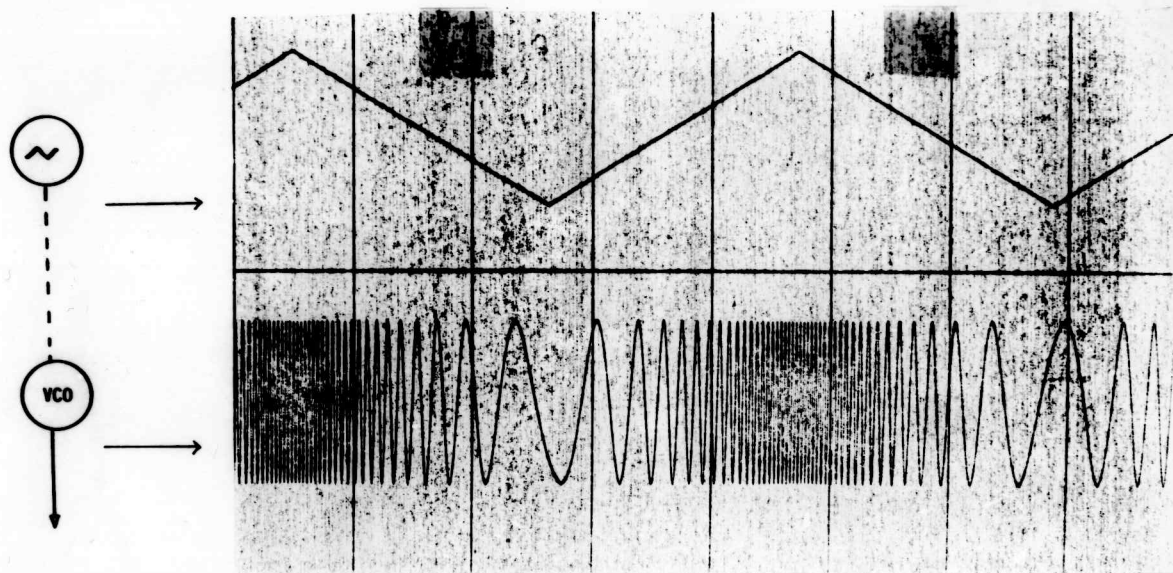


EXAMPLE 2a: Frequency alteration by means of constant sinewave.

Commentary:

The top part of the diagram shows a low-frequent sinewave signal, used here for voltage control; the lower part shows a high-frequent audio signal which, at a constant amplitude, conforms in its frequency to the amplitude of the control signal.

The ratio between the frequency of the control signal and the frequency range of the resulting audio signal was selected in this and all subsequent examples so that the dependency can be easily read. The corresponding ratios in the sound models are different, and were recorded independently of the diagrams.

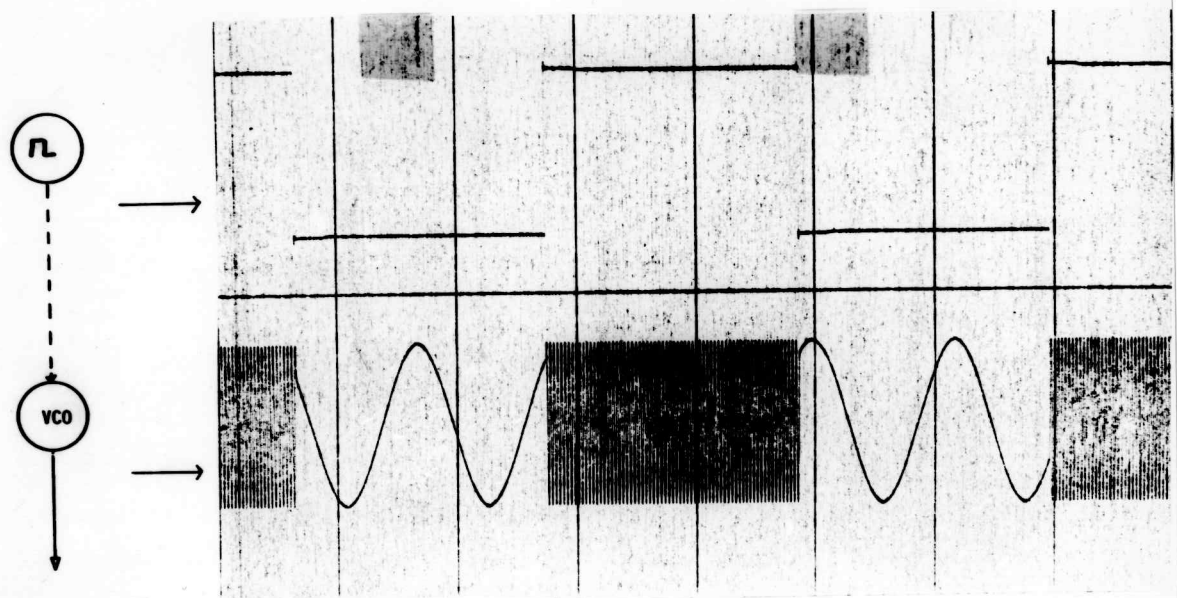


EXAMPLE 2b: Frequency alteration by means of constant triangular wave.

Commentary:

The sinewave control signal from example 2a was replaced here by a triangular control signal.

This obviously has hardly any consequences for the resulting audio signal.



EXAMPLE 2c: Frequency alteration by means of constant square wave.

Commentary:

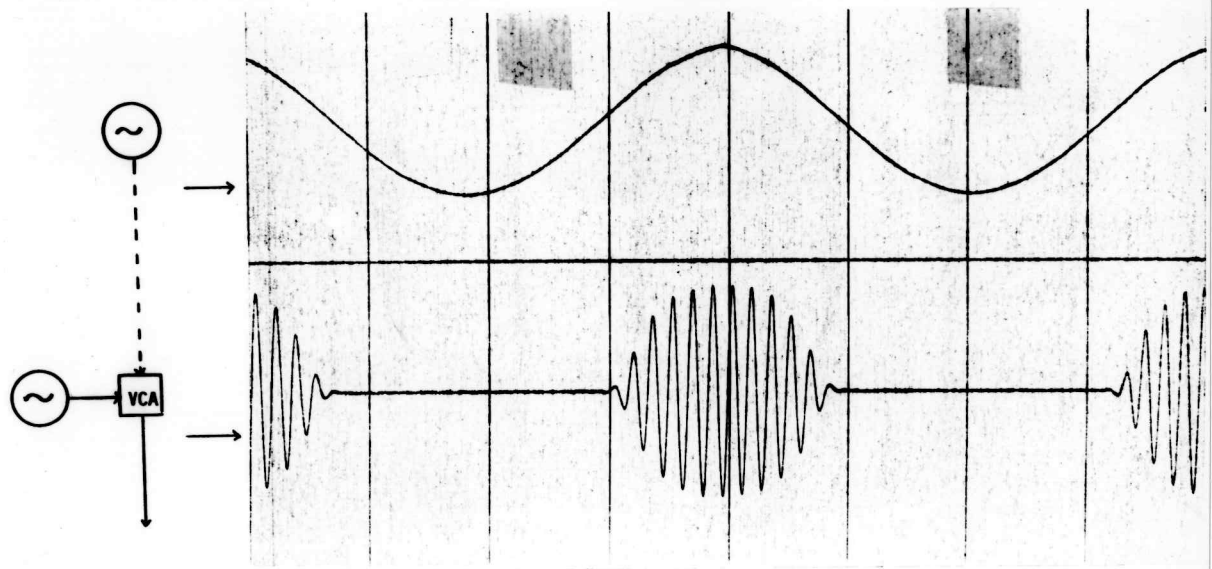
The sinewave control signal from example 2a was replaced here by a square control signal.

The frequency of the result can be seen to jump to and fro between two frequencies, instead (as in the two previous examples) of sliding to and fro.

On tape only:

EXAMPLE 3: Frequency alteration of a square wave signal by means of constant sinewave.

EXAMPLE 4: Frequency alteration by means of variable control frequency.

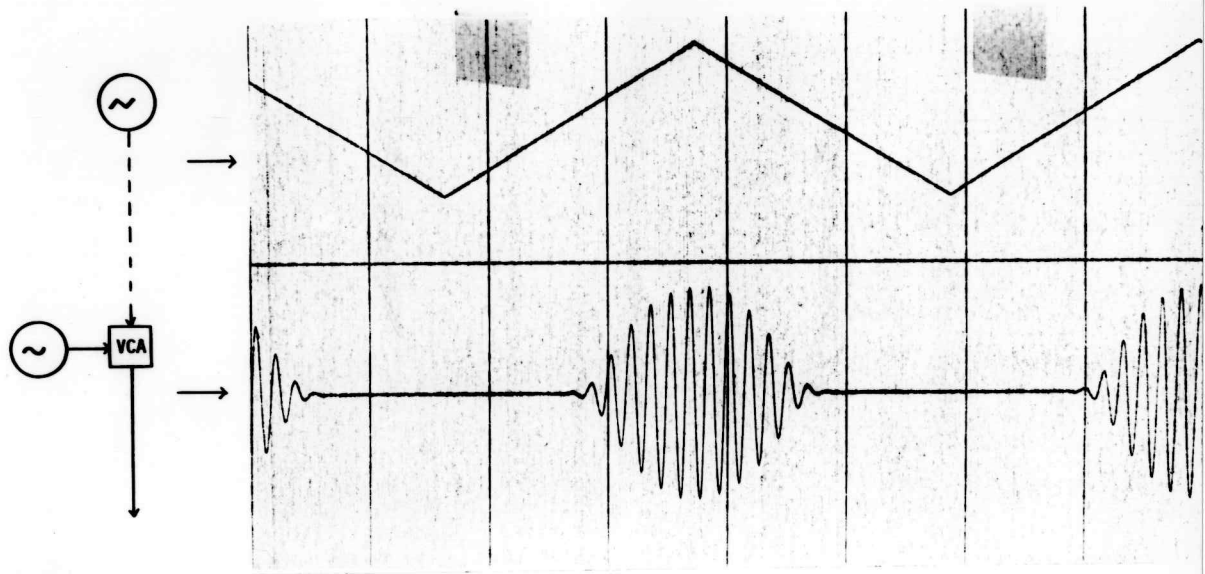


EXAMPLE 5a: Amplitude alteration by means of constant sinewave.

Commentary:

The top part of the diagram shows a low-frequent, sinewave control signal and the lower part an audio signal whose amplitude is regulated by a VCA [V-AMM].

In this example and the following, the amplitude modulator was set to positive voltages only; the result therefore has an amplitude of zero when the control signal is negative. In order to avoid this, the control signal could have been shifted to the positive range by a [DCA].

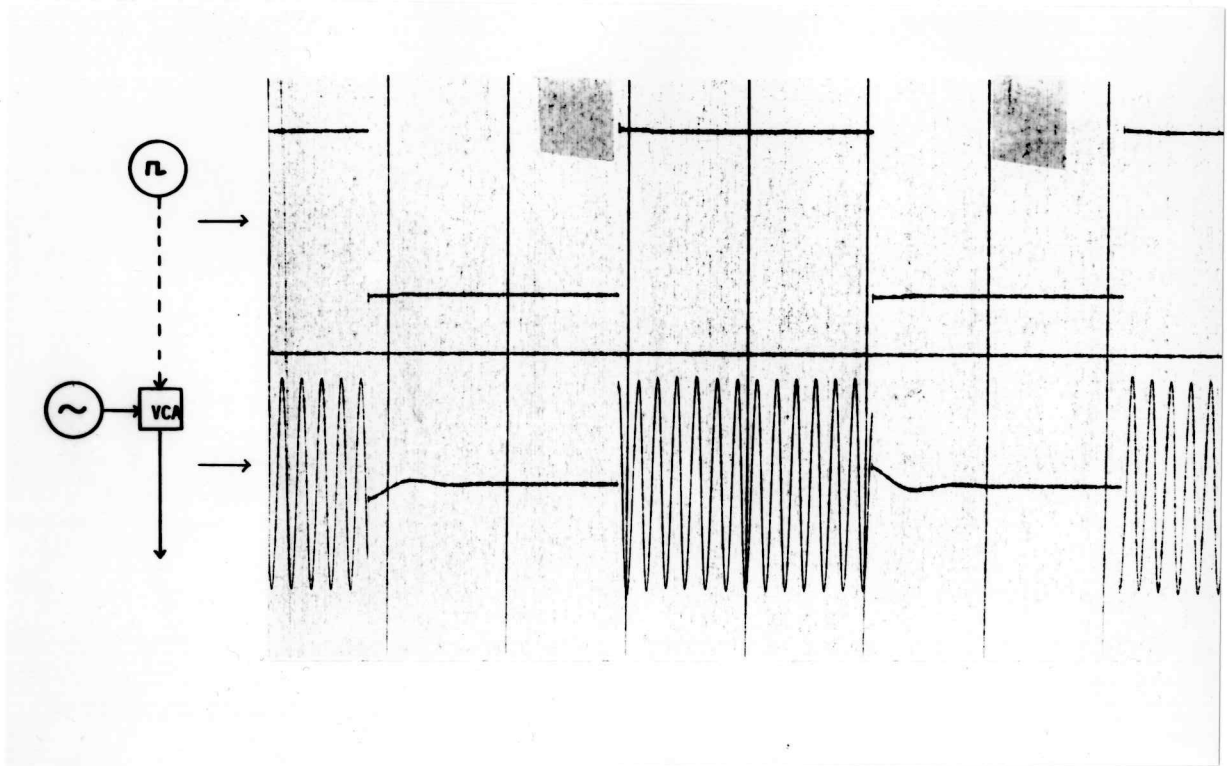


EXAMPLE 5b: Amplitude alteration by means of constant triangular wave.

Commentary:

The sinewave control signal in example 5a was replaced here by a triangular control signal.

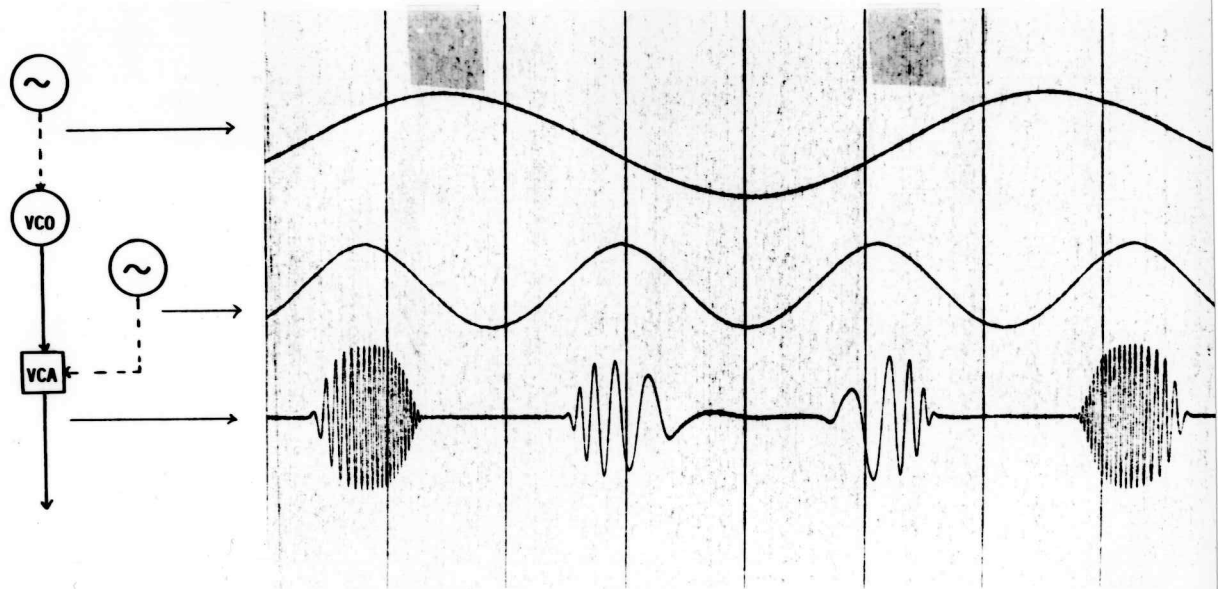
This does not make much difference to the result (compare examples 2a and 2b).



EXAMPLE 5c: Amplitude alteration by means of constant square wave.

