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ELECTRONIC ORGAN UTILIZING PROPORTIONAL FREQUENCY CHANGERS FOR HARMONIC STRUCTURE

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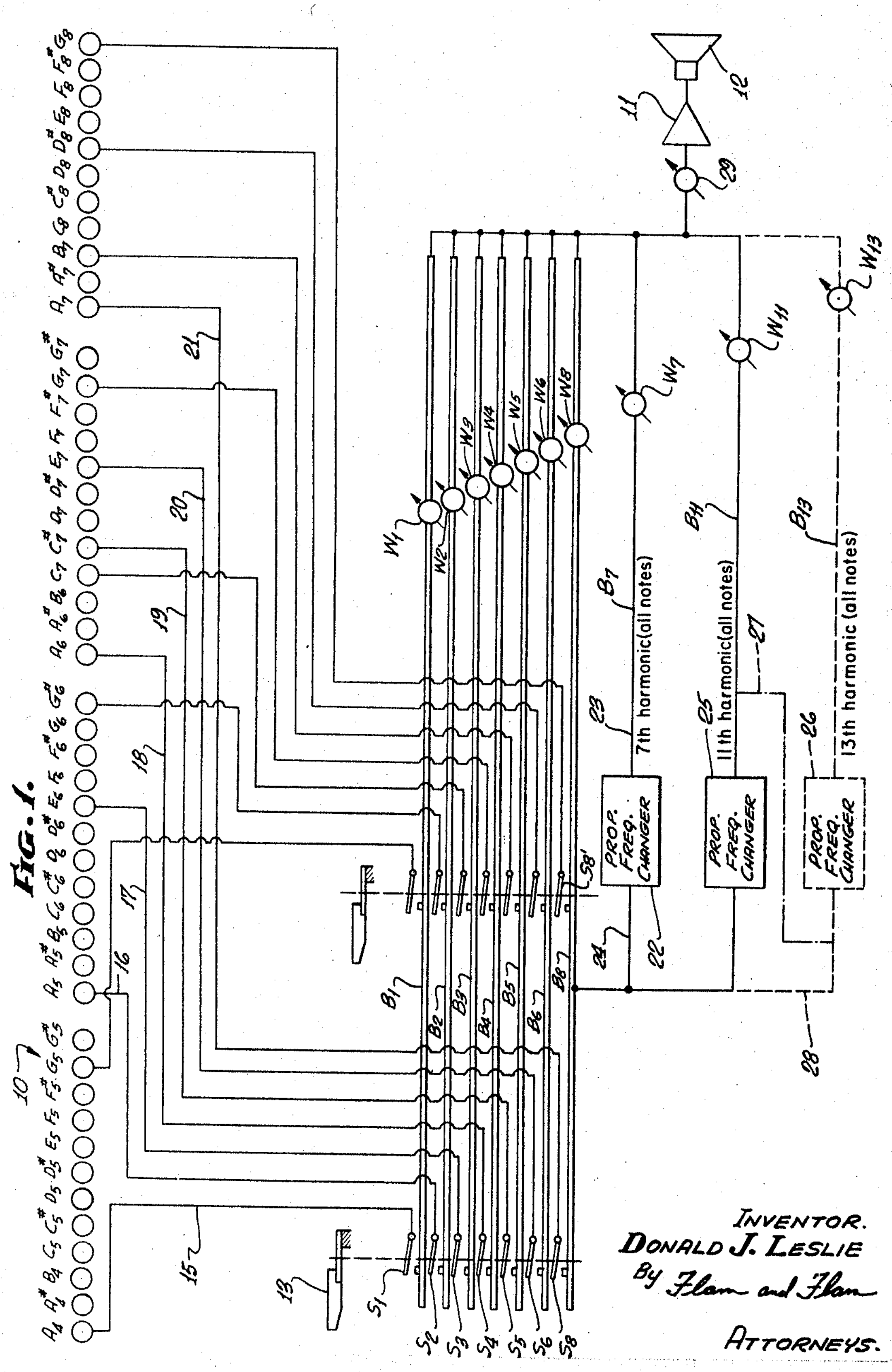

FIG. 1.

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FIG. 2.

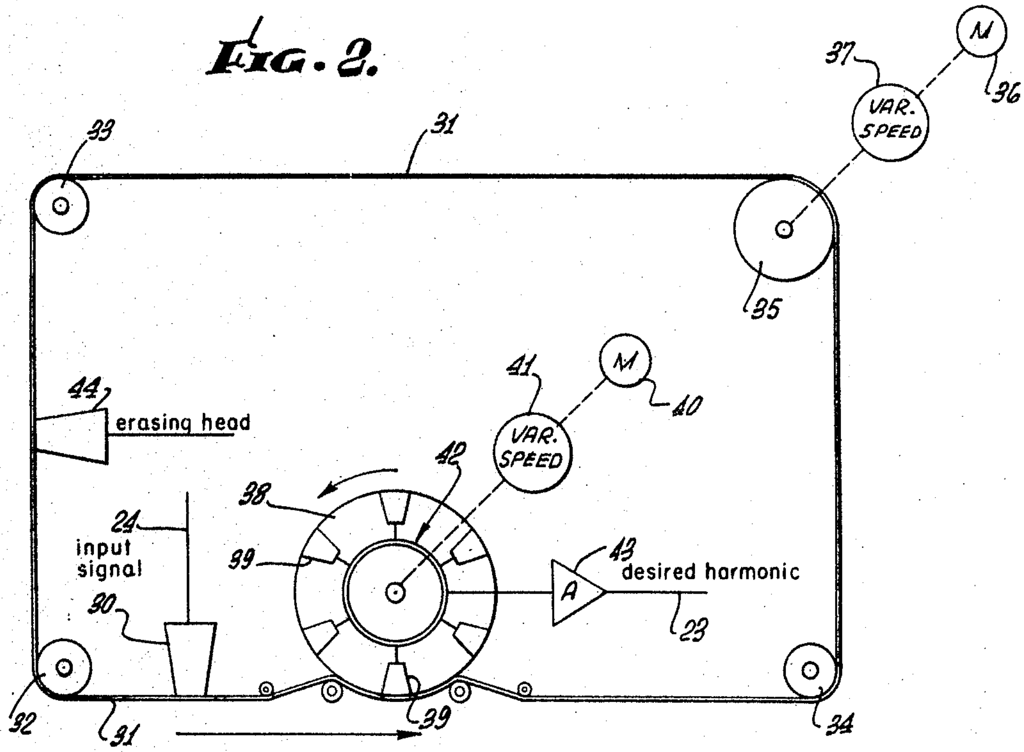
