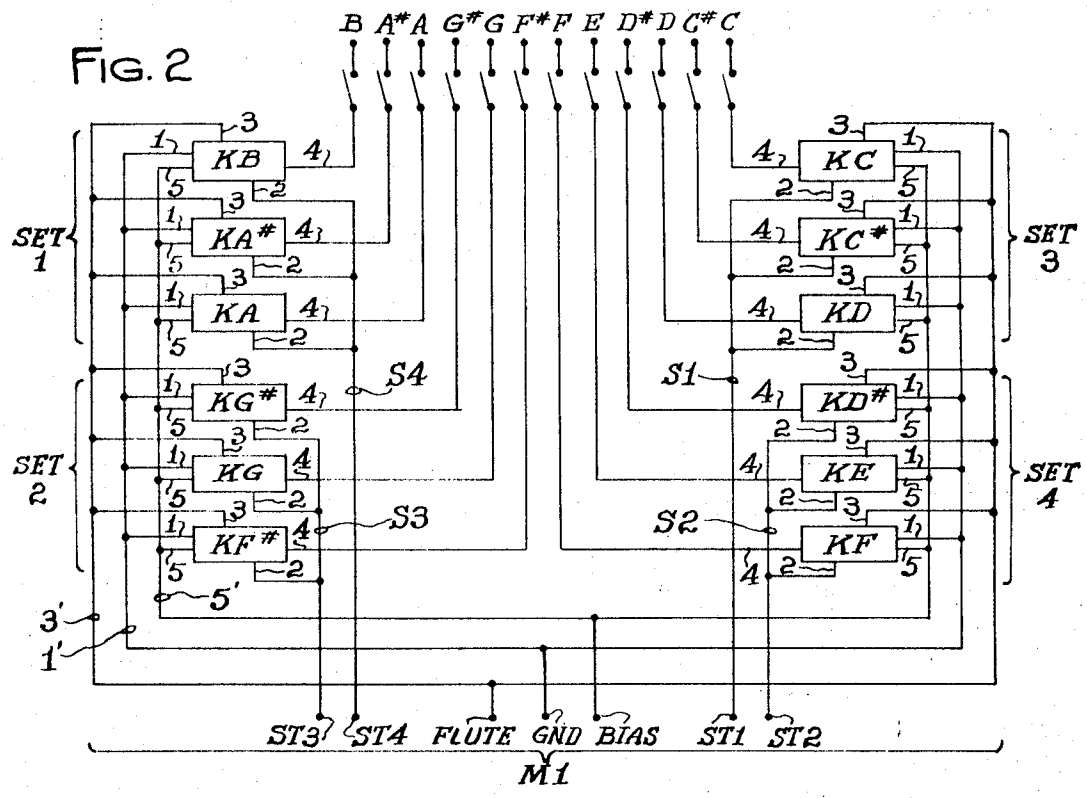
Aug. 5, 1969 R. L. EBY 3,459,869

ELECTRONIC ORGAN WITH LOCK-IN CIRCUIT FOR TONE-SIGNAL GENERATORS THEREOF

Filed April 29, 1965

FIG. 2



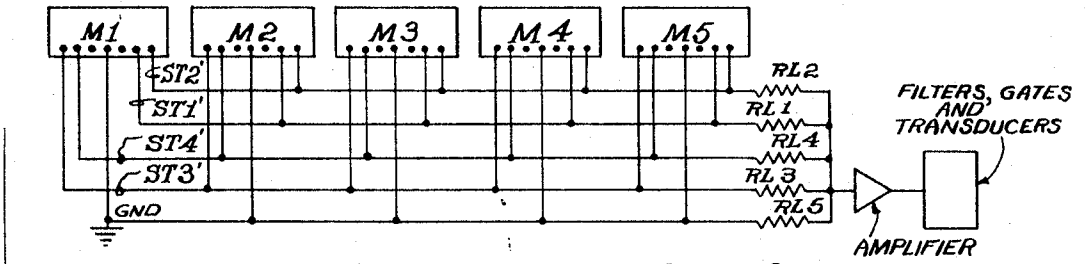


FIG. 3

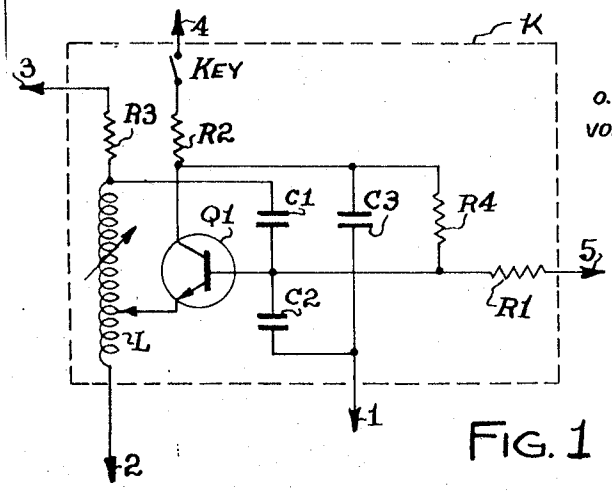


FIG. 1

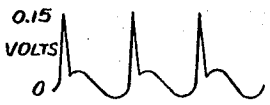


FIG. 4

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ELECTRONIC ORGAN WITH LOCK-IN CIRCUIT FOR TONE-SIGNAL GENERATORS THEREOF

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U.S. Cl. 84—1.01 9 Claims

ABSTRACT OF THE DISCLOSURE

An electronic organ having a plurality of tone-generating devices for generating octavely-related signals wherein each generating device is independently keyable and including means for interlocking concurrently keyed octavely-related generating devices to prevent undesirable octave-interval beat effects. The interlocking function is performed by means responsive to operation of the circuit to produce in the output line a signal of the fundamental frequency of the oscillatory circuit which signal includes a sharp, high-amplitude, short-duration peak during each oscillation. Additionally, the output lines of a plurality of the octavely-related generating devices are interconnected in such manner that the related generating devices are beneficially influenced by the harmonic-rich signal of another operating generating device to maintain the octavely-related generating devices functioning free of octave-interval beating.

The invention hereinafter disclosed pertains to improvements in musical instruments in which musical tones or notes are produced by electromagnetic transducers or "speaker" means to which are transmitted tone-signals of appropriate frequencies and of the character of electric waves that are generated by electronic tone-signal generating devices such as electronic oscillators.

More particularly, the invention pertains to means for stabilizing the frequency relationship between any two or more of such devices of a specified plurality of such devices having a particular frequency relationship and/or between particularly related ones of such deivces comprised in corresponding sets in octavely-related groups of such tone-signal generating devices.

