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SAMPLING TONE GENERATOR SYSTEM FOR ELECTRONIC ORGANS

Filed Sept. 27, 1963 2 Sheets-Sheet 1

Fig. 1

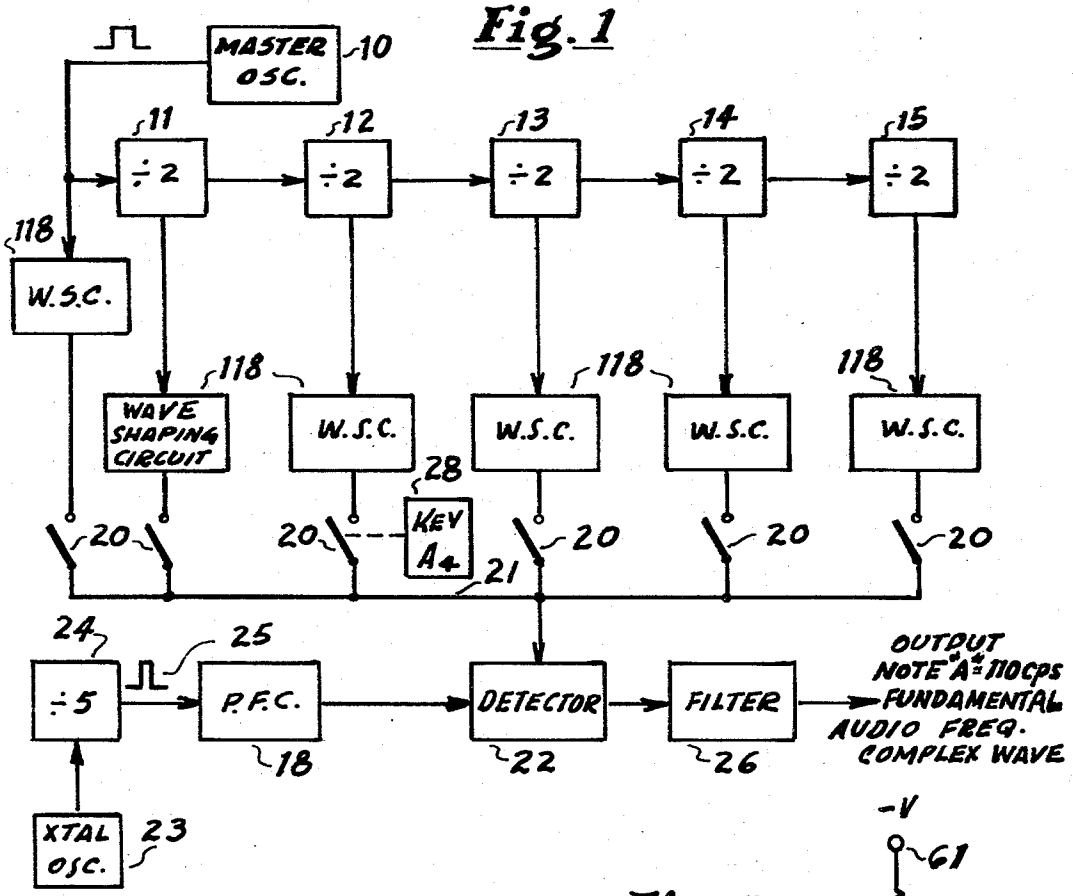


Fig. 2

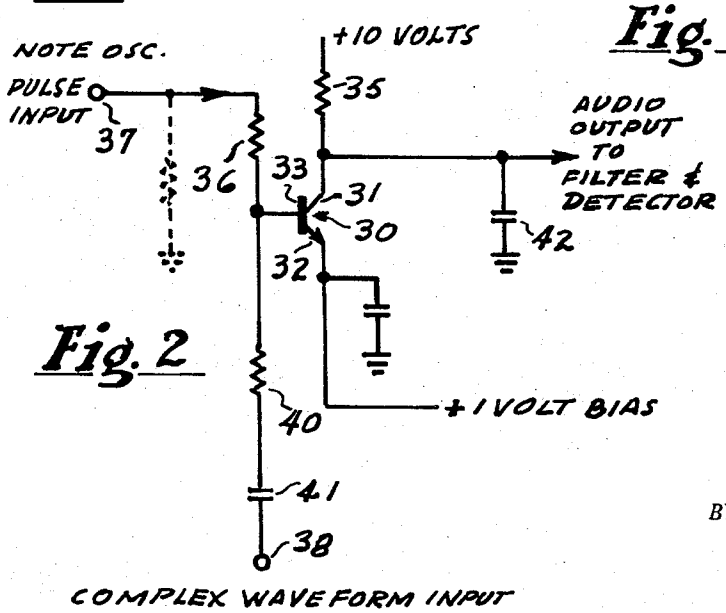