Commentary:

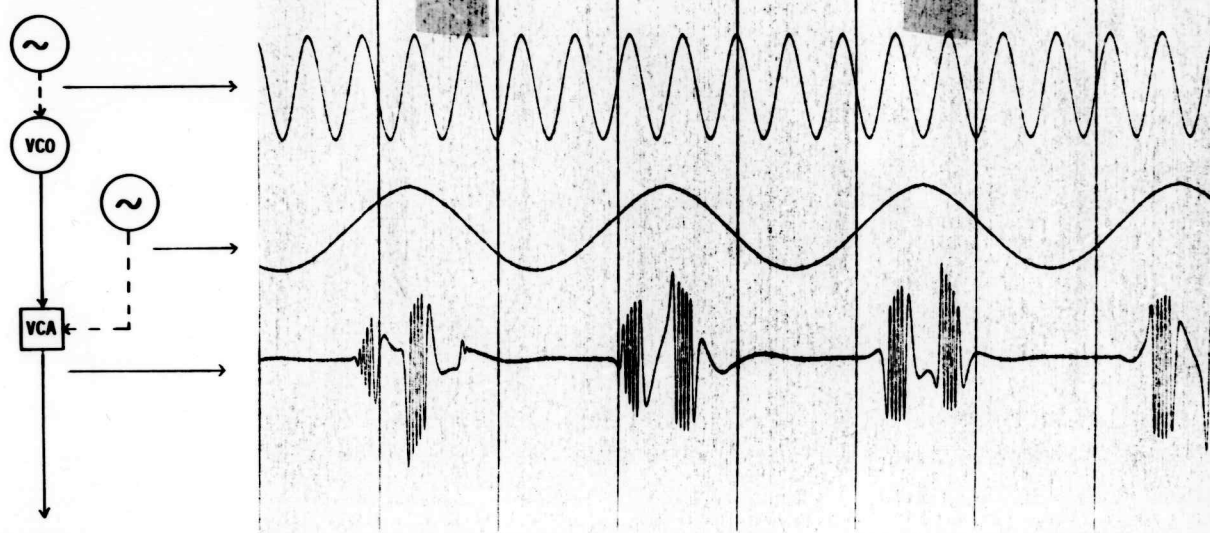
The sinewave control signal in example 5a was replaced here by a square control signal. The amplitude modulator now works as a chopper, either letting the input signal through as a whole or not at all.



EXAMPLE 6a: Frequency and amplitude alteration by means of two independent control frequencies. Different sounds result from different frequency ratios between the two control frequencies.

Commentary:

The top part of the diagram shows two independent sinewave oscillations of different frequency. The top one controls a generator VCO [V-FUG], the bottom one an amplitude modulator VCA [V-AMM]. Whilst the first signal produces a sine glissando moving between two limit values at a particular rate, the second signal is used to cut the first one into pieces and to give each piece a growing and decaying envelope. Because of the different frequencies of the control signals, each envelope has different "contents": a different piece of the glissando.

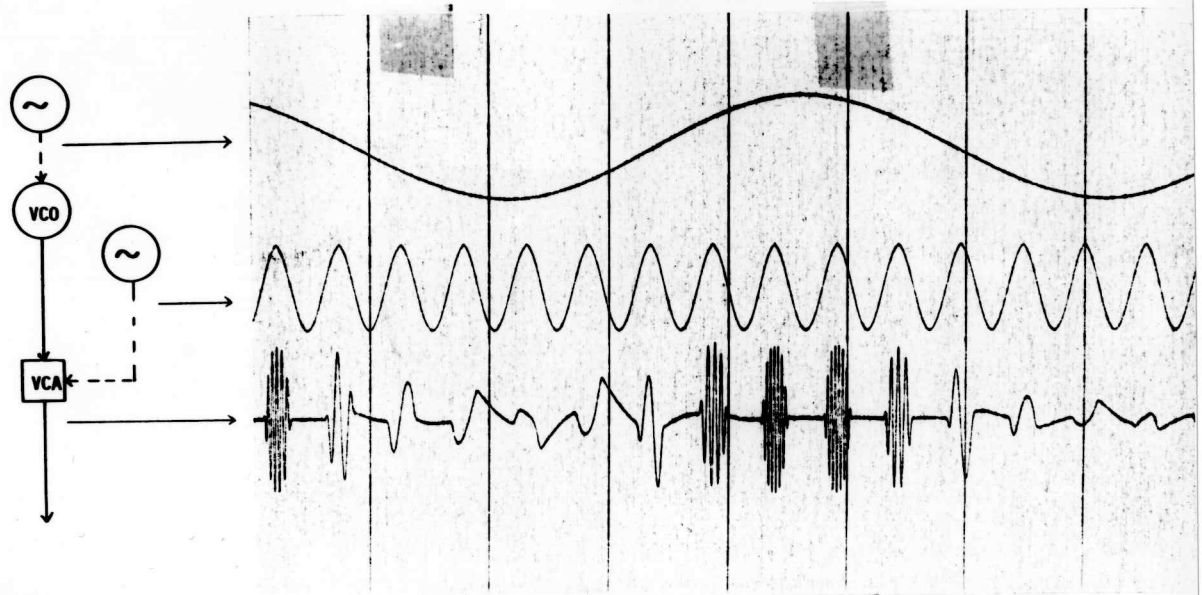


EXAMPLE 6b (see ex. 6a).

Commentary:

In this example the circumstances of example 6a are reversed: the glissando moves rapidly up and down, whilst relatively long envelopes permit several glissandi to be heard.

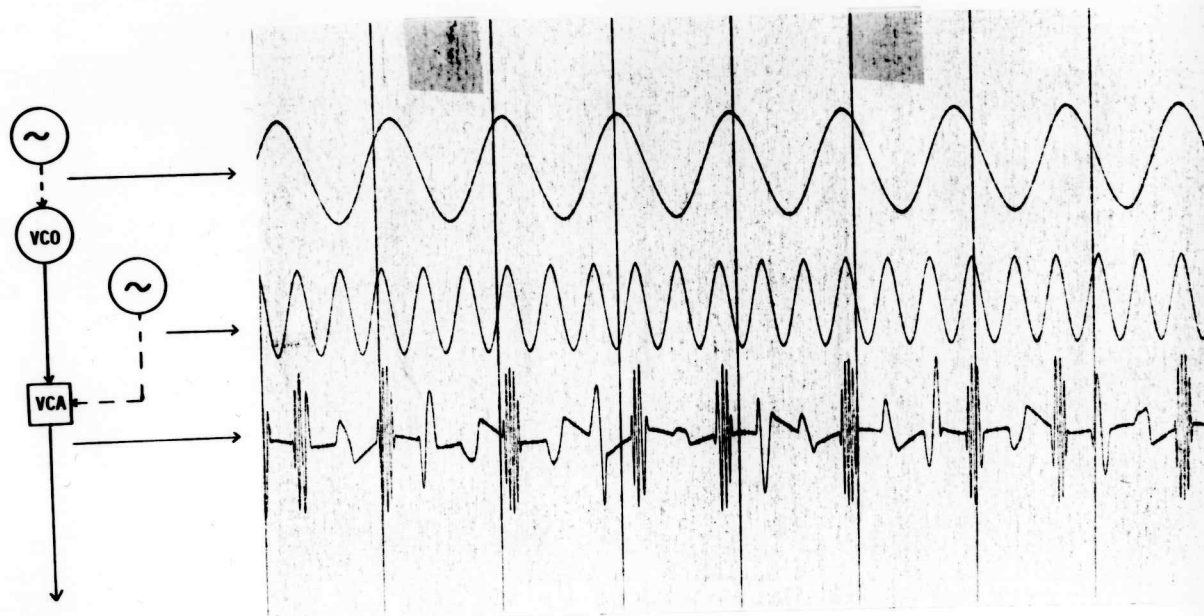
The ratio of the frequencies of both control signals can be changed by hand at will.



EXAMPLE 6c (see ex. 6a).

Commentary:

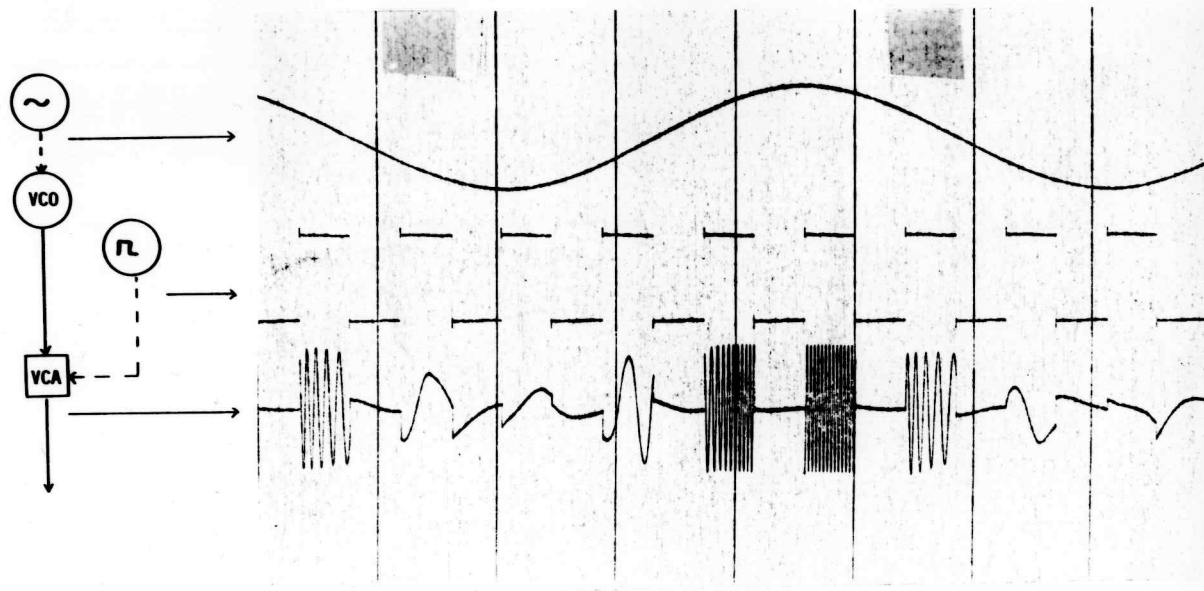
An example of an extreme ratio between the frequencies of the control voltages: slow pitch change, rapid envelopes.



EXAMPLE 6d (see ex. 6a).

Commentary:

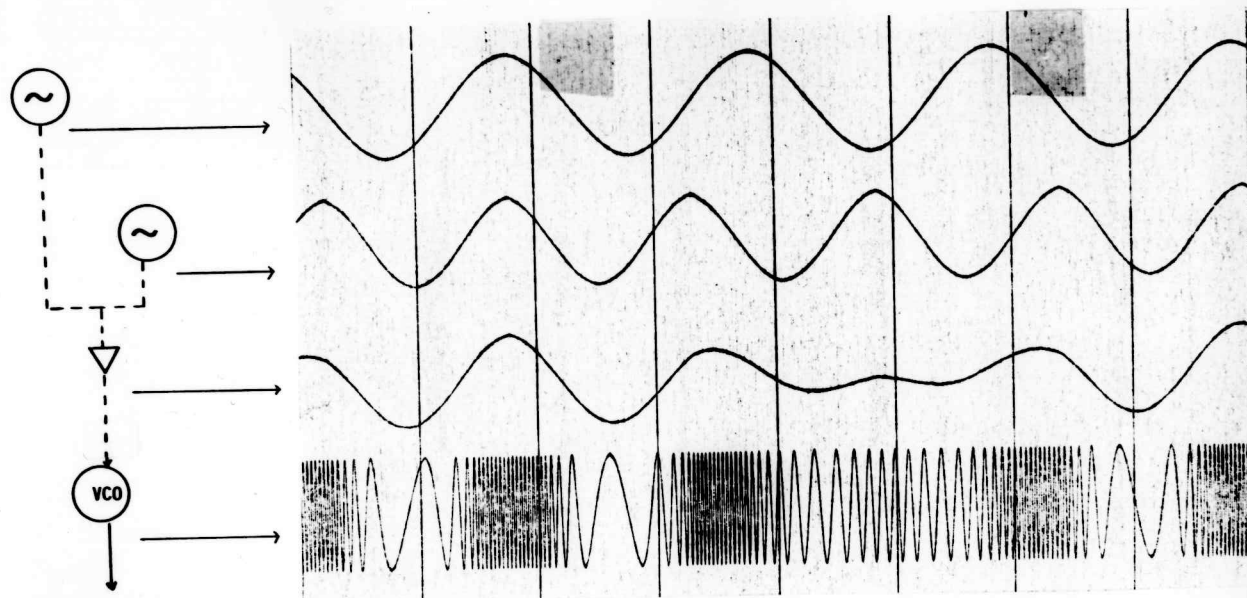
An example of the use of higher frequencies for both control signals.



EXAMPLE 7: As ex. 6, but amplitude alteration by means of square wave signal.

Commentary:

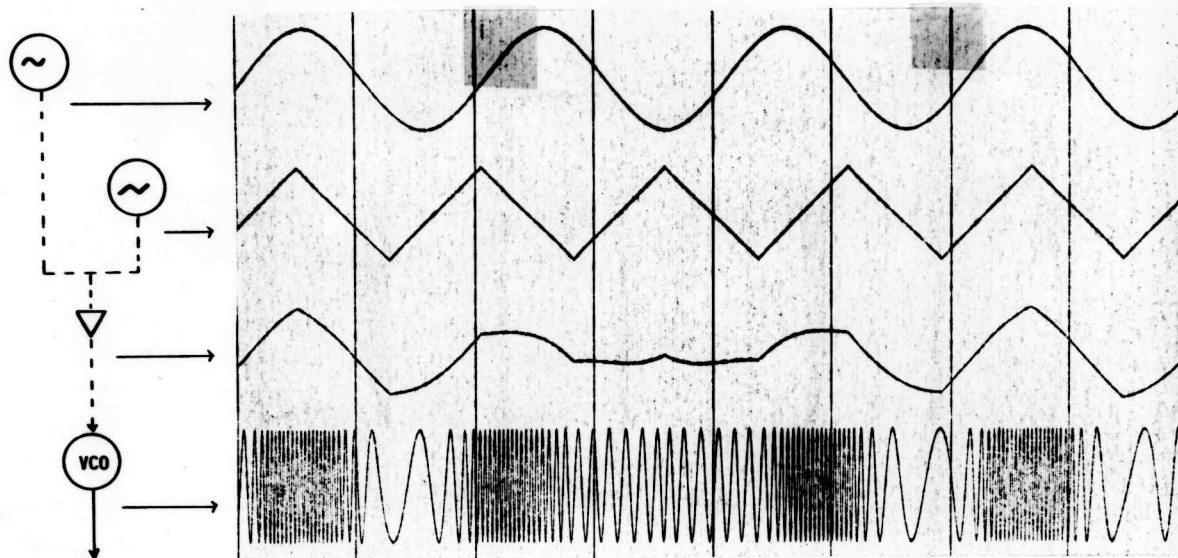
Pitch glissando as in the previous examples, but with "chopping" instead of envelopes.



EXAMPLE 8a: Addition of two sinewaves in order to control the frequency.

Commentary:

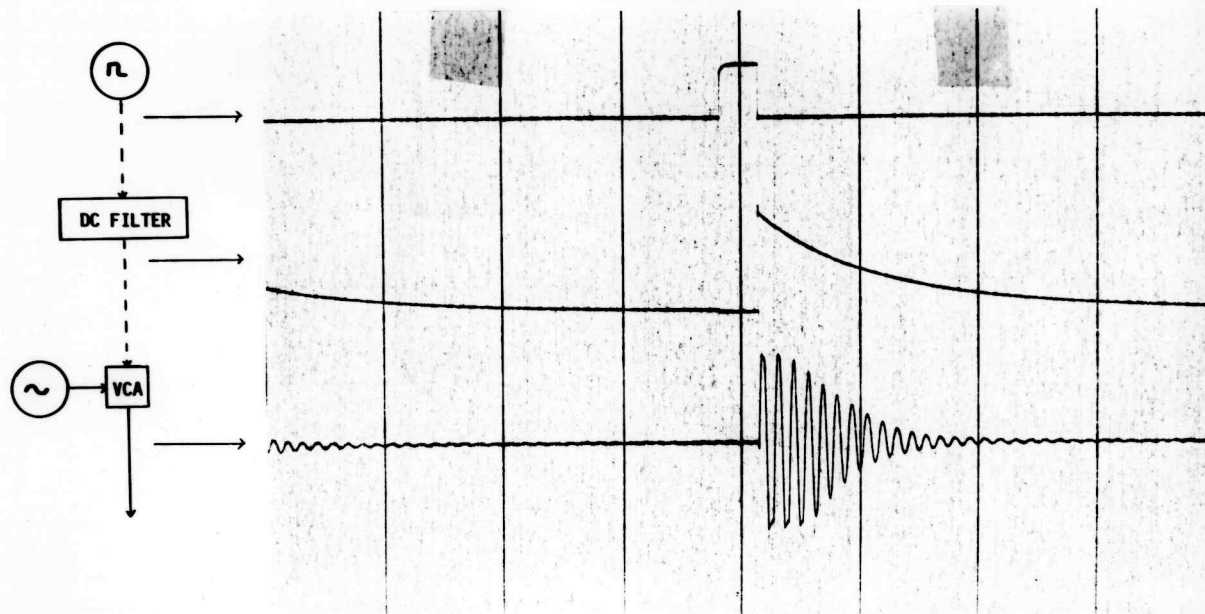
The example shows that control signals can be combined: two low-frequent control signals (sinewave) are added in a [MXA] before their algebraic sum (shown smaller in amplitude in the diagram to save space) is used to control the oscillator VCO [V-FUG].



EXAMPLE 8b: Addition of a sine and a triangular wave in order to control the frequency.