In United States Patent No. 3,309,624 granted to Robert D. Allen, entitled Tone Generator for Musical Instrument, there is disclosed a novel tone-signal generating device which comprises electronic oscillator and circuit connection means especially adapted for the purposes and objects of the present invention. The novel generating device comprises an oscillator especially adapted to provide a plurality of tone signals or waves of respective characteristics and which oscillator is adapted to be individually keyed on and off, that is, set into oscillation and switched off individually in response to operation of a respective switch actuating key of a musical instrument. The circuit of that oscillator or generating device is briefly described herein; however for full details reference may be made to the noted companion application, the disclosure of which is incorporated herein by reference.

By means of the present invention, a desired constant frequency relationship is attained between a tone-signal

generating device of a selected set thereof in one octave group and one or more such devices in corresponding selected sets in octavely-related other groups thereof, despite the fact that the several oscillators are individually started into oscillation and stopped in response to keying and are not in continuous operation. The desired substantially constant or fixed frequency relationship between one tone-signal generating device and another thereof in a different group, is attained and maintained during concurrent keying of both of the generating devices by means which causes interaction between the oscillatory circuit of any operating generator and any other such oscillatory circuit of an octavely-related generator that is uniquely connected to the former generator in accord with the invention. Such interaction, or locking in of the frequency of one relative to that of another, is effected by circuit interconnecting means of particular character.