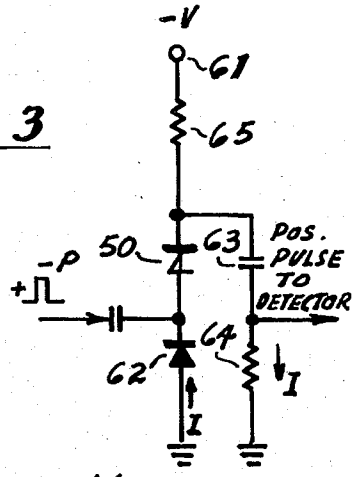


Fig. 3



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SAMPLING TONE GENERATOR SYSTEM FOR ELECTRONIC ORGANS

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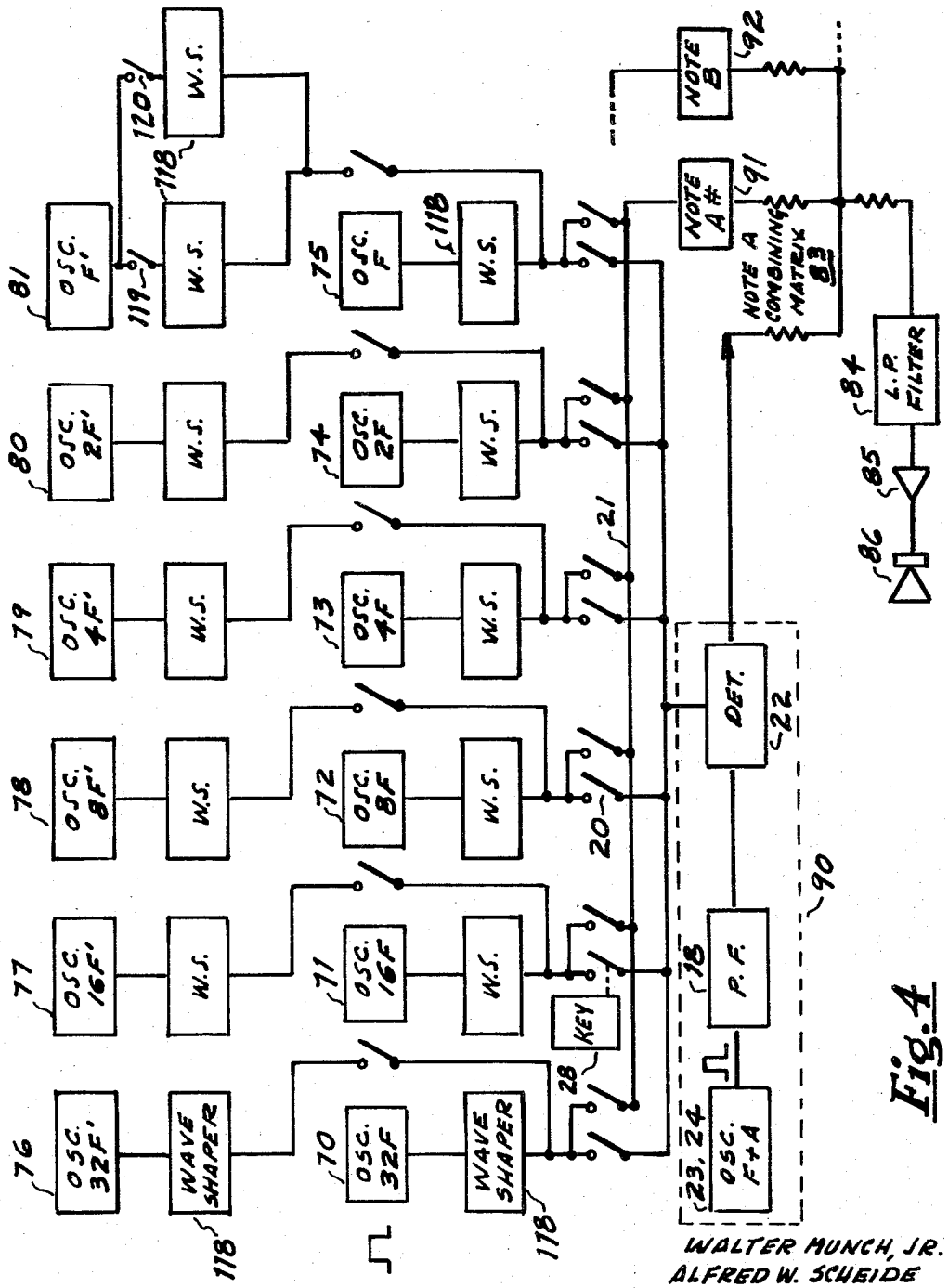