Commentary:

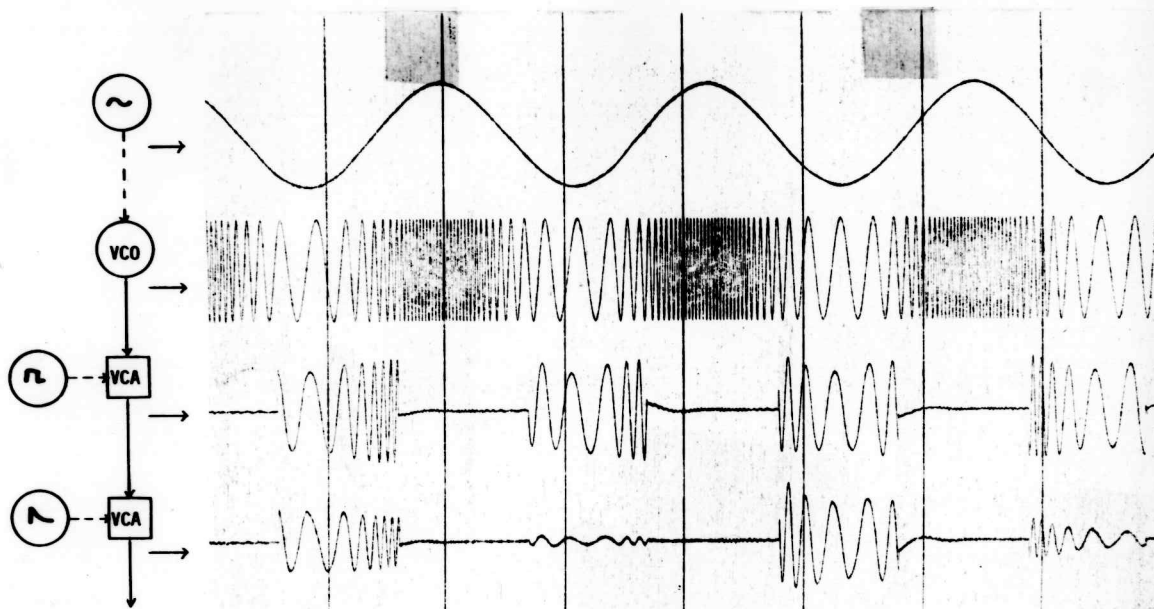
Addition of two different control signals.
Compare example 8a.



EXAMPLE 9: Percussive sounds by means of an amplitude-modulated sinewave signal.
The square wave controlling the amplitude modulator is filtered first.

Commentary:

The diagram shows one of the ways of producing percussive sounds. An impulse sequence is sent through a DC-FILTER [RDF] in such a way as to result in a direct voltage signal with sudden attack and gradual decay, used to control an amplitude modulator VCA [V-AMM].

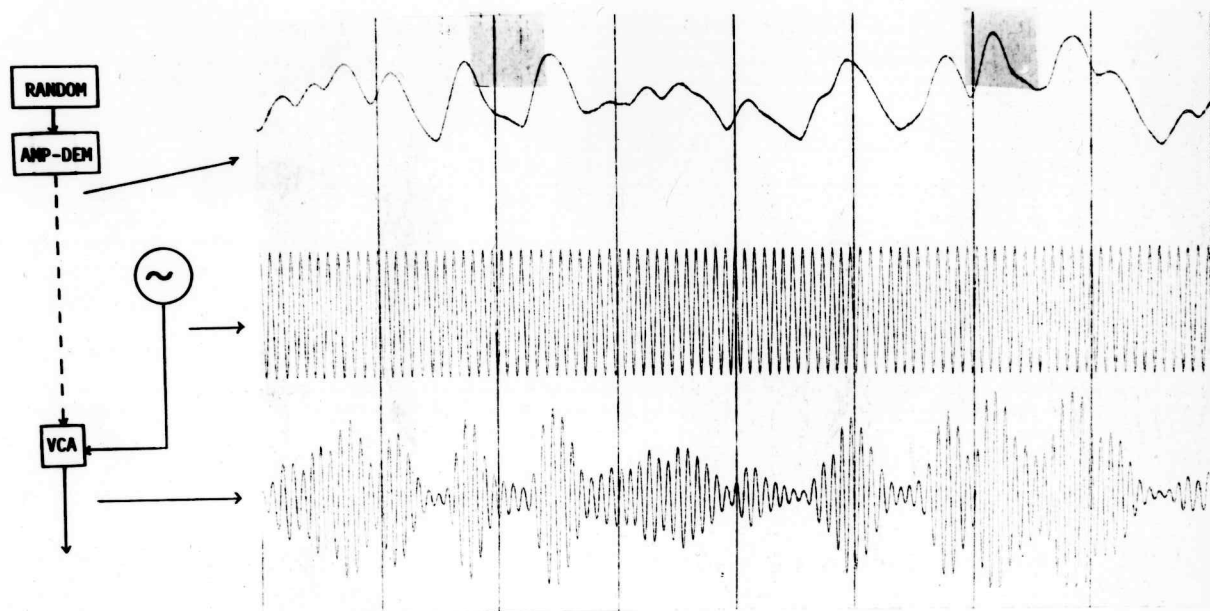


EXAMPLE 10: Combination of chopping and envelope decay.
 A sinewave is chopped periodically in one amplitude modulator by means of a square wave signal; in a second amplitude modulator the chopped material is provided with an envelope which has, as in ex. 9, the form of a filtered square wave.

Commentary:

The diagram shows a combination of chopping with an independent decay function. The audio signal (sinusoidally frequency-modulated), which is already chopped periodically, is sent to a second amplitude modulator controlled by a signal as shown in example 9.

Since the diagram only provides a limited idea of the sound, compare the taped sound model.



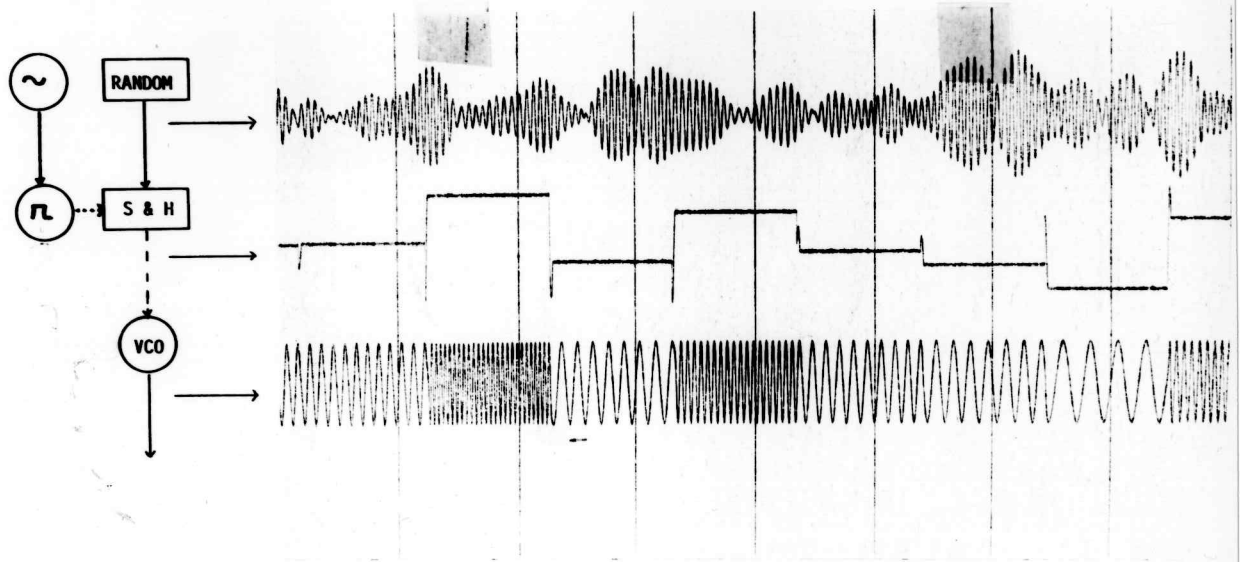
EXAMPLE 11a: Aperiodic amplitude alteration of a sinewave.

Here, as in the following examples, a noise generator is used for the production of an aperiodic control signal. If the changes in the noise's amplitude are too fast for the intended purpose, the noise signal can be decelerated by means of filtering and/or amplitude demodulation.

Commentary:

White noise is used as a standard source for random distribution. Since the amplitude changes extremely quickly in the original noise signal RANDOM [NSG], it is necessary to slow it down - by means of amplitude demodulation, for instance. A signal obtained in this manner (first line in diagram) can then be used to control an amplitude modulator VCA [V-AMM].

EXAMPLE 11b: sound model for random amplitude modulation of a square oscillation.



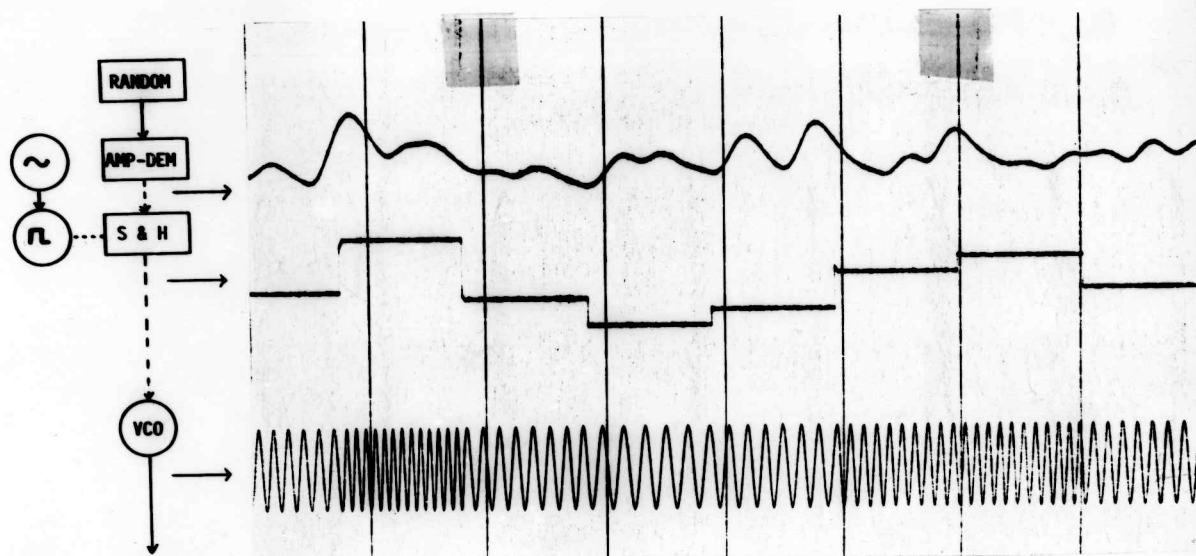
EXAMPLE 12a: Pitch alteration of a sinewave by means of random function.

"Samples" are taken at regular intervals from filtered noise and used to control the VCO.

See ex. 25a and 25b for SAMPLE&HOLD CIRCUIT.

Commentary:

The noise signal can also be used to derive a control signal which leaps in steps (compare examples 2c and 26). The circuit plan shows how a periodic trigger signal is first produced with [SWG] and [T-DIG] and used to control a sample-and-hold circuit S&H [SAH]. At each trigger impulse the momentary amplitude of the noise signal is measured and held until the next trigger impulse (second line in diagram). The steplike signal finally controls a generator VCO [V-FUG] (bottom line).



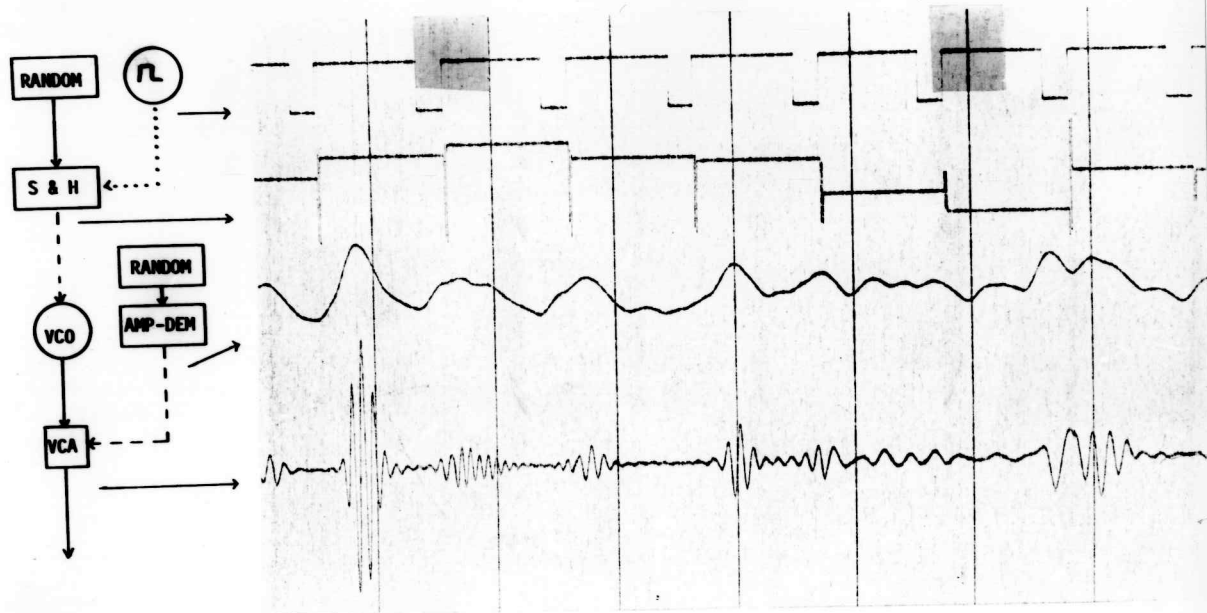
EXAMPLE 12b: as ex. 12a, but the filtered noise is amplitude-de-modulated too.

The SAMPLE&HOLD CIRCUIT can, as a comparison of fig. 12a and 12b shows, follow the slower noise signal better.

Commentary:

As example 12a, but this time the noise signal is also amplitude-demodulated with AMP-DEM [AMD]. You can see that basically this has no effect on the function of the [SAH], but that it facilitates the click-free search for the amplitude value in the [SAH].

Compare the sound examples.



EXAMPLE 13: Sinewave with changing pitch and amplitude.
Both alterations are based on noise signals; the noise is "sampled" (as in ex. 12a) for the pitch alteration, and is amplitude-demodulated for amplitude alteration.

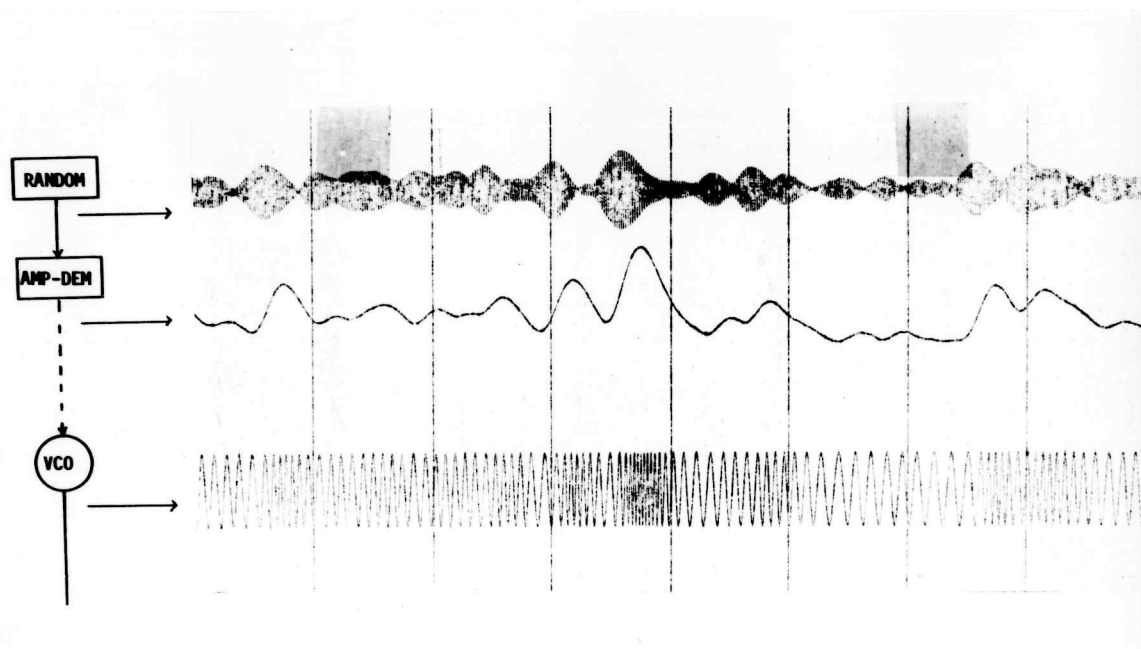
Commentary:

In this example both pitch and amplitude of a sine oscillation are random-modulated.

The generator VCO [F-FUG] gets its control signal from the sample-and-hold circuit [SAH], which a periodic trigger signal causes to take samples (top part of circuit plan, lines 1 and 2 in diagram).

The amplitude modulator VCA [V-AMM] is controlled by amplitude-demodulated noise (bottom part of circuit plan, third line of diagram). Demodulation is performed by the amplitude demodulator AMP-DEM [AMD].