It is well known in the prior art to establish fixed or stable frequency relationships between tone-signal generating oscillators employed in musical instruments. However that result was heretofore accomplished by utilizing a continuously operating, precisely controlled generator or oscillator as a master or control oscillator and arranging other continuously operating oscillators as slave devices locked-in, frequency-wise, to the master oscillator. In the present invention, all tone-signal generators comprise respective discontinuously-operating oscillators; and hence none is a master oscillator. Rather, any tone-signal generator comprised in a uniquely interconnected plurality thereof, is, incident to keying thereof, made to assume the proper frequency relationship to any other currently operating generator comprised in that plurality of the generators.

Thus, according to the invention, any newly keyed tone generator oscillator is required to "lock-in" to any currently oscillating oscillator comprised in the uniquely interconnected plurality of tone-signal generators. To that end, use is made of the fact that the novel tone-signal generating device is arranged to provide on one of the output signal lines thereof a signal that comprises the base or fundamenal oscillation frequency and is also rich in harmonics of that frequency; and use is further made of the fact that appropriately interconnected octavely-related oscillators producing tone-signals having strong common harmonic frequency components will "lock-in" and maintain a stable frequency relationship during concurrent operation. As is evident, locking-in of two or more tone-signal generators as indicated requires interconnection of only generators having appropriate tone-signal frequency relationships. To that end, according to the invention, the numerous tone-signal generators or devices comprised in an instrument are divided into octavely-related groups, whereby harmonic frequency relationship between generators assigned to a particular note of the scale is generally established; and further, the generators or devices within each group are divided into sets so that certain undesirable interactions may be avoided, as will presently be explained. Thus direct interconnection of harmonic-rich output lines (herein termed the strings tones lines) of the tone-signal generators of a set thereof is established, and direct interconnection of the thus-interconnected strings tones lines of corresponding sets in the several octavely-related groups is established, all of the direct interconnections being by bus conductors.

As thus far indicated, and using tone-signal generating

devices arranged to provide signals for the production of notes for several octaves N in number and each comprising the twelve notes of an octave of the tempered scale system as the preferred exemplary arrangement, the octave group of twelve tone-signal generators is divided into four sets of three generators or devices each interconnection of the strings output line (strings-tones line) of the first set of (three) generators of the first octave (I) is made by connection to a first bus line, and similarly with the first set of generators in each of the other octaves. The several first set bus conductors are interconnected, to provide the interconnection between octavely-related sets. Similar interconnections are made relative to the generators of each of the other three sets of generators in the (octave I) group; and similar interconnections of corresponding octavely-related sets are made. Thus four strings tone-signals output lines are established, and each of these output lines is connected via respective isolating resistor to signal utilizing means including transducer (speaker, e.g.) means, preferably by way of and including an amplifying device. Other tone-signal output lines (such as flute not lines) and ground connection lines leading to and from the several tone-signal generators of the instrument may be connected to respective interconnecting buses, and the power input lines are connected to a power source via respective key switches of the instrument.

The preceding brief general explanation and description makes it evident that it is a principal object of the invention to provide general improvements in tone-signal generator arrangements in electronic musical instruments.

Another object of the invention is to provide an improved means and method of interconnecting and effecting frequency-interlocking of octavely-related keyed tone-signal generators in electronic musical instruments.

An additional object of the invention is to provide automatic frequency interlocking of appropriately frequency-related intermittently keyed concurrently operated tone-signal generating devices in an electronic organ or like instrument.

Other objects or advantages of the invention will hereinafter be stated or made evident in the appended claims or in the following description of a preferred physical arrangement of devices and components according to the invention, the preferred arrangement and component details being diagrammatically illustrated in the accompanying drawings in which:

FIGURE 1 is an electronic circuit diagram of an electronic tone-signal generating device and appurtenant connections, used in the exemplary embodiment of the invention;

FIGURE 2 is a diagrammatic representation of electrical interconnections between tone-signal generators comprised in an exemplary octave group of such generators, according to the invention;

FIGURE 3 is a diagrammatic representation of electrical interconnections between octave groups of tone-signal generators, and of the connections of tone-signal lines to transducer means; and

FIGURE 4 is a diagrammatic representation of an electrical wave, useful in explaining the invention.