Fig. 4

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SAMPLING TONE GENERATOR SYSTEM FOR ELECTRONIC ORGANS

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14 Claims. (Cl. 84—1.23)

The present invention relates generally to electronic organs, and more particularly to heterodyne tone generation systems for electronic organs.

In the usual tone generator of an electronic organ, an array of oscillators is provided which operates at tone frequency and accordingly it is essential to provide at least one oscillator for each note, or twelve per octave. In accordance with the present invention on the other hand, an array of n oscillators provides frequency components for each of n octaves, and a further array of twelve oscillators provides further components for each of the twelve notes of one octave. The various components are selectively combined in sampling devices, which provide audio tones. A complete array of six octaves of tones can be generated by six harmonic oscillators and twelve further harmonic oscillators, each of the tones comprising an array of harmonics. Thereby, considerable reduction of components of the tone generator of an electronic organ can be achieved.

In accordance with the invention, an array of octave oscillators is provided, one for each octave of a tone generator. Each oscillator generates a gamut of harmonically related frequencies. These frequencies may be described by their fundamentals, F, 2F, 4F, 8F, 16F, 32F, in a six octave generator. Associated with the array of octave oscillators are twelve note oscillators. These oscillators generate extremely short pulses, and therefore gamuts of harmonically related frequencies. The fundamentals of the note oscillators differ from the frequency F by amounts equal to the frequencies of notes of the musical scale. For example if F=20 kc., the frequency of the note oscillator A pertaining to all notes of nomenclature A, has a frequency of 20.110 kc., i.e. $F+A$. The gamut of notes A are then generated by sampling note oscillator A with selected ones of the octave oscillators. If octave oscillator F is selected, the lowest A of the organ will sound, while if 32F is selected, the highest.

The system not only has the advantage of minimizing the number of oscillators required in a tone generator, but easily permits the paralleling of octave and/or note oscillators which are slightly different in frequencies, with consequent attainment of pipe organ or chorus effect. Since only six octave oscillators are required, these may be free running, if desired, without introducing problems of tuning many oscillators, as is the case in a conventional oscillator. Whereas, in a conventional organ using frequency divider chains to generate the entire required gamut of musical tones phase locking of the notes is present, the present system inherently reduces phase locking to notes of one nomenclature, and no two notes of different nomenclature, even where the octave oscillators are phase locked with each other.

It is, accordingly, a broad object of the invention to provide novel tone generators of electronic organs.

It is another object of the invention to provide a sampling tone generator for an electronic organ, wherein is employed one note oscillator for each tone of a single octave, and one additional octave oscillator for each octave of the organ, within a tone division, the note and octave oscillations being sampled to generate the full gamut of notes of the division.

It is another object of the invention to provide chorus

effect in electronic organs by duplicating the note oscillators and/or the octave oscillators of a sampling tone generator.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of one specific embodiment thereof, especially when taken in conjunction with the accompanying drawings, wherein:

FIGURE 1 is a block diagram of a system for generating the note of one nomenclature, in a sampling tone generator;

FIGURE 2 is a detector used for sampling note and octave oscillations, in the system of FIGURE 1;

FIGURE 3 is a pulse forming network used in the system of FIGURE 1; and

FIGURE 4 is a modification of the system of FIGURE 1, employing independent octave oscillators, and duplicate octave and note oscillators, to achieve maximum chorus effect, and minimum phase lock of notes.