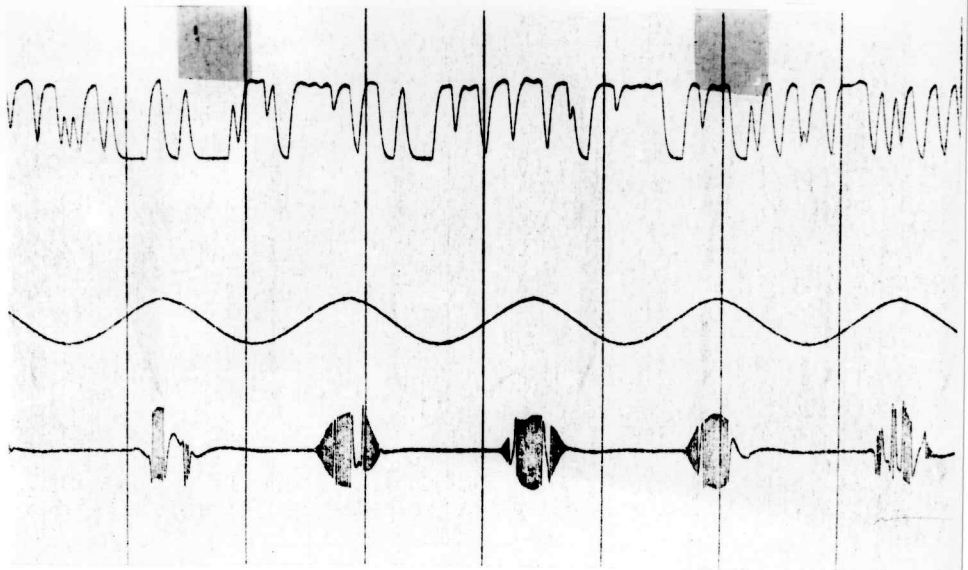
The combination of both signals (amplitude modulation of the random-controlled pitches) is shown in the bottom line of the diagram.



EXAMPLE 14: Continuous alteration of pitch by means of filtered and demodulated noise signal.

Commentary:

If no samples are taken from the noise signal, amplitude demodulation [AMD] of the noise signal and control of generator VCO [V-FUG] by the demodulated noise result in a random glissando.

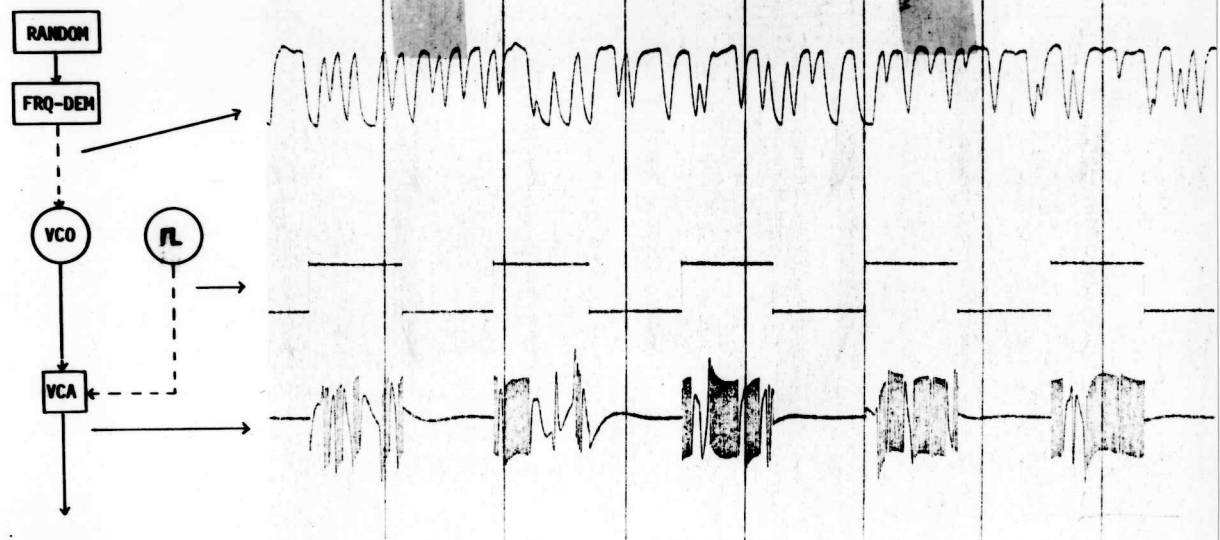


EXAMPLE 15a: Continuous alteration of pitch by means of frequency-demodulated signal, amplitude alteration by means of sinewave.

Commentary:

The example shows the combination of a regular control signal with an irregular one.

The regular signal (sine) controls the amplitude via VCA [V-AMM], the irregular one (frequency-demodulated noise) controls the frequency of a sine produced in generator VCO [V-FUG]. Demodulator FRQ-DEM [FRD] is used for frequency demodulation.



EXAMPLE 15b: as ex. 15a, with amplitude alteration by means of square wave (chopping).

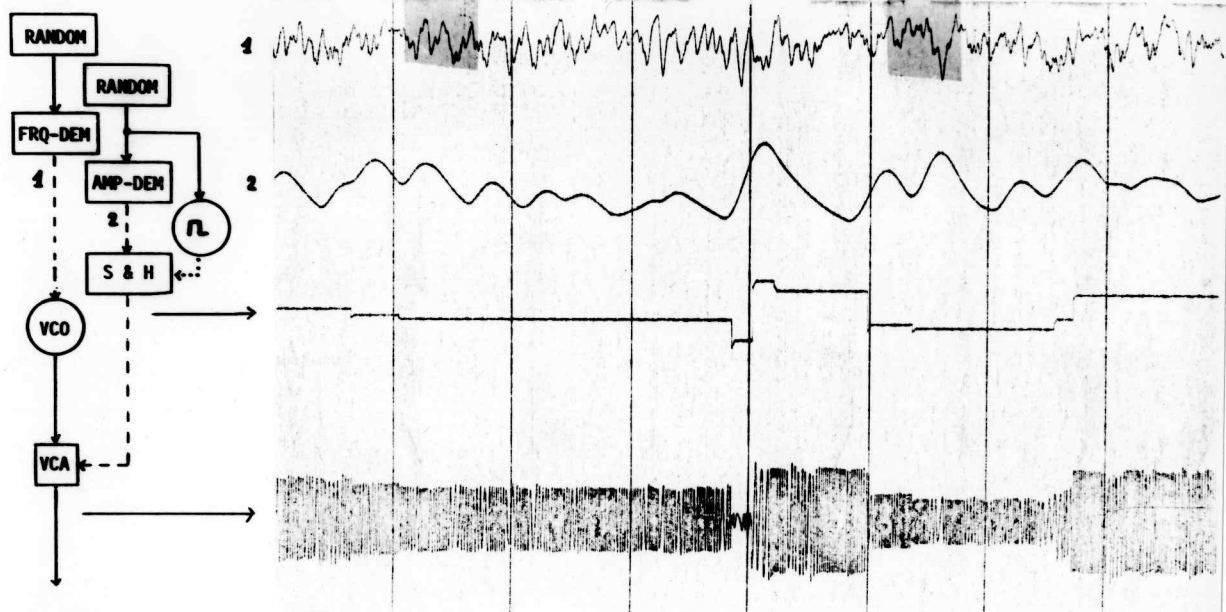
Commentary:

The irregular frequency glissando from example 15a is chopped here instead of being continuously amplitude-modulated.

Amplitude modulator VCA [V-AMM] is used for chopping, but controlled by a square signal instead of a sine.

On tape only:

EXAMPLE 15c: as previous examples, but with very slow amplitude alteration.



EXAMPLE 16: Rapid and continuous pitch alteration (by means of frequency-demodulated noise signal), irregular and stepwise amplitude alteration by sampling a filtered noise. The trigger impulses for the SAMPLE&HOLD CIRCUIT are taken from the unfiltered noise.

Commentary:

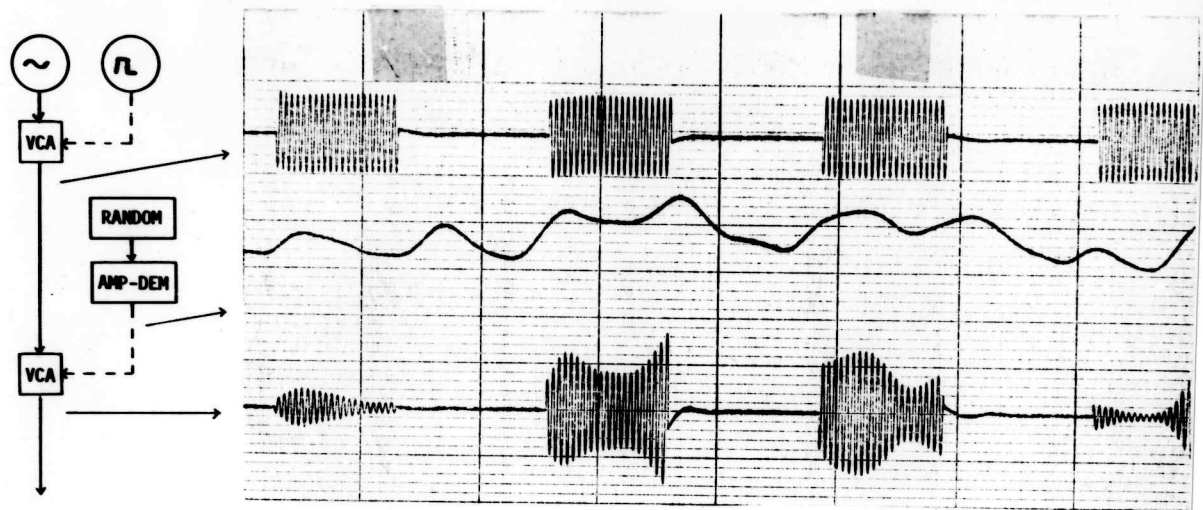
The example shows a random-controlled sample-and-hold circuit [SAH] on the right-hand side of the diagram. The noise signal RANDOM [NSG] is divided for this; then

- (a) its amplitude is demodulated with AMP-DEM [AMD],
- (b) it is used to control an impulse generator [I-DIG]; these impulses trigger the S&H [SAH], resulting in the signal in the third line of the diagram.

On the left-hand side of the diagram a noise signal, frequency-demodulated with FRQ-DEM [FRD] (first line in diagram), is used to control a VCO [V-FUG]. This audio signal, which glissandos rapidly and irregularly in its frequency, is given the above-described amplitude, leaping in steps, in amplitude modulator VCA [V-AMM].

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EXAMPLE 17: Irregular, stepwise pitch alteration by means of noise samples.

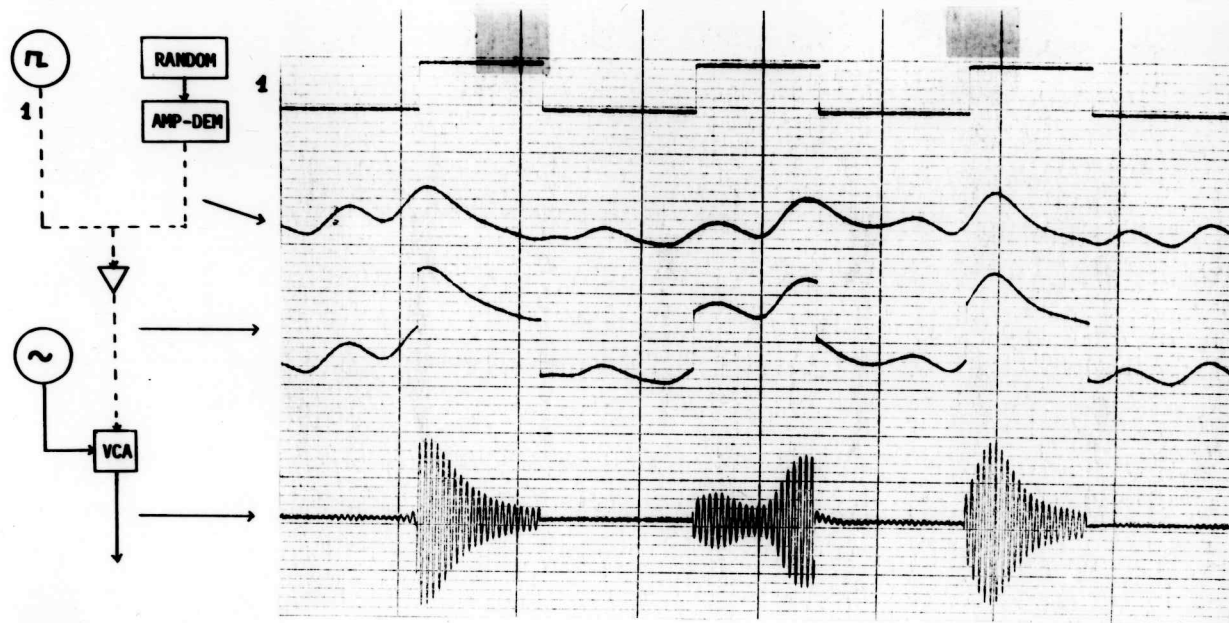


EXAMPLE 18a: Periodically chopped sinewave with the envelope of a demodulated noise.

Commentary:

Short sound-blocks (sinewaves with constant frequency in this example) are given random-controlled envelopes.

On the left-hand side of the circuit plan the sound-blocks are produced by means of amplitude modulation with VCA [V-AMM], on the right-hand side of the circuit plan there is a continuous control signal, obtained by amplitude demodulation [AMD] of a noise source RANDOM [NSG]. The prepared sound-blocks are given their final envelope in a second amplitude modulator.

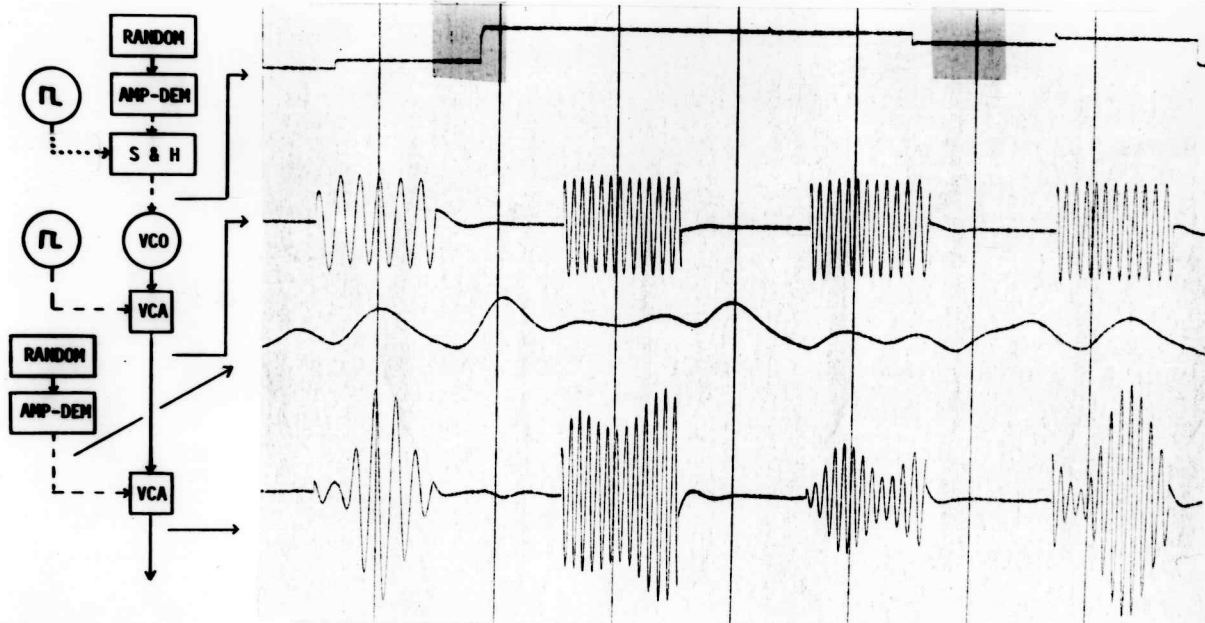


EXAMPLE 18b: The two control signals in ex. 18a can also be added first and then sent to an amplitude modulator (no sound example).

Commentary:

The same result as in example 18a can also be obtained by just using an amplitude modulator VCA [V-AMM].

The two control signals that are to be chopped (first line of diagram) and for the envelope (second line of diagram) are first mixed in the mixer [MXA] and then sent to the modulator; suitable calibration makes it possible to separate the bigger amplitudes from the smaller ones in the VCA.