Referring to FIGURE 1, the unique tone-signal generator used in combination with other like generators and interconnected therewith in a group to provide output signals representing notes of an octave, is depicted in electronic circuit diagram form. A dotted line enclosure, labeled K, is used to indicate that each such generator, having a ground line **1**, a strings tones signal output line **2**, a flute tone signal output line **3**, a keyed input power line **4**, and a celeste and vibrato bias input line **5**, is considered herein as a tone-signal generating device or generator. As is more fully explained in the aforementioned copending companion application, the generator comprises an oscillatory circuit composed essentially of interconnected capacitors **C1** and **C2**, inductive coil L (together forming a tank circuit), and transistor **Q1**, connected to the lines **1**, **2**, **3**, **4** and **5** as indicated. The collector of the transistor Q1 is connected via a resistor **R2** and a key operated switch KEY to a grounded source of power (not shown) by line **4**. A resistor **R4** is connected between the collector and the base of the transistor. A flute tone-signal output line **3** is provided, which, being connected to the tank circuit via a resistive means only, receives a substantially pure sine wave signal of the frequency of the oscillator. Resistor **R3** serves as an isolation resistor for the tank circuit, relative to the flute tone signal line. An isolation resistor **R1** connects bias line **5** to the base of transistor **Q1** and the tank circuit, whereby a relatively slowly varying bias potential of vibrato frequency may be made effective to vary the natural frequency of the tank circuit over a small frequency shift range to provide vibrato effects in the outputs of the generator. The ground line **1** is provided whereby the circuit is connected to the ground of the power source previously mentioned. The resistive ground return for the emitter of the transistor, line **2**, provides a tone-signal line on which an electric wave that is rich in harmonics is generated or appears, as is explained in the companion application previously mentioned. The rich harmonics content of the electric wave made to appear on line **2** is due to the pulse type of conduction through the transistor **Q1**. The oscillator is set into operation by closure of the corresponding key switch of the instrument, and during closure of the switch the transistor (**Q1**) alternately conducts and cuts off, conduction occurring during about one tenth of a cycle of oscillation. The current conducted by the transistor passes through line **2** of the wave generator or oscillator, which line serves as a ground return line for the current conducted by the transistor. Thus, as indicated in FIGURE 4, the wave signal on line **2** of the oscillator comprises a generally sinusoidal wave principally, and during all but the initial portion of each cycle; but, during about the first one tenth of the cycle (during conduction of emitter-collector current through the transistor) the wave includes a relatively high amplitude spike. Thus the wave has a component rich in harmonics of the fundamental frequency. Advantage is taken of the rich harmonic content of the output signal on line **2**, to lock together the oscillator of the tone-signal generator with operating oscillators of other harmonically-related tone-signal generators.

Referring now to FIGURE 2, an octave group of tone-signal generating devices is shown, designated generally **M1**, with each device designated by prefix K and a suffix indicating the musical note corresponding to the fundamental frequency of the respective device. Also, each device is represented by a respective rectangle simulating circuitry like that comprised within the dotted rectangle in FIGURE 1. For example, the first three tone-signal generating devices, corresponding to the first three notes, C, C# and D of the octave, are designated KC, KC# and KD. The several input and output lines of each of the devices are numbered according to the convention established in FIGURE 1. The octave group of tone-signal generators comprises twelve of the devices KC, KC#, KD . . . KA, KA#, KB. The keying or power input line **4** of each of the generators is connected to a respective one of key switch terminals C, C#, D . . . A, A# and B, as indicated. For reasons presently more fully made evident, the group of twelve tone-signal generators is divided into four sets, each set comprising three generators, as indicated.

Since neither of the flute tone signal lines **3** nor the bias (vibrato) lines **5** are significant in the matter of locking-in of harmonically-related tone-signal generators, the several lines **3** are connected to a common bus **3'** and all are thus connected to a terminal or junction FLUTE; and similarly the several bias lines **5** are connected to a common bus **5'** and all thus are connected to a terminal or junction BIAS. The several ground lines **1** are

similarly connected to a common ground bus 1' and thus are connected to a terminal or junction GND.