Referring now to the accompanying drawings, in FIGURE 1, **10** is an oscillator generating square pulses. The oscillator **10** drives a chain of dividers, composed of frequency dividers **11**, **12**, **13**, **14** and **15**. Divider **15** provides the lowest frequency output, and is at 20 kc. Dividers **14**, **13**, **12**, and **11** and oscillator **10** have frequencies, respectively, of 40, kc., 80 kc., 160 kc., 320 kc., and 640 kc. The outputs of oscillator **10** and dividers **11–15** are separated by octaves, and hence are called octave oscillators, there being one octave oscillator for each of six octaves. The wave forms at the output of the oscillators **10–15**, inclusive may be shaped by wave shaping circuits **118**, if desired, these being, however, optional. The outputs of the wave shapers **118** are gamuts of harmonically related frequencies. The outputs of the wave shapers **118** are selected at will by key switches **20**, and collected on a lead **21**, which is connected to a sampling detector **22**.

To the detector **22** is also connected an oscillation source comprising a stable source such as crystal oscillator **23**, driving a frequency divider **24**, which in turn supplies relatively short pulses **25** at its output. A pulse sharpener **18** is included to provide an extremely short pulse output. The pulse frequency is 20.110 kc. for the example specified, i.e. where F=20 kc., 110 c.p.s. being the freqency A_1 of an organ, i.e. A in the lowest octave of a given division.

At the output of detector **22** is provided an audio filter **26**. An A_4 key **28** of the keyboard of the organ would close switch **20** of oscillator **12**. Oscillator **12** and wave shaping circuit **118** generate complex waves at 160 kc. and oscillator **23** provides very short pulses **25** at 20.110 kc., at the output of the pulse forming circuit **18**. An audio difference frequency between harmonic frequencies of the pulses is generated by detector **22** and is selected by L.P. filter **26**.

If it were desired to play note A_2, the outputs of oscillators **14** and **23** would be combined. If we denominate the fundamental output of oscillator **23** as f_1 and that of oscillator **15** as F, then $A_1=f_1-F$, where f_1 is above F. Obviously f_1 could have been chosen below F. A_2, on the other hand, equals $2f_1-2F$, and is 220 c.p.s. Any sampled combinations of NF with nf, where N and n are integers, does not result in an audio frequency unless N and n are equal.

It will be clear that multiple keys **20** may be closed simultaneously, to generate combinations of A_n. Were detector **22** a mere non-linear device, difficulty would ensue if A_1 and A_3 were attempted at once, in that $A_3-A_1=60$ kc.$=3F$, which would be generated by the detector as a higher order intermodulation product, and would produce in turn, by combination with $3f$, an undesired audio sig-

nal. To avoid this possibility a special detector is employed, illustrated in FIGURE 2.

The wave shaping circuit may be any one of several types of devices, without departing from the true spirit of the invention. For example, the outputs of oscillators **10–15** may be converted to shorter pulses, or to sawtooth waves, or filtered to provide sine waves or formed arrays of harmonics having predetermined relative amplitudes. The output of the system, in terms of tonal content is entirely determined by the character, i.e. frequency values and relative amplitudes of the frequency components, at the outputs of the wave forming circuits. If desired, each wave forming circuit may actually consist of a parallel array of circuits, as **118**, **118'**, each for selecting a different tone type, i.e. flute, diapason and the like, and these may be selected or inserted in circuit by means of switches **119**, **120**, as shown in FIGURE 4.

FIGURE 1 illustrates how one gamut of notes, i.e. A, is formed. Reference is made to FIGURE 4, for a more complete illustration of an organ.