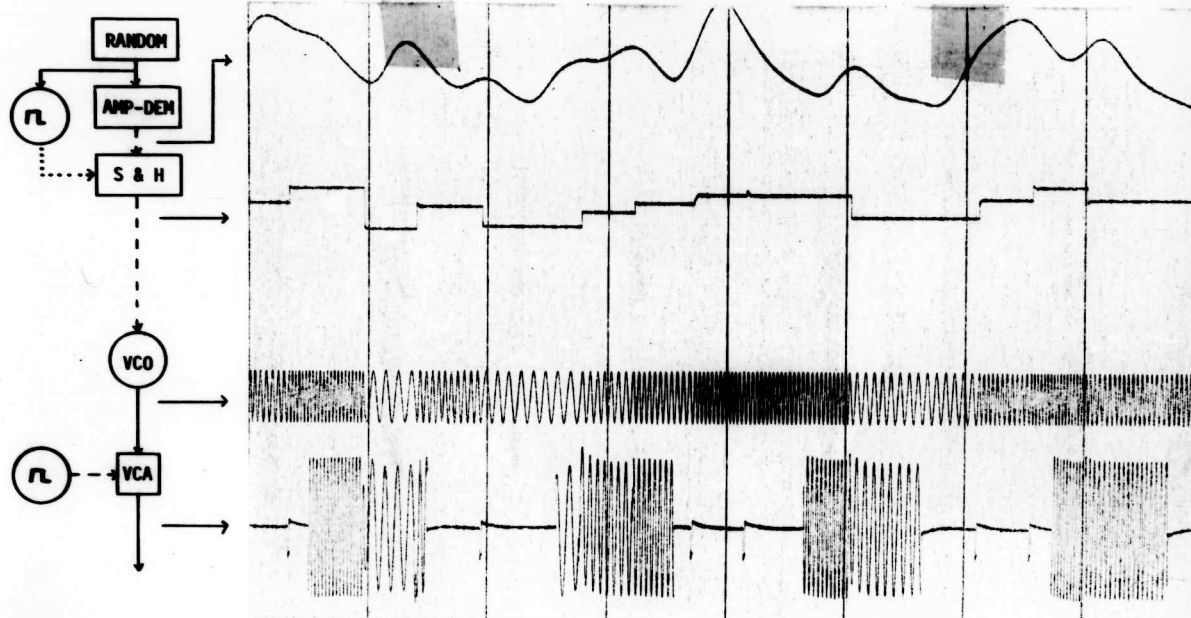
EXAMPLE 19: Periodically chopped and randomly amplitude-modulated signal as in ex. 18.

In this example the frequency of the chopped sinewave is however altered arbitrarily by sampling a demodulated noise.

Commentary:

Sound-blocks as in examples 18a and 18b; however, the sinewave of constant frequency is replaced by a "melody" of tones of equal length. Because the "rhythmification" by different frequencies is not synchronized with rhythmification by the chopper, tones can be skipped, or more than one tone can occur in a sound segment.

As in example 16, the control signal for the tone sequence is produced in the top part of the circuit plan (first line in diagram). In the middle part of the circuit plan the tone sequence is chopped evenly in the amplitude modulator (second line in diagram). In the lower part of the circuit plan amplitude-demodulated noise (third line in diagram) controls a second amplitude modulator, which modulates variable envelopes on to the sound-blocks (fourth line in diagram).



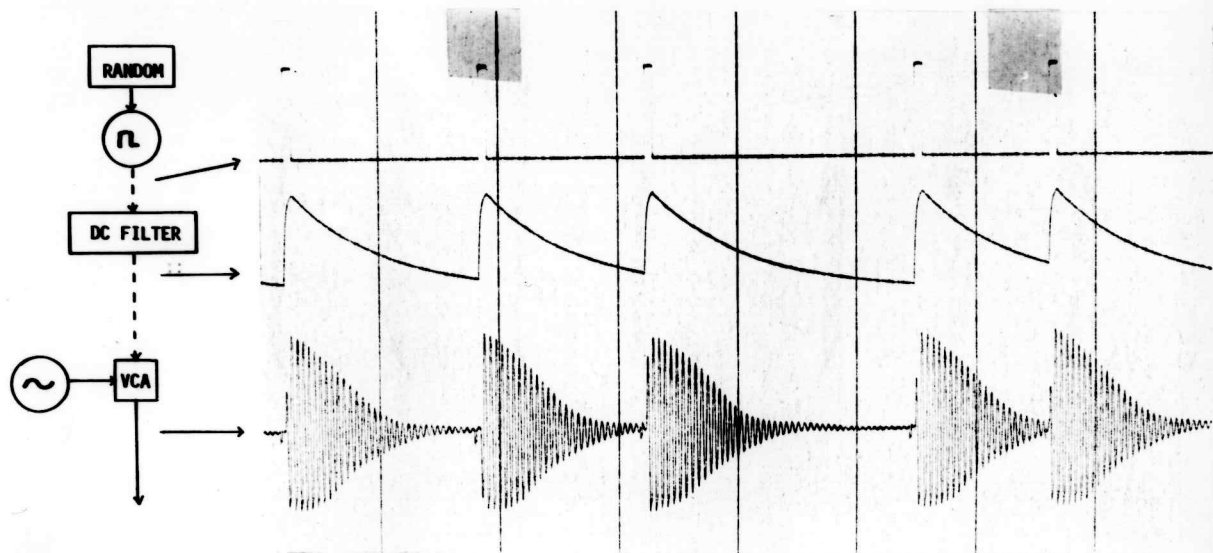
EXAMPLE 20a: Regularly chopped sinewave, the frequency of which alters in steps of irregular height and duration. Trigger impulses for the SAMPLE&HOLD CIRCUIT are derived from the noise signal, the samples being taken from the demodulated noise. Chopping is done by means of a square wave and an amplitude modulator.

Commentary:

Alternative circuit without envelopes; the continuous tone sequence (top part of circuit plan as in example 16) is chopped evenly in amplitude modulator VCA [V-AMM].

On tape only:

EXAMPLE 20b: Chopped signal as in ex. 20a, but with variable chopping rate.



EXAMPLE 21a: Percussive sounds at irregular intervals from sine-waves of constant frequency.

For this purpose a sequence of impulses, derived from noise, is filtered and sent to the amplitude modulator.

Commentary:

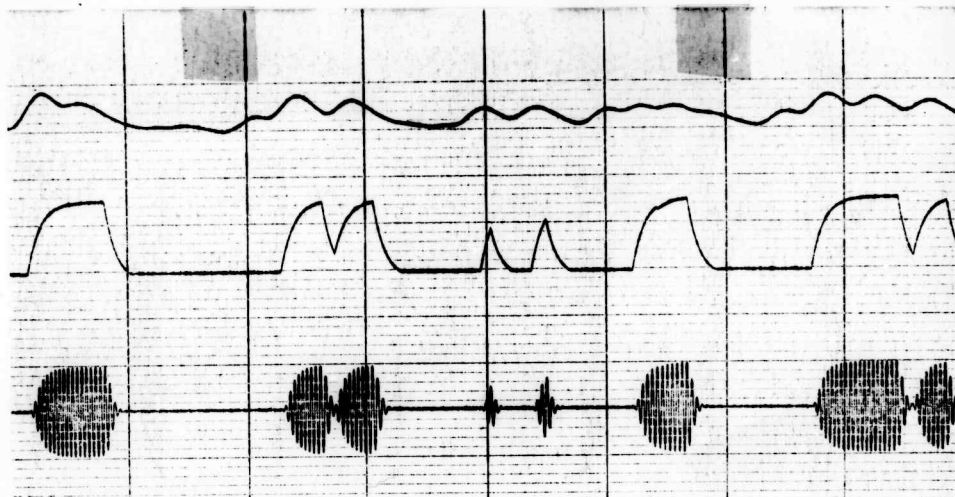
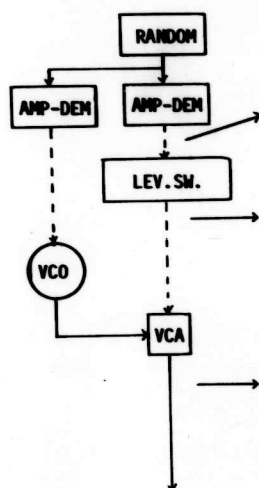
Irregular sequence of percussive sounds with the same frequency (variant of example 9).

An impulse generator [T-DIG] is triggered by a noise signal (first line in diagram), the impulses are changed in DC-FILTER [RDF] into decaying control signals (second line in diagram).

Amplitude modulator VCA [V-AMM] modulates a sinewave of constant frequency with this signal.

On tape only:

EXAMPLE 21b: Percussive sounds as in ex. 21a, but from changing spectra instead of sinewave.



EXAMPLE 22a: Sinewaves of variable frequency, chopped by means of the LEVEL SWITCH (see ex. 23).

Since the same demodulated noise signal serves the amplitude modulator (through the LEVEL SWITCH) and controls the VCO, only a small amplitude range is left over for frequency alteration. In order to avoid this, two different noise signals could be used.

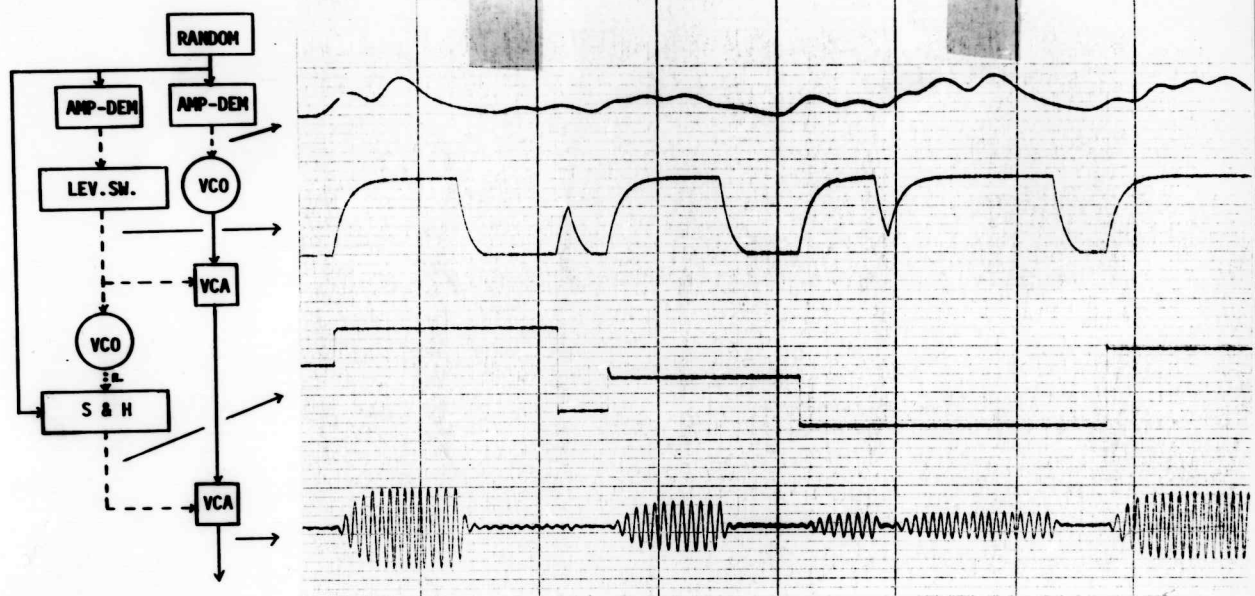
Commentary:

The example shows how aperiodic chopping can be performed, derived from an aperiodic (noise) signal. The LEVEL SWITCH [VVC] in the top part of the circuit plan is used for this (compare example 23 a-c).

The LEV.SW. supplies a +5 V signal as long as the input signal (amplitude-demodulated noise) exceeds a comparative level set at the LEV.SW.

The ON/OFF function at the output of the LEV.SW. controls amplitude modulator VCA [V-AMM], which chops a given signal. In this case the given signal is a randomly frequency-modulated sinewave.

Nowadays the small amplitude range referred to in the caption could be increased by a DC amplifier [DCA].



EXAMPLE 22b: as in ex. 22a, but with amplitude modulation by means of sampled noise signal.

This causes the sound blocks to have different amplitudes.

The SAMPLE&HOLD CIRCUIT is controlled by the LEVEL SWITCH, so that the amplitude modulation is in time with the chopping, resulting in blocks of constant amplitude.

The intermediate VCO (supplying square waves) is for converting the LEVEL SWITCH signal into trigger impulses for the SAMPLE&HOLD CIRCUIT.

Commentary:

The circuit plan is more complicated than the one in example 22a, its purpose being to give the sound-blocks produced in the previous example different amplitudes. For this, the sample-and-hold circuit [SAH] which produces the amplitude levels must be synchronized with the LEV.SW. [VVC] which is responsible for the chopping.

Synchronisation is shown on the left-hand side of the circuit plan. The amplitude-demodulated noise (first line in diagram) is transformed by the LEV.SW. into the desired ON/OFF function (second line in diagram), which triggers the S&H via a VCO [V-FUG] (which supplies synchronous impulses). The S&H takes the amplitude samples from the same noise that was connected with the LEV.SW. (third line in diagram). Comparison of the second line in the diagram with the third clearly shows that at each new "block" of the LEV.SW., a new level leaves the S&H too.

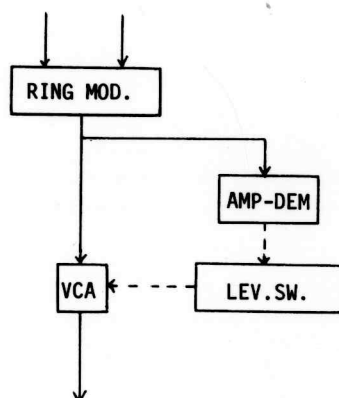
On the right-hand side of the circuit plan a random frequency-modulated sinewave passes two amplitude modulators. The first is controlled by the LEV.SW. and is responsible for chopping, the second is controlled by the S&H and gives each sound-block its amplitude.

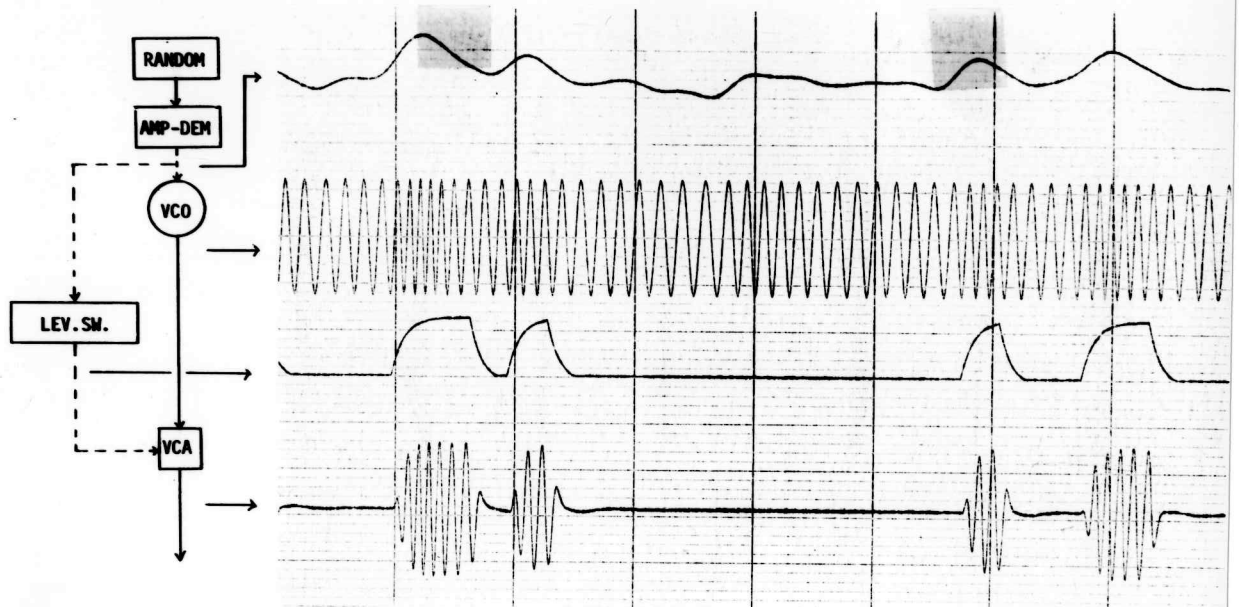
THE LEVEL SWITCH (examples 23a - 23d)

This device makes it possible to indicate for a given direct voltage signal when and for how long a set threshold value is exceeded or not reached (function NORMAL or INVERSE). In each of these cases the LEVEL SWITCH supplies either 5 V or 0 V. At the output of the LEVEL SWITCH there is thus a square signal in time with the voltage that is more or less than the threshold value.

The threshold value can be set so that the LEVEL SWITCH only supplies 5 V if the amplitude (of the amplitude modulated signal) or the frequency (of the frequency modulated signal) is more or less than the required value. An important application of the LEVEL SWITCH results from the desire to eliminate the unwanted (even though weak) portions of the ring modulation of two chopped signals. The illustration shows a ring modulation (of two audio signals), the result of which is sent to an amplitude modulator. The ring modulator signal, which is amplitude demodulated, is at the same time sent to the LEVEL SWITCH, which then supplies 0 V, thus closing the amplitude modulator, if the ring modulator "leaks", but supplies 5 V (thus opening the amplitude modulator fully) if ring modulation occurs.

The LEVEL SWITCH is at present called the VARIABLE VOLTAGE COMPARATOR [VVC] at the institute.