As was previously indicated, the strings-tones lines 2, carrying signals rich in harmonics, are employed to effect locking-in of selected tone-signal generators with other harmonically-related generators similarly disposed in other octave groups. To prevent undesirable locking-in of certain generators within an octave group, each octave group is divided into the noted four sets of three generators each, and four strings-tones signal bus conductors are provided, each for a respective set of generators. Each bus is used to establish connection, via an interconnecting bus conductor and a similar set bus in each of the other octave groups of generators, with the corresponding strings-tones lines 2 of the corresponding set of generators in all of the octave groups of the instrument. Thus the strings-tones signal lines 2 of the first three generators, KC, KC# and KD, comprised in the first set, are connected to a common bus S1 and thereby to a terminal or junction ST1. Similarly the strings-tones lines 2 of the generators of a second set (KD#, KE and KF) are connected to a common bus S2 and thereby to a terminal or junction ST2. Likewise, lines 2 of the generators of the third set (KF#, KG and KG#) are connected to a common bus S3 and thus to a terminal or junction ST3; and lines 2 of the fourth set, comprising generators KA, KA#, and KB are connected to a bus S4 and to a terminal or junction ST4. The entire octave group as a unit is designated M1.

It is evident that within any set of generating devices, oscillation of one generator will not adversely affect any other, since there is no significant harmonic relationship between the fundamental waves and harmonics thereof of generators within a set. To provide for lockin of any generator with any other operating generator harmonically-related thereto, interconnections are made between octave groups, as indicated in FIGURES 3. In the latter figure, five octave groups of tone signal generators are represented by respective rectangles and designated M1, M2, M3, M4 and M5. It will be understood that each octave group is constituted as is group M1 in FIGURE 2 except that the twelve tone-signal generators are octavely related, as to fundamental frequency, to the respective similarly disposed generators in group M1. As shown in FIGURE 3, each octave group or block has seven terminals or junctions, corresponding to those shown in greater detail in FIGURE 2. Since the BIAS and FLUTE interconnections are not per se of the invention here of interest, they have been omitted from FIGURE 3 in the interest of clarity. The connections of those interconnections to input means of transducers are as known in the art. As indicated in FIGURE 3, the several ST2 junctions are connected to a common bus conductor ST2'; and the bus is connected to the input of conventional amplifier means via an isolation resistor RL2. Similarly the ST1 junctions of the octave groups are interconnected by a bus ST1' and to the amplifier means by isolation resistor RL2. As is now evident, similar interconnection of the strings tones signal lines junctions ST3 is effected by a bus ST3' which is connected to the amplifier by way of resistor RL3; and junctions ST4 are interconnected by bus ST4' leading to the amplifier by way of resistor RL4. The several resistors RL1, RL2, etc., serve to prevent effective interaction of signals on one bus with generators connected to another of the bus conductors.

The GND terminals or junctions of the octave groups are interconnected as indicated in FIGURE 3; and a resistive line comprising resistor RL5 connects the common junction of resistors RL1–RL4 and the amplifier input terminal to ground as shown. Typical values and characteristics of components are as indicated in Table 1 herein, from which it will be noted that resistor RL5 is of lower value than that of resistors RL1–RL4.

TABLE I

R1—1 megohm, about ½ watt
R2—270K ohms, about ½ watt
R3—2.2 megohms, about ½ watt
R4—150K ohms, about ½ watt
RL1—47 ohms, about ½ watt
RL2—47 ohms, about ½ watt
RL3—47 ohms, about ½ watt
RL4—47 ohms, about ½ watt
RL5—15 ohms, about ½ watt
C1, C2—Function of frequency (nominal range 0.68 mfd. to 0.00068 mfd.)
C3—Nominal 0.47 mfd.
Q1—2N3393