In the detector of FIGURE 2 the pulses from the note oscillators **23** are used to sample the complex wave forms of the master oscillator and divider chain. The transistor **30** is of NPN type, and includes a collector **31**, an emitter **32** and a base **33**. The emitter **32** is biased to +1 volt, and the collector to +10 volts through a resistance **35**. The +1 volt bias maintains the transistor cut off. A pulse forming circuit **18**, providing a note oscillator pulse output, supplies 6 volt pulses to the base **33**, through current limiting resistance **36**, at terminal **37**, and the selected components of the master oscillator-divided chain output is applied at terminal **38**, via resistance **40** and capacitor **41** which maintain the latter currents below cut off, so that no current flows into the collector **31** except when the beat oscillator pulses **25** are applied. When conduction occurs base current has two components, i.e. one due to the positive beat oscillator pulse **25**, and the other due to the octave oscillators. The base current thus varies, during each beat oscillator pulse **25**, according to the then amplitude of the octave oscillators. A form of pulse modulation ensues, having an envelope component due to the difference frequencies and representative thereof. These difference frequencies represent a complex spectrum, including audio and supersonic components and the pulses supplied by the detector **22** must contain all these frequencies. Capacitor **42** integrates the amplified current output pulses available at collector **31**, and the integrated current is abstracted as a voltage across capacitor **42**, and filtered, by audio low pass filter **26**. The filtered output is the desired audio tone.

The pulse formers **18** employ a four layer diode **60** (FIGURE 3) as a switching element. The four layer diode has a volt-ampere characteristic like a neon cell in that the diode goes into conduction when a firing voltage is attained, and thereafter stays in conduction until its voltage is reduced below a fairly critical small value. In the system of FIGURE 3, the negative supply **61** is below firing potential. When a positive pulse P is applied across diode **62** the terminal voltage of four layer diode **60** increases above firing potential and it fires, discharging capacitor **63** through diodes **60**, **62** and resistance **64**. When the capacitor **63** discharges the diode **60** turns off and the capacitor begins to recharge through resistance **64**. Charge time is made sufficiently great that the capacitor **63** does not build up to supply voltage before the next trigger pulse arrives. Output is taken on lead **66** across resistance **64**, and is positive since discharge current I is toward ground in resistance **64**.

In the alternative system of FIGURE 4, the oscillators **70–75** are independent of each other. This reduces phase locking, in the audio output of the system, but is otherwise a matter of choice over the system of FIGURE 1. A more important additive feature of FIGURE 4 is that each of oscillators **70–75** is paralleled by an additional oscillator **76–81**, nominally of the same frequency, i.e. *n*F, but actually very slightly different in frequency, i.e. *n*F'. FIGURE 4 also indicates how detectors and beat oscillators for various notes, as **90**, **91**, **92**, for the notes A, A# and B may be resistance matrixed in an adding circuit **83**, and commonly applied to low pass filter **84** for application to power amplifier **85** and speaker **86**.

The addition of oscillators **76–81** is particularly valuable since these can be selected in frequency to provide a small difference between F and F', but a relatively large difference between 32F and 32F', where the oscillators are all independent. Were the oscillators locked in a chain, as in FIGURE 1, this same result would automatically accrue because of the frequency division process which continually divides not only the frequencies but also the difference between *n*F and *n*F'. This leads to minimum cost for achieving chorus effect, since there are only six octaves to duplicate.

The keying system of FIGURE 4 assumes that actuation of any organ key **28** connects a selected switch, as **20'**, which selects (1) an octave oscillator, and (2) a note detector, appropriate to the key. The switches **95** then serve to add the oscillators **76–81** to the system at will, to produce chorus effect.

While we have described and illustrated one specific embodiment of our invention, it will be clear that variations of the details of construction which are specifically illustrated and described may be resorted to without departing from the true spirit and scope of the invention as defined in the appended claims.

What we claim is:

1. A tone generating system for an electronic organ, comprising a plurality of supersonic harmonic rich signal sources having fundamental frequencies arranged at least approximately in octave relationship, at least one narrow pulse signal source generating sampling signals in the form of sharp pulses in a frequency range having at least one fundamental frequency differing from the lowest fundamental frequency of said plurality of sources by a difference at least approximately equal to the fundamental frequency of a note in the musical scale, a sampling device connected to said at least one narrow pulse source, and means for connecting said plurality of signal sources to said sampling device selectively at will in any combination, and means connected to said sampling device for deriving therefrom audio tone components.