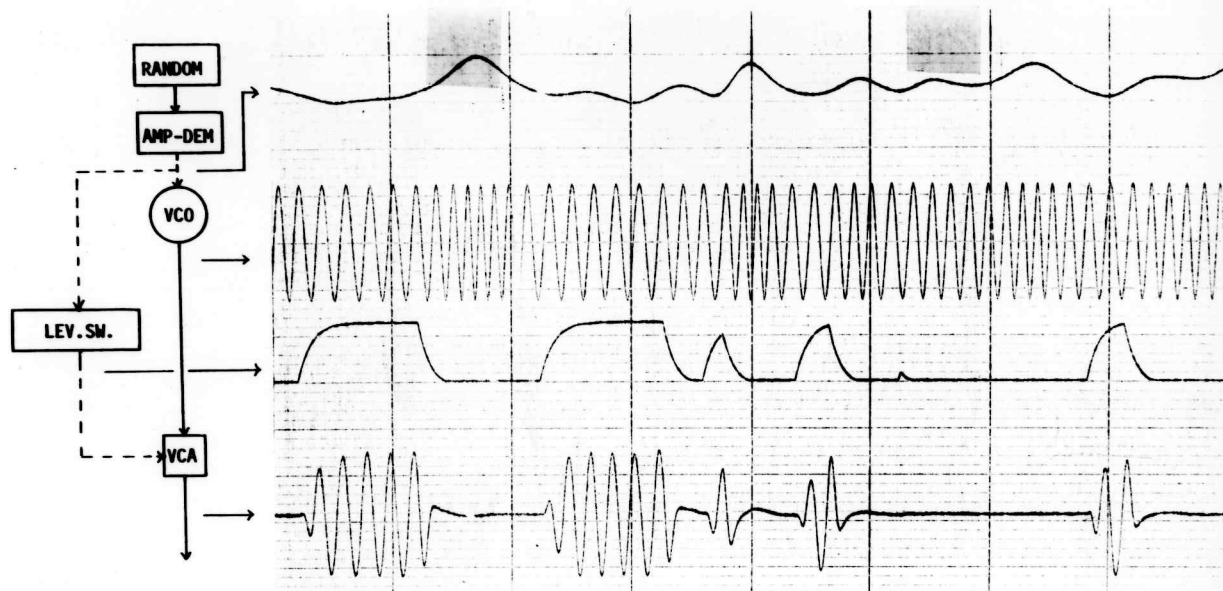


EXAMPLE 23a: An amplitude modulator only lets through the higher frequencies (corresponding to the higher amplitude of the controlling signal) in a waveform whose frequency is controlled by a demodulated noise.
As shown in the illustration, the LEVEL SWITCH only reacts to large amplitudes.

Commentary:

The example shows how only the higher amplitudes of a control signal are used to frequency-modulate a sinewave. This is done by chopping the result in amplitude modulator VCA [V-AMM], which is controlled by the LEV.SW. [VVC]. The amplitude range to which the [VVC] is to react with a +5 V signal can be set on the apparatus.

As the third line in the diagram shows, the LEV.SW. reacts to the input signal with a certain degree of inertia. If an inertia-free signal is required, it can be obtained with a Schmitt trigger [SMT] following the [VVC].



EXAMPLE 23b: as in ex. 23a, but with the LEVEL SWITCH in the INVERSE position.

As shown in the illustration, the LEVEL SWITCH only reacts to the smaller amplitudes of the demodulated noise here, so that the amplitude modulator only lets the lower frequencies through.

Commentary:

Variant on example 23a. The circuit plan is the same, but the LEV.SW. [VVC] is used in the INVERS position this time.



EXAMPLE 23c: Combination of two LEVEL SWITCHES, one in the NORMAL position, the other in INVERSE. In this manner the amplitude modulators only "sieve out" the frequencies which correspond to the control voltage between the two amplitude threshold values.

Commentary:

Two LEV.SW. [VVC] can be combined in such a way that only a medium amplitude range of the control signal supplies the +5 V output. Both LEV.SW. control two amplitude modulators VCA [V-AMM], switched in series, which treat the audio signal in two stages.

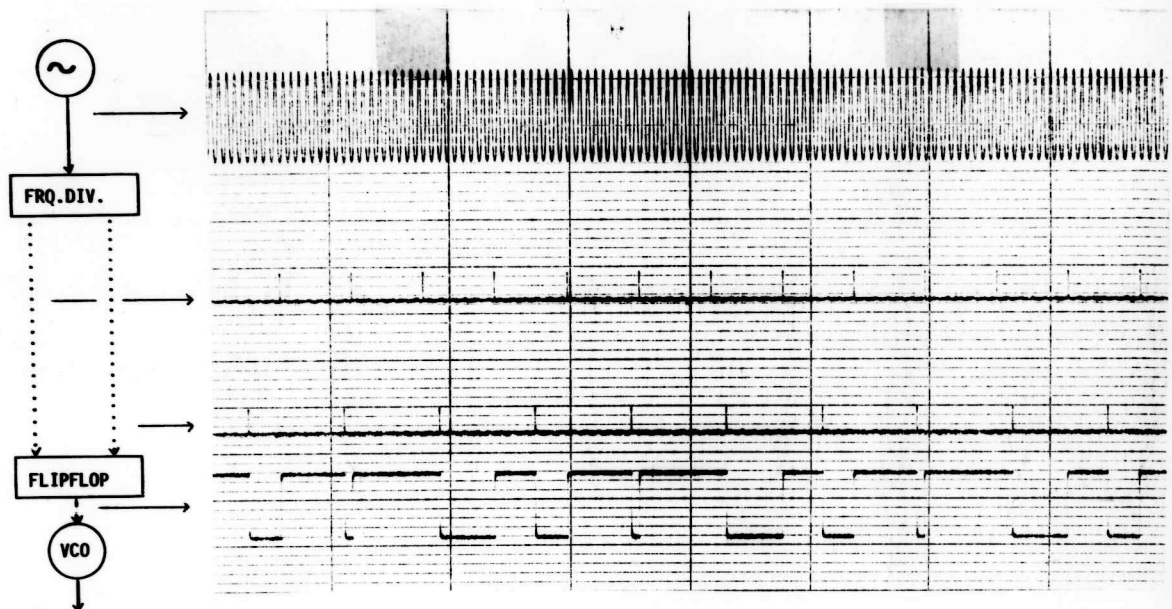
In example 23c the first (upper) LEV.SW. is set to the NORMAL position and supplies an output voltage for all amplitudes above the set threshold; this threshold indicates the lower limit of the desired range. The other (lower) LEV.SW. is in the INVERS position and thus supplies an output voltage for all amplitudes below the set threshold; this threshold indicates the upper limit of the desired range.

To summarize: the first LEV.SW. selects the desired range and everything above it; the second LEV.SW. selects the desired range and everything below it. There is nothing below it, however, because the first LEV.SW. did not react below the lower limit; everything that still came through above the upper limit is now removed by the second LEV.SW.

The width and position of the pass-range only depend on the setting of the two threshold values, provided that the given signal fills the entire 5V range. Signals which do not can be correspondingly amplified by a DC amplifier [DCA] and shifted with respect to 0 V.

On tape only:

EXAMPLE 23d: Transformations of a spoken sentence by means of the LEVEL SWITCH.

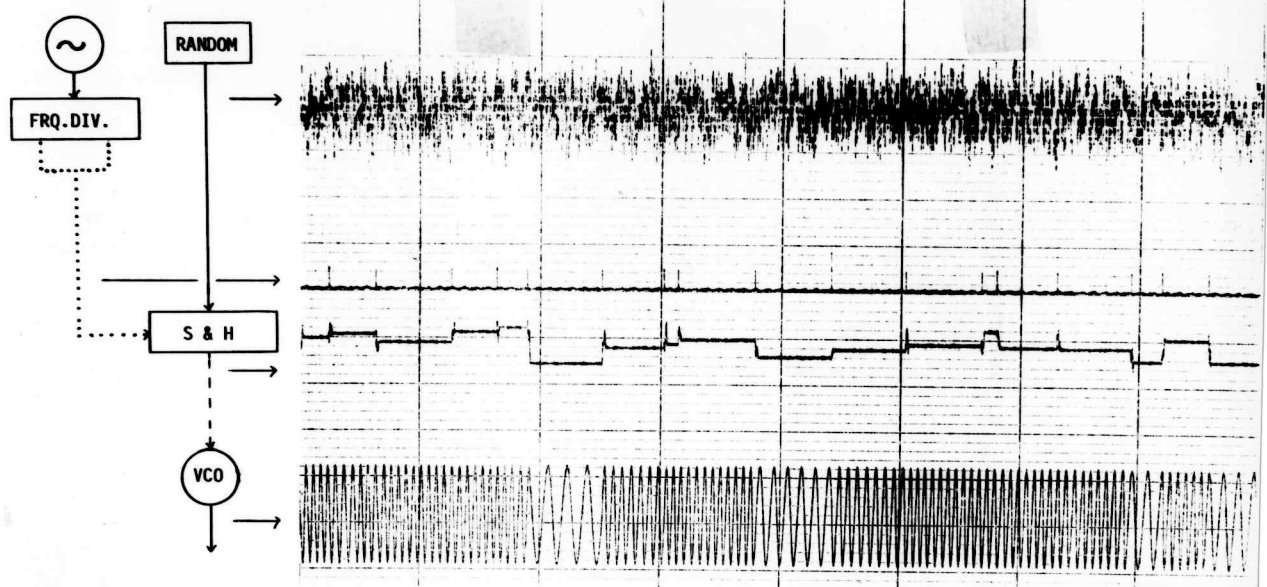


EXAMPLE 24: The FLIPFLOP

The FLIPFLOP supplies - like the LEVEL SWITCH - a signal of 5 V or 0 V, according to whether it is in the SET or RESET position. The position is changed by impulses which must be sent to the two inputs for SET and RESET. The FLIPFLOP only reacts to a SET impulse if it is in the RESET position, and vice versa. If both impulses arrive at the same time, the FLIPFLOP switches to whatever the other position is.

THE SAMPLE & HOLD CIRCUIT (examples 25a - 25b).

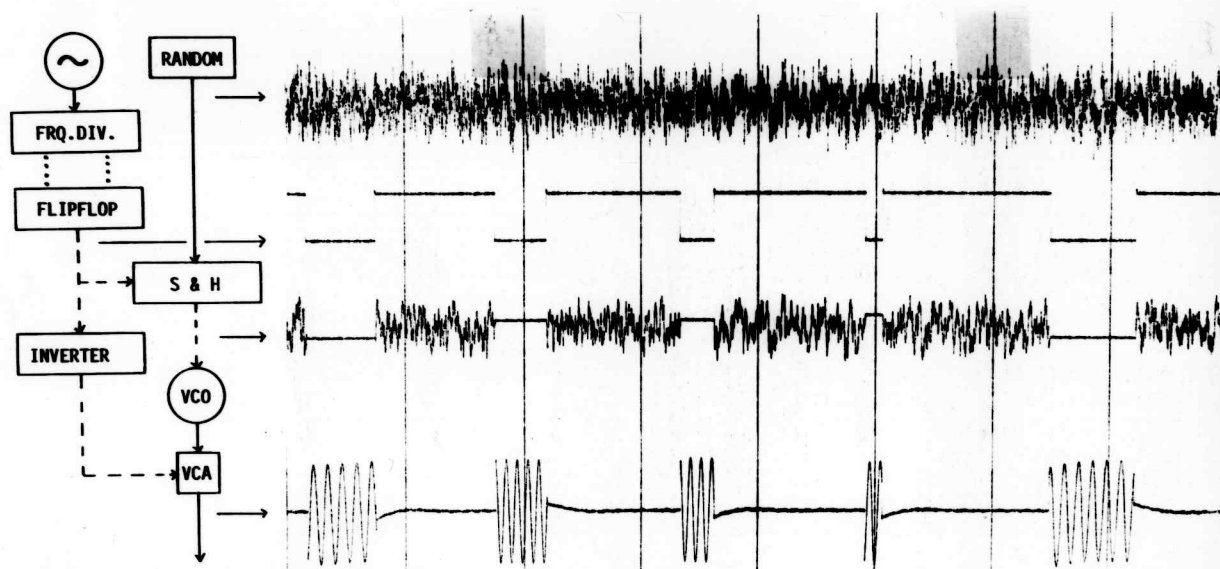
This device has two functions which can be indicated as HOLD and FOLLOW, demonstrated in ex. 25a and 25b. In the more frequently used HOLD position the SAMPLE&HOLD CIRCUIT reacts to an impulse by measuring the momentary value of a direct voltage sent to it, and holding on to it until the next impulse arrives. An arbitrary signal (e.g. a noise signal) is thus transformed into discrete but arbitrarily varying steps; the durations of these steps depend on the time-intervals between the impulses.



EXAMPLE 25a: SAMPLE&HOLD CIRCUIT in the HOLD position.
 Given: a noise signal, to be divided up into single samples. Here
 for control purpose an impulse sequence is used consisting of two
 periodic series of impulses.

Commentary:

To trigger the sample-and-hold circuit S&H [SAH], periodic (impulse generator) or aperiodic (random-controlled impulse generator) impulse sequences can be used. In this example a periodic function (sine) was divided by two factors, using a FRQ.DIV. (now called double scaler [T-DSC]), both results being combined to form a longer period. The compound impulse sequence triggers the S&H which itself had sampled a noise signal RANDOM [NSG], controlling generator VCO [V-FUG] with these samples.



EXAMPLE 25b: SAMPLE&HOLD CIRCUIT in the FOLLOW position. Instead of an impulse for taking the next sample, a square voltage alternating between 5 V and 0 V is required here.

This voltage can be obtained from a square wave oscillator, but also from a FLIPFLOP or a LEVEL SWITCH. The SAMPLE&HOLD CIRCUIT reacts to 0 V as in the HOLD position: the momentary value of the arriving signal is measured and held on to. But the SAMPLE&HOLD CIRCUIT does not react to 5 V at all, i.e. the arriving signal is simply let through.

The above circuit was conceived with reference to the sound example that goes with it. A noise signal is alternately sampled and let through by the SAMPLE&HOLD CIRCUIT and frequency modulated with a VCO. However, an amplitude modulator ensures that only constant frequencies (resulting from constant control voltage at 0 V for control of the SAMPLE&HOLD CIRCUIT) are let through. For this the FLIPFLOP signal which controls the SAMPLE&HOLD CIRCUIT must also control the amplitude modulator. To make this possible, the FLIPFLOP signal which controls the SAMPLE&HOLD CIRCUIT is first reversed by means of an inverter so that the amplitude modulator receives 5 V when the SAMPLE&HOLD CIRCUIT gets 0 V, and vice versa.

Commentary:

In the FOLLOW position, the [SAH] only reacts to control voltages of 0 and +5 V. It reacts to 0 V as long as this voltage is unchanged, as is the case in the HOLD position between two trigger impulses: it measures the amplitude of the input signal and supplies it to the output. If the control voltage is +5 V, the input signal is supplied to the output unchanged. The effect of the FOLLOW position can be clearly seen in the top three lines of the diagram. The control signal for the [SAH] was produced as in example 25a by two frequency divisions; the FLIPFLOP [T-FFP] uses both impulse sequences as SET and RESET signals (compare example 24).

To demonstrate the FOLLOW position it would suffice to connect the [SAH] with generator VCO [V-FUG]. During the HOLD phase you would hear a sinewave with a different frequency each time, during the FOLLOW phase you would hear white noise.

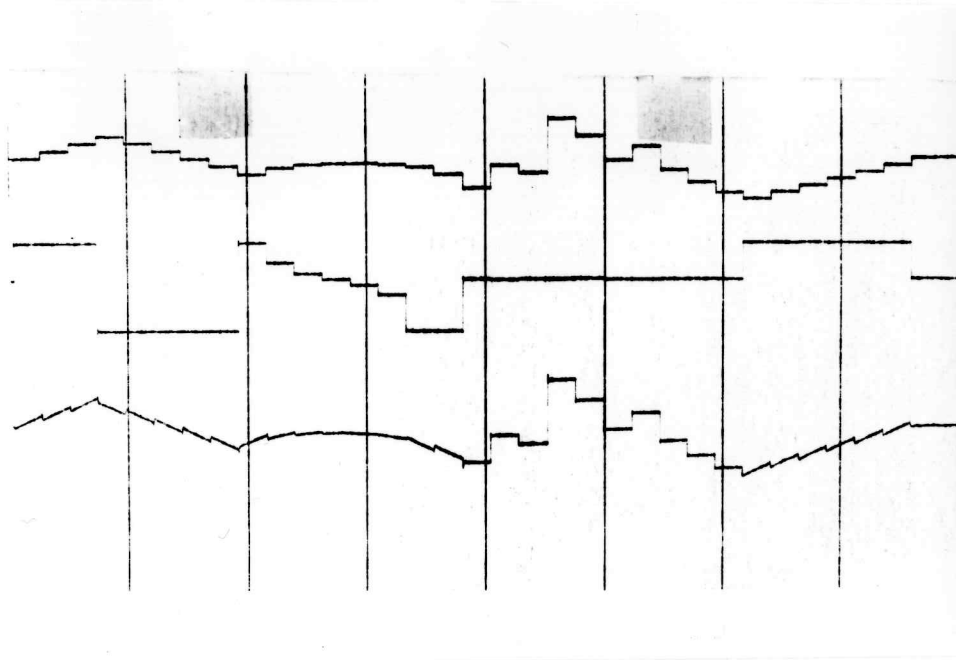
In this example however the two phases are separated in such a way that only the HOLD phase is audible (or visible). The resulting signal is sent through an amplitude modulator VCA [V-AMM] for this, controlled by the inverted [T-FFP] signal.

A [MXA] was used as INVERTER, which has an inverted output as well as a normal one.

The VARIABLE FUNCTION GENERATOR (VFG), designed at the Utrecht studio, permits two direct voltage curves to be set, each consisting of a maximum of 100 individual levels which can be reproduced synchronously at any speed, periodically or aperiodically. The levels used (the same number for both curves) together form a "period". Two independent impulse generators supply the signals for starting a whole period and for shifting from one level to the next. The impulse generators can be replaced by external signal sources.

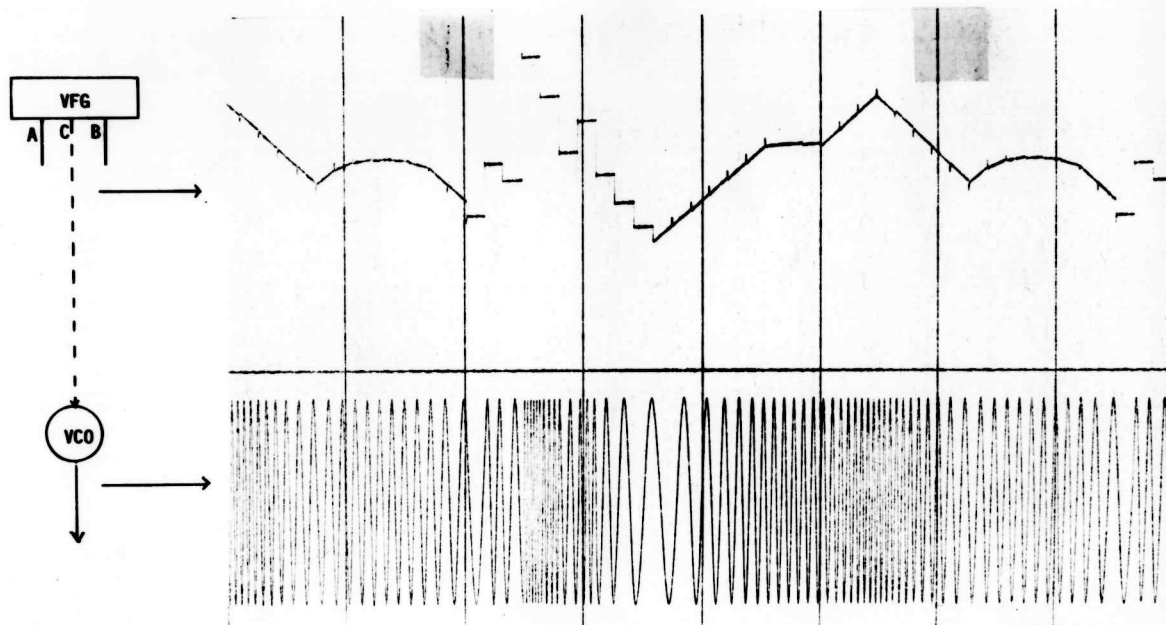
The two voltage series are indicated as A and B. There is also an output C, representing a common output for A and B, but in such a way that the B-amplitudes convert the constant A-voltage into a rising or falling voltage. Suitable voltage values in the B-series can make it possible for the levels defined in the A-series to be joined together by means of slanting connections as shown in ex. 26.

It is superfluous to go into the VARIABLE FUNCTION GENERATOR in more detail here; there are descriptions of it in ELECTRONIC MUSIC REPORTS #2 and in the studio manual. The following three examples merely illustrate the three outputs of the VARIABLE FUNCTION GENERATOR and the use of the voltage-time converter [VTC], without embarking on a description of the many applications of the apparatus.



EXAMPLE 26

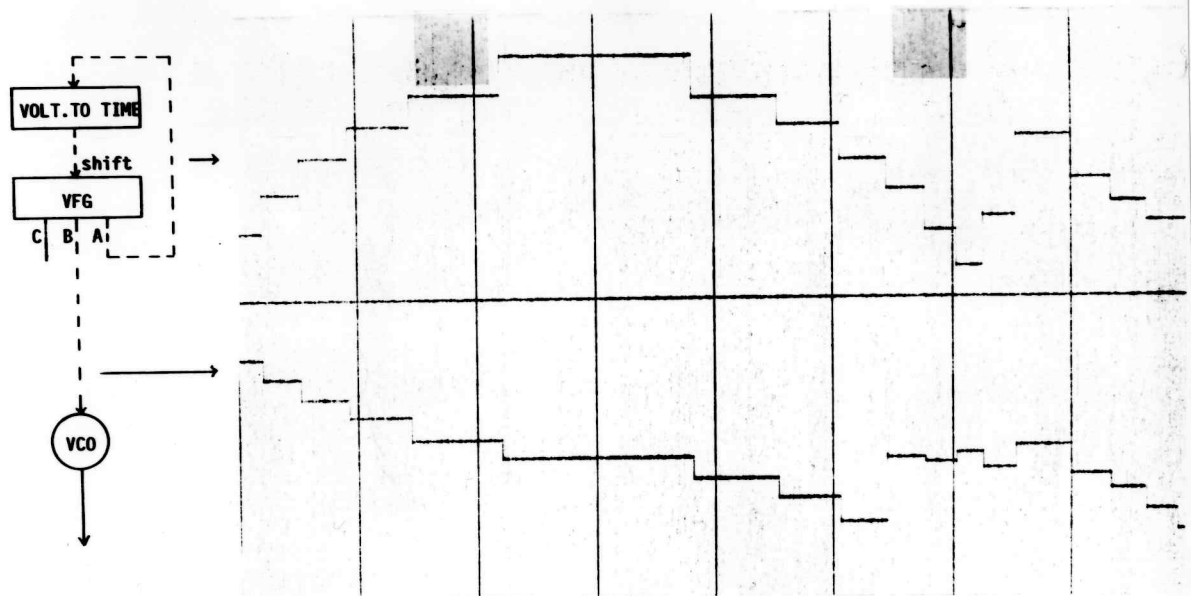
The illustration shows, reading downwards: the voltage levels of the A-series, the voltage levels of the B-series, the C-series. It must be realised that the levels of the B-series determine the size of the angle by which the relevant A-level is made to turn, as it were. The fact that in the illustration the slanting lines of the C-series do not always join up exactly depends on setting difficulties when the shift impulse frequency is low.



EXAMPLE 27a: The C-output of the VFG controls a VCO. The waveform below does not follow the control voltage perfectly because of the low frequency (vertical lines mark 1/10 of a second).

On tape only:

EXAMPLE 27b: The VCO is alternately controlled by the A and B-series of the VFG.



EXAMPLE 28

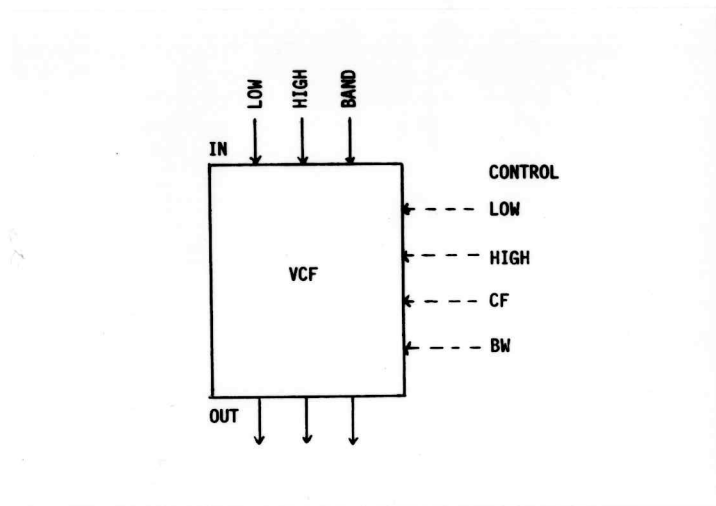
A voltage-to-time converter [VTC] makes it possible to convert a direct voltage amplitude into a corresponding time value; an impulse is supplied after this length of time.

This additional circuit can be used, for example, to convert the voltage levels of the A-series into an impulse sequence which is used as external shift signal. Since the two voltage series are reproduced synchronously, a new time value is generated for each voltage.

The illustration shows clearly in the top line that larger time values are produced for higher amplitudes. The amplitudes in the B-series (bottom line) are set arbitrarily, but "rhythmified" by the A-series.

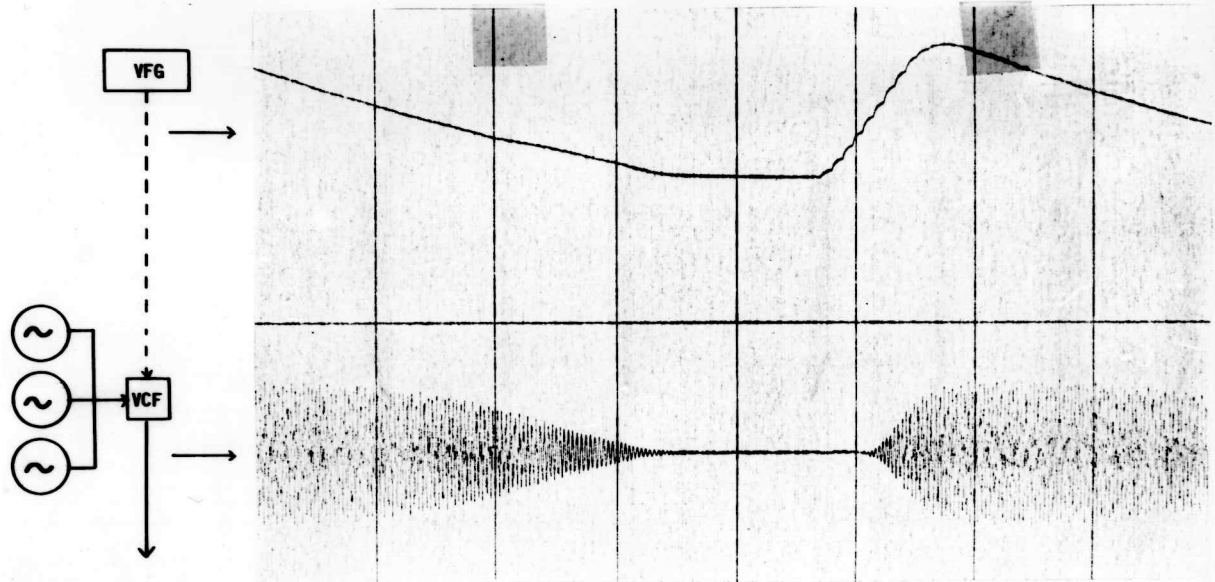
THE VOLTAGE-CONTROLLED FILTER (examples 29 -33).

The voltage-controlled filter (designed in the Utrecht studio) can be used as low-pass, high-pass, band-pass and band-stop filter. For most of the examples a sound with the frequencies 300, 1000 and 3500 Hz (approx.) is used, white noise is used in the others. The control voltages were produced with the VFG or sinewave oscillators.



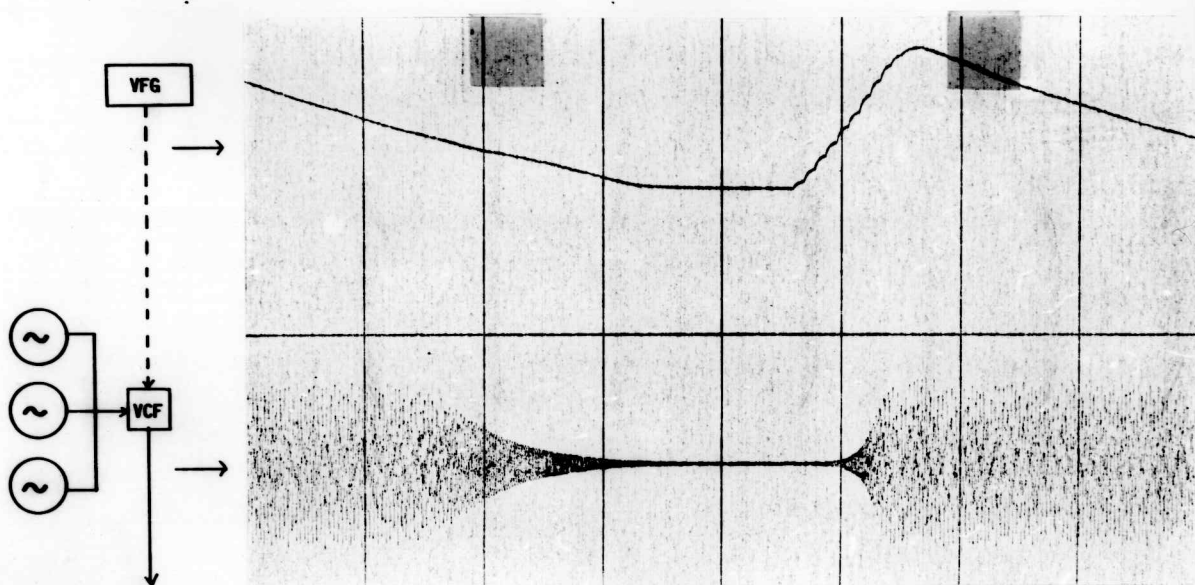
The following examples refer to a type of filter no longer in use at the institute. The functions of a new model of the same type as [V-HLF] would not differ sufficiently from the old model to justify the production of new examples.

It can generally be stated that the purpose of this book is achieved with the description of the most important means of programmable sound synthesis; the section on filtering is to be regarded more as an appendix to supplement a survey.



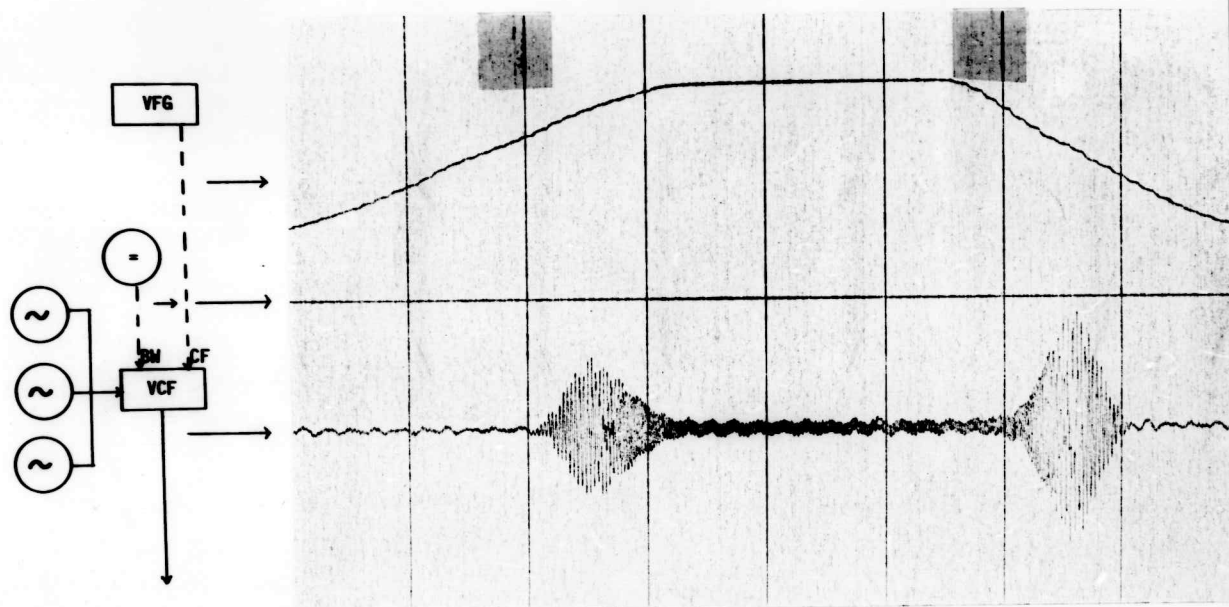
EXAMPLE 29: LOW-PASS.

The falling control voltage ensures that the filter which is open at first narrows down to the smallest pass-band (lowest frequencies).



EXAMPLE 30: HIGH-PASS.

The falling control voltage ensures that the filter which is open at first narrows down to the smallest pass-band (highest frequencies).



EXAMPLE 31a: BAND-PASS.