It will be noted from the preceding description that incident to keying of any oscillator or tone-signal generator, that oscillator will be induced to lock-in with any other oscillator then oscillating in another octave group, providing only that both oscillators have their strings-tone output signal lines 2 directly interconnected by bus conductors. In the event no other harmonically-related oscillator is at the moment operating, keying an oscillator merely sets the latter in operation at its natural frequency. As previously noted, locking-in of octavely-related tone generators occurs due to the appearance, at the tank circuits of all octavely-related oscillators, of a wave having a harmonic relationship thereto, whenever an octavely-related oscillator is being keyed. Locking-in is substantially instantaneous, occurring within a few cycles; and as a result of locking-in, beat effects between harmonically-related tone-signal generators are obviated. If several related oscillators are keyed concurrently, any frequency error or errors becomes averaged and of no consequence.

The resistor RL5 is common to the ground path of all of the strings-tones lines, but it is of such low value (typically 15 ohms) as to prevent interaction between the several bus conductors while still providing a harmonics-rich wave for creation, in the transducer, of the strings and reeds voices of the organ stop list.

While the particular electronic organ with lock-in circuit for tone-signal generators thereof herein shown and disclosed in detail is fully capable of attaining the objects and providing the advantages hereinbefore stated, it is to be understood that it is merely illustrative of the presently preferred embodiment of the invention and that no limitations are intended to the details of construction or design herein shown other than as defined in the appended claims.

I claim:

1. An arrangement of electronic tone-signal generating devices for generating octavely-related electric wave signals for use in an electronic musical instrument and in which arrangement each generating device is independently keyed into and out of operation and in which device concurrently keyed octavely-related tone-signal generating devices are effectively electrically interlocked to prevent undesirable octave interval beat effects, said arrangement comprising: a plurality of electronic tone-signal generating devices each comprising a respective independently keyed oscillatory circuit and an output line and means in the circuit for producing on the output line a wave signal of the fundamental frequency of the oscillatory circuit and the said wave signal including a sharp high-amplitude short-duration peak during each cycle of oscillation whereby the wave signal is rich in harmonics of the fundamental frequency, certain of said generating devices being octavely-related to others thereof by having fundamental frequencies of oscillation octavely-related to others thereof; means interconnecting the output lines of a plurality of said octavely-related tone-signal generating devices so arranged that the oscillatory circuit of each of the thus interconnected devices when oscillating is influenced by the harmonics-rich wave signal of another concurrently oscillating oscillatory circuit of one

of said interconnected devices and effective to hold the frequency of oscillation of any oscillating one of the said plurality of octavely-related tone-signal generating devices fixed relative to that of any other concurrently oscillating one of said plurality of octavely-related devices, thereby to prevent octave-interval beating of said octavely-related devices; and means, including transducer means, connected to said interconnected lines, for utilizing the electric wave signals impressed upon said interconnected lines.

2. An arrangement of electronic tone-signal generating devices according to claim 1, in which arrangement there are N octave groups of twelve tone-signal generating devices each, and in which each octave group thereof is divided into four sets of three generating devices each, and in which the said output lines of the devices in any set are interconnected, and in which the interconnected output lines of octavely-related corresponding sets of generating devices are interconnected, whereby locking in of oscillating octavely-related oscillators of frequencies associated with any selected note of the musical scale are interlocked to prevent beating between the output signals thereof.

3. An arrangement of electronic tone-signal generating devices according to claim 1, in which each tone-signal generating device comprises a respective individually keyed oscillatory circuit with a keying line, a ground line, a flute-tone line connected to the oscillatory circuit, a transistor connected to pass one brief high-amplitude pulse of current per cycle of operation, a strings-tone line carrying the current passed by the transistor and forming said output line of the device, and a bias line connected for varying the frequency of oscillation of the oscillator in accord with an applied A.C. low-frequency signal.

4. An arrangement of electronic tone-signal generating devices according to claim 3, in which arrangement there are N octave groups of twelve tone-signal generating devices each, and in which each octave group thereof is divided into four sets of three generating devices each, and and in which the said output lines of the devices in any set are interconnected, and in which the interconnected output lines of octavely-related corresponding sets of generating devices are interconnected, whereby locking-in of oscillating octavely-related oscillators of frequencies associated with any selected note of the musical scale are interlocked during concurrent oscillation to prevent octave beating between output signals thereof.