2. The combination according to claim **1** wherein said plurality of harmonic rich signal sources comprises a master oscillator and a chain of frequency dividers.

3. The combination according to claim **1** wherein said plurality of sources comprise oscillators only approximately in octave relation.

4. The combination according to claim **1** further comprising means associated with each of said supersonic harmonic rich signal sources for selectively varying the harmonic content of each of said harmonic rich signals to selectively change the tones of said audio tone components.

5. The combination according to claim **1** wherein said plurality of supersonic harmonic rich signal sources comprises a plurality of independent signal sources to reduce phase locking of said audio tone components.

6. The combination according to claim **1** wherein said means for connecting said plurality of signal sources to said sampling device selectively at will in any combination comprises a plurality of keys, a single key only for each of said plurality of signal sources, one side of each of said keys being connected together and to said sampling device, the other side of each of said keys being connected to a different one of said plurality of signal sources.

7. A tone generating system for an electronic organ, comprising a plurality of arrays of harmonic rich supersonic signal sources, each of said arrays having fundamental frequencies arranged in at least approximately octave relation, and the separate arrays of said plurality

having similar arrays of fundamental frequencies, a sampling device, a further sharp pulse signal source having a fundamental frequency differing from the lowest approximately equal fundamental frequencies of said plurality of sources by a difference at least approximately equal to the fundamental frequency of a note in the musical scale, means connecting said further sharp pulse signal source to said sampling device, means for connecting said plurality of signal sources in any combination to said sampling device selectively at will to be sampled by said sharp pulse signal, and means connected to said sampling device for deriving therefrom harmonic rich audio tone components.

8. The combination according to claim 7 further comprising means associated with each of said arrays of harmonic rich supersonic signal sources for selectively varying the harmonic content of each of said harmonic rich supersonic signals to selectively change the tones of said audio tone components.

9. The combination according to claim 7 wherein said plurality of arrays of harmonic rich supersonic signal sources comprises a plurality of independent signal sources to reduce phase locking of said audio tone components.

10. A tone generating system for an electronic organ, comprising an array of harmonic rich supersonic signal sources having fundamental frequencies arranged in at least approximately octave relationship, a plurality of sampling pulse sources having approximately equal fundamental frequencies differing from the lowermost fundamental frequency of said array of sources by amounts at least approximately equal to the fundamental frequencies of notes in the musical scale, a sampling device connected to said sampling pulse sources, means for connecting said array of signal sources to said sampling device in any combination selectively at will, and means for deriving from said sampling device only audio tone components.

11. In a system for generating organ tones, one source of supersonic wave shapes having frequencies F, 2F, 3F . . . , further sources of supersonic wave shapes having frequencies nF, $2n$F, $3n$F, where n assumes a different one of values, 2, 4, 8, 16 . . . in separate ones of said sources, another source of sharp pulse having supersonic frequencies f, $2f$, $3f$ . . . , where the difference of f and F is a tone frequency of the musical scale, and sampling means for deriving from said sources at will any one or more of frequency arrays or differences of (1) $2+F$, $2f+2F$, $3f+3F$ . . . (2) $2f+2F$, $4f+4F$, $8f+8F$ (3) $4f+4F$, $8f+8F$, $12f+12F$ . . . , any one or more of the complete arrays (1), (2), (3) . . . representing components of one harmonic rich tone.

12. A tone generating system for an electronic organ, comprising a plurality of harmonic rich supersonic signal sources having fundamental frequencies arranged in at least approximately octave relationship, a plurality of sampling pulse sources having approximately equal fundamental frequencies differing from the lowermost fundamental frequency of said array of sources by amounts at least approximately equal to the fundamental frequencies of notes in the musical scale, a plurality of sampling devices connected one for one to said sampling pulse sources, means for connecting said plurality of signal sources to said plurality of sampling devices in any combination selectively at will, and means for deriving from said plurality of sampling devices only audio tone components.

13. The combination according to claim 12 further comprising means associated with each of said harmonic rich supersonic signal sources for selectively varying the harmonic content of said harmonic rich signals to selectively change the tones of said audio tone components.

14. The combination according to claim 12 wherein said plurality of harmonic rich supersonic signal sources comprises a plurality of independent signal sources to reduce phase locking of said audio tone components.

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