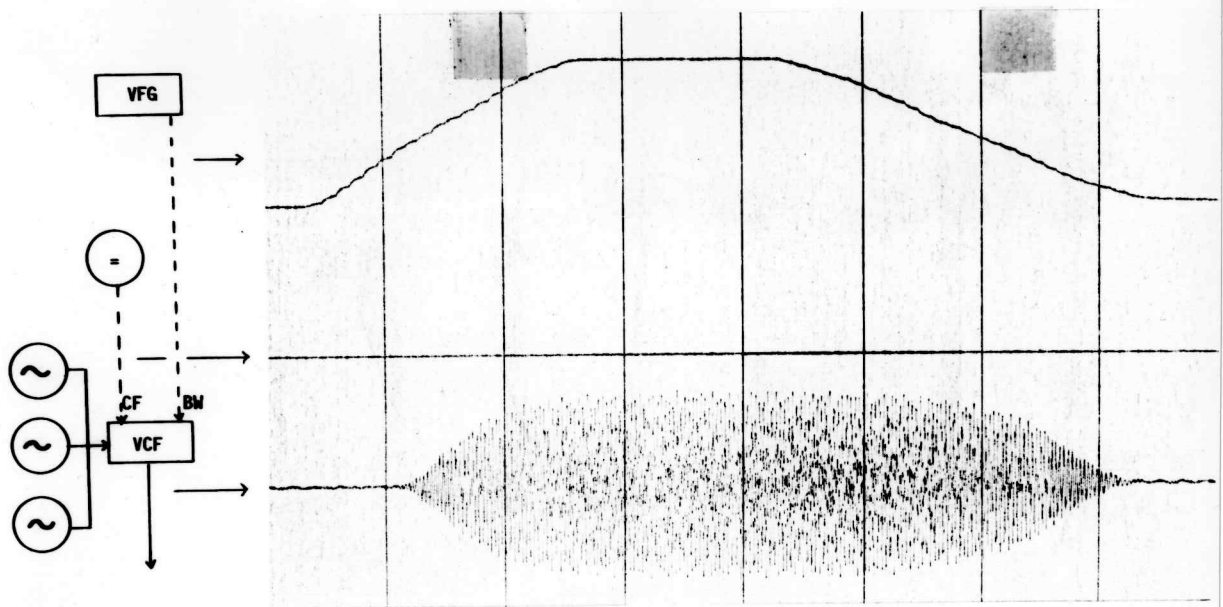
There are two possibilities of setting a band-pass filter:

- (a) by combining high and low-pass,
- (b) by defining the centre frequency and bandwidth.

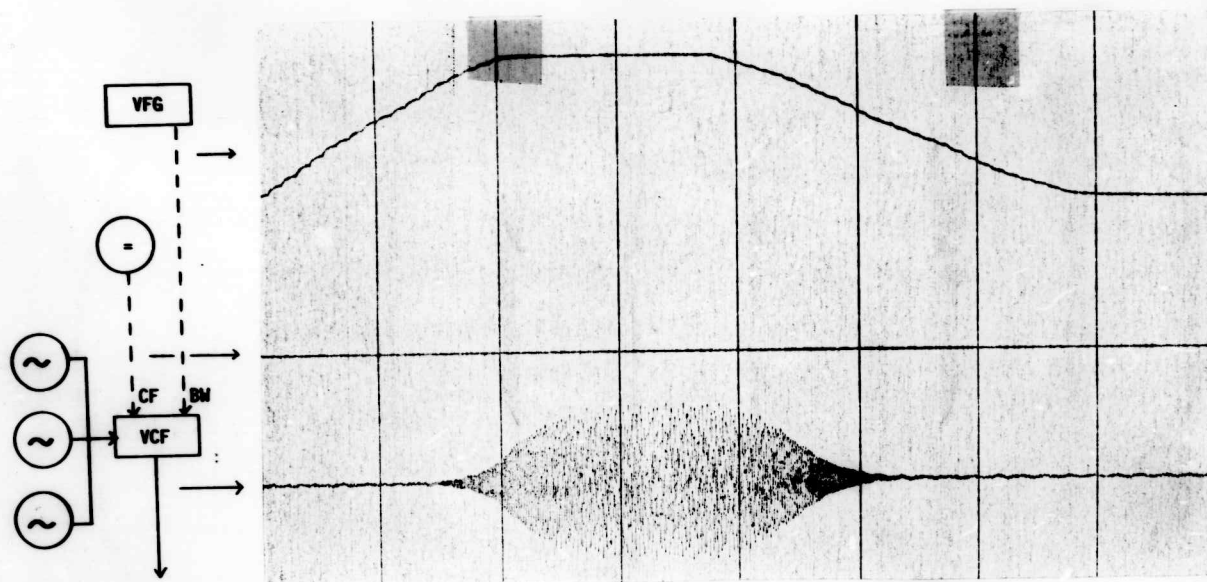
In both cases two control voltages are required.

The following examples only show the latter application.

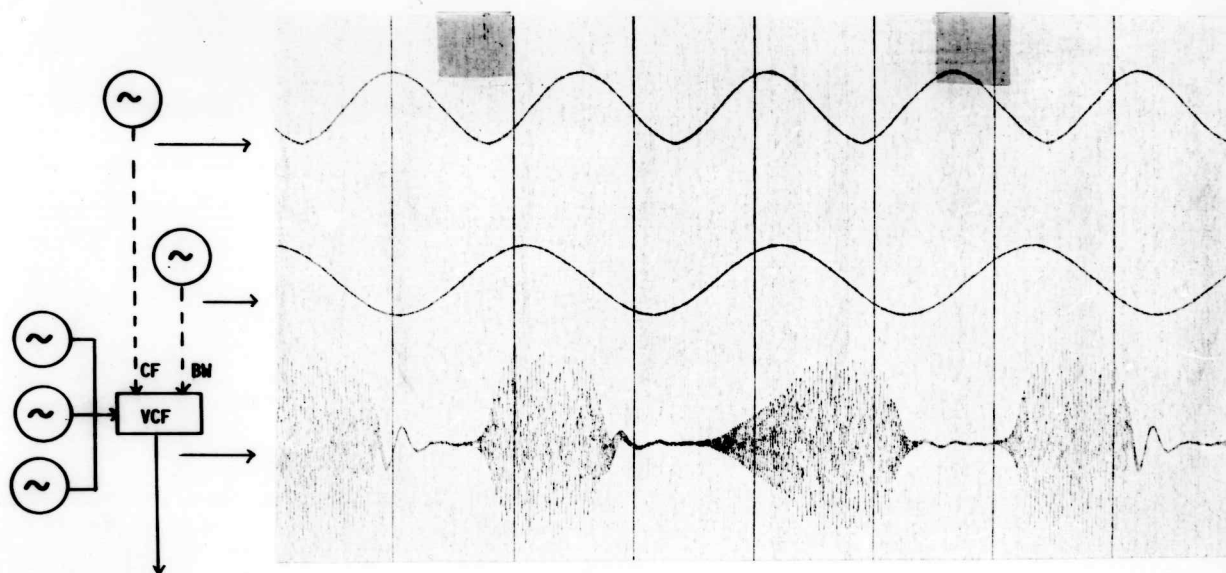
In ex. 31a a small constant bandwidth was chosen to shift the centre frequency upwards.



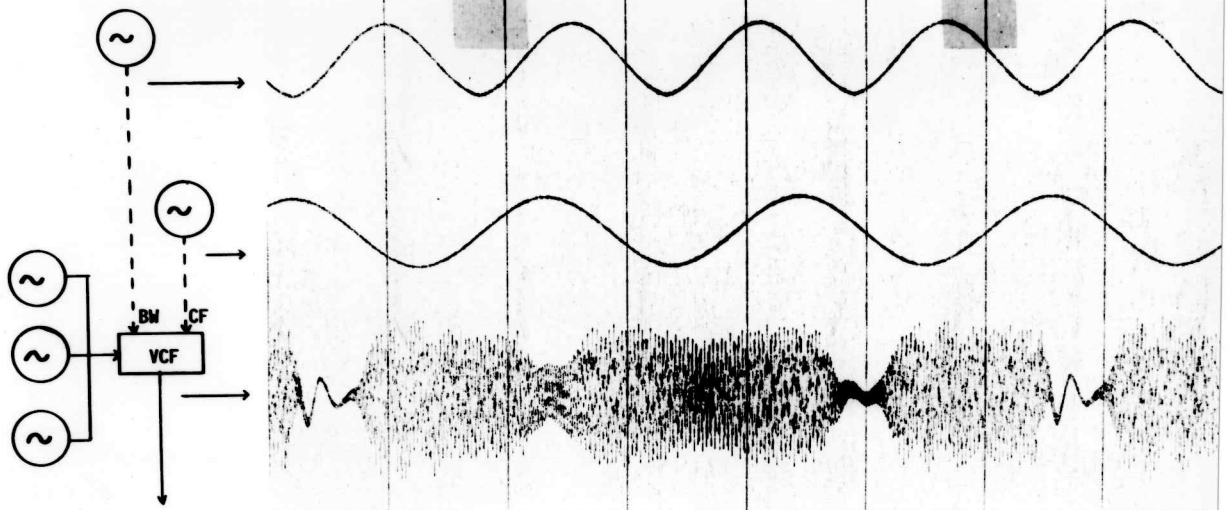
EXAMPLE 31b: BAND-PASS.
Fixed setting of a low centre frequency, variable bandwidth.



EXAMPLE 31c: BAND-PASS.
Fixed setting of a high centre frequency, variable bandwidth.

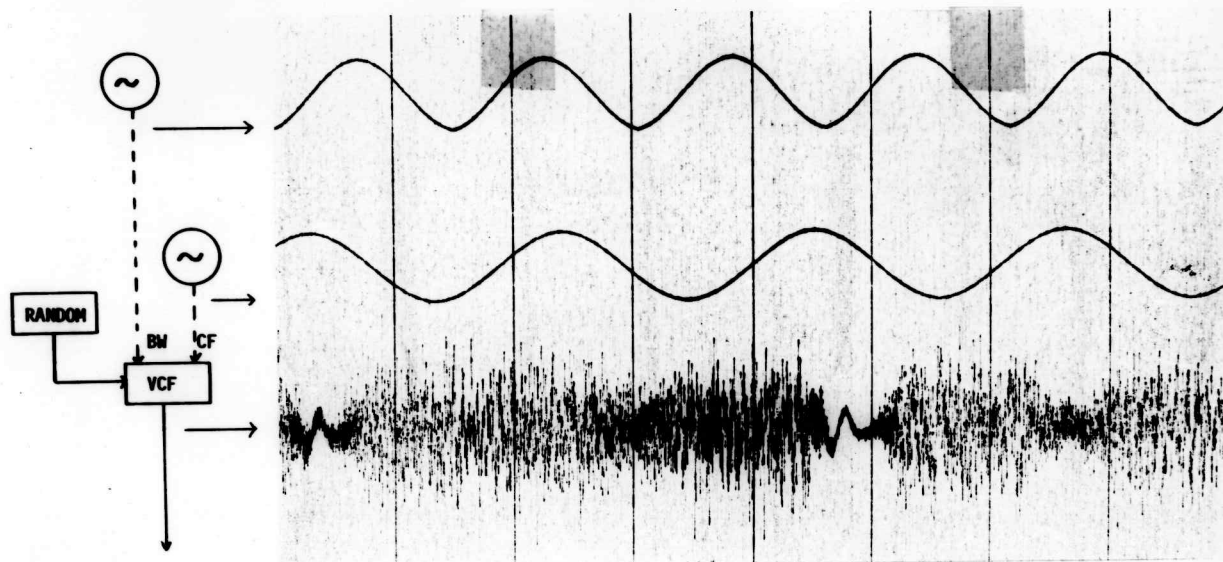


EXAMPLE 32a: BAND-PASS.
Two sinewaves of different frequency control the centre frequency and bandwidth.



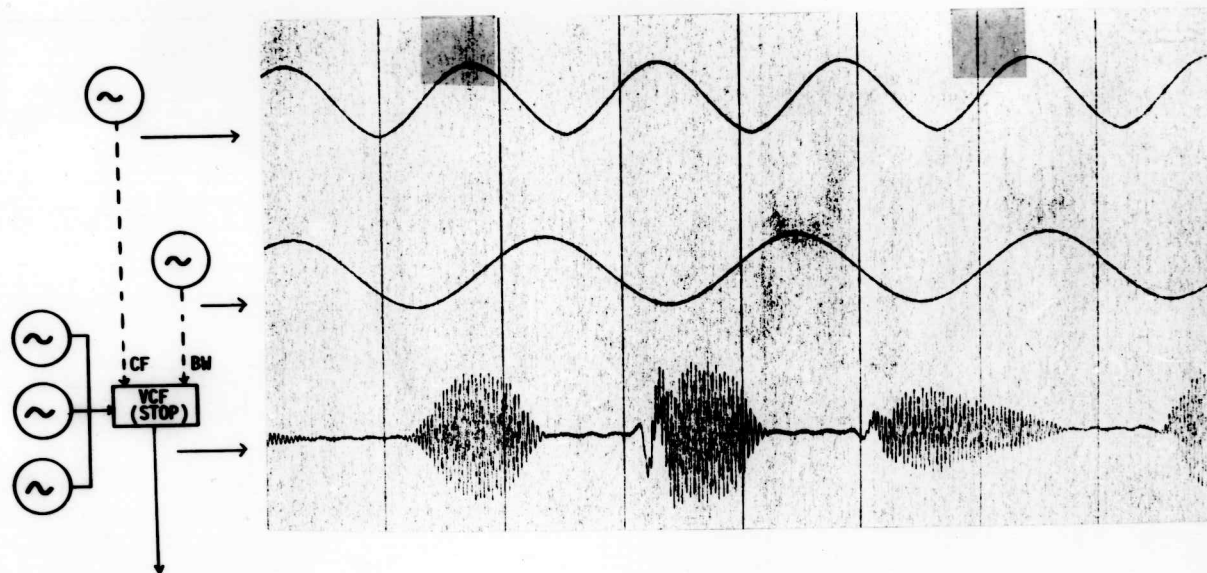
EXAMPLE 32b: BAND-PASS.

As in ex. 32a, but with opposite connections of the two control frequencies.



EXAMPLE 32c: BAND-PASS.

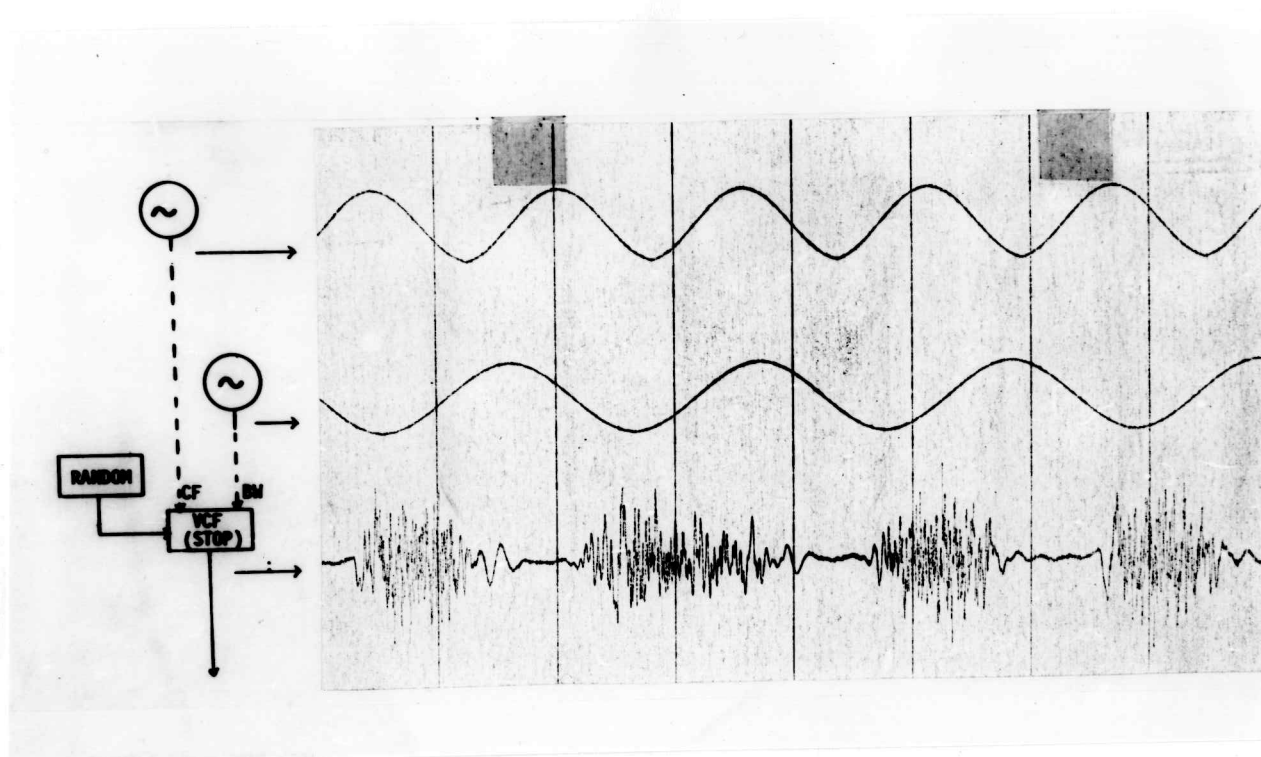
As in ex. 32b, but with white noise instead of sinewave mixture.



EXAMPLE 33a: BAND-STOP.

For the band-stop the centre frequency and bandwidth are still defined, but only the set frequency band is eliminated, the rest of the spectrum being let through.

In this example the above-mentioned sinewave mixture is filtered with the band-stop; bandwidth and centre frequency are controlled by two sinewaves of different frequency.



EXAMPLE 33b: BAND-STOP.
As in ex. 33a, but with white noise instead of the sinewave mixture.