5. An arrangement of electronic tone-signal generating devices according to claim 4, in which the ground lines of all of said devices are interconnected and connected to a common ground, each of said keying lines is connected to a respective keying device, all of said flute-tone lines are interconnected and connected to a common bus, and all of said bias lines are interconnected for application of an A.C. low-frequency signal to all the bias lines concurrently.

6. A keyed electronic musical instrument comprising: a plurality of octavely-related groups of independently keyed electronic tone-signal generating devices, each of said devices including a respective oscillatory tank circuit, a transistor connected to the tank circuit to periodically pass a pulse of current to energize the tank circuit during a small percentage of each cycle of oscillation of the tank circuit, a strings-tones line connected to said tank circuit and to conduct current passed by said transistor and thus have impressed thereon an electric wave of fundamental frequency equal to the frequency of oscillation of the tank circuit and rich in harmonic content, each of the tank circuits of said tone-signal generating devices in any group thereof being arranged to oscillate at a respective frequency corresponding to a respective note to the musical scale; conductor means interconnecting the strings-tones lines of all said generating devices arranged to oscillate at respective frequencies corresponding to any selected one of the notes of the musical scale and including means whereby when octavely-related ones of said devices corresponding to a selected note are concurrently keyed the respective oscillatory circuits will lock-in and prevent octave interval beating between the strings-tones signals thereof; and means connected to utilize the signals produced on said strings-tones lines.

7. An instrument according to claim 6, in which there are N octave groups of said tone-signal generating devices, each group comprising twelve generating devices each divided into four sets of three devices each, and in which said conductor means are four in number and each interconnects the strings-tones lines of the three generating devices in a respective set and interconnects the strings-tones lines of corresponding sets of generating devices in all of the N octave groups of said devices, and in which each of said conductor means is connected to a common junction via a respective isolation resistor, whereby lock-in of an plurality of concurrently oscillating octavely-related tone-signal generating devices occurs and prevents octave interval beating in the output signals from said devices.

8. An organized arrangement of electronic tone-signal generating devices each including an individually keyed oscillatory circuit arranged to oscillate and provide signals at a respective natural frequency corresponding to a musical note, each said oscillatory circuit having connected thereto a respective keying line, a flute-tone line, a strings-tones line, a bias line, and a ground line, said arrangement comprising: N octavely-related groups of said generating devices, each group thereof including M sets of the said devices, N being a whole number in excess of 1 and M being a whole number at least equal to 2 but not exceeding 3; connections means connecting together and to a first junction the strings-tones lines of a first set of said devices of each of said groups of devices; connections means connecting together and to a second junction the strings-tones lines of a second set of said devices of each of said groups of devices; means including a plurality of resistive means, each resistive means thereof connected at one terminal thereof to a respective one of said connections means and at the other terminal thereof to the corresponding other terminals of the others of said resistive means; and means for utilizing the common interconnection of said plurality of resistive means as an input for signal transducer means operable to provide frequency interlocking between any oscillating tone-signal generating device of one of said sets thereof and any other oscillating octavely-related tone-signal generating device within the corresponding set of another group thereof.

9. An arrangement of tone-signal generating devices according to claim 8, wherein $M=5$ and $N=3$, and in which third and forth connections means are provided for the third sets and for the fourth sets, respectively, of said devices as specified for said first and second sets, respectively, and said arrangement including third and fourth resistive means each connected to a respective one of third and fourth connections means at one terminal, and in common to the said other terminals of said plurality of resistive means, the natural frequencies of the devices of any set thereof corresponding to three successive notes of the musical scale.

References Cited

UNITED STATES PATENTS

2,498,337	2/1950	Kent	84—1.22
2,681,585	6/1954	Hanert	84—1.22
2,811,069	10/1957	Faulkner	84—1.01
2,830,481	4/1958	Hanert	84—1.01
2,941,435	6/1960	Henley	84—1.22
3,327,043	6/1967	Martin	84—1.19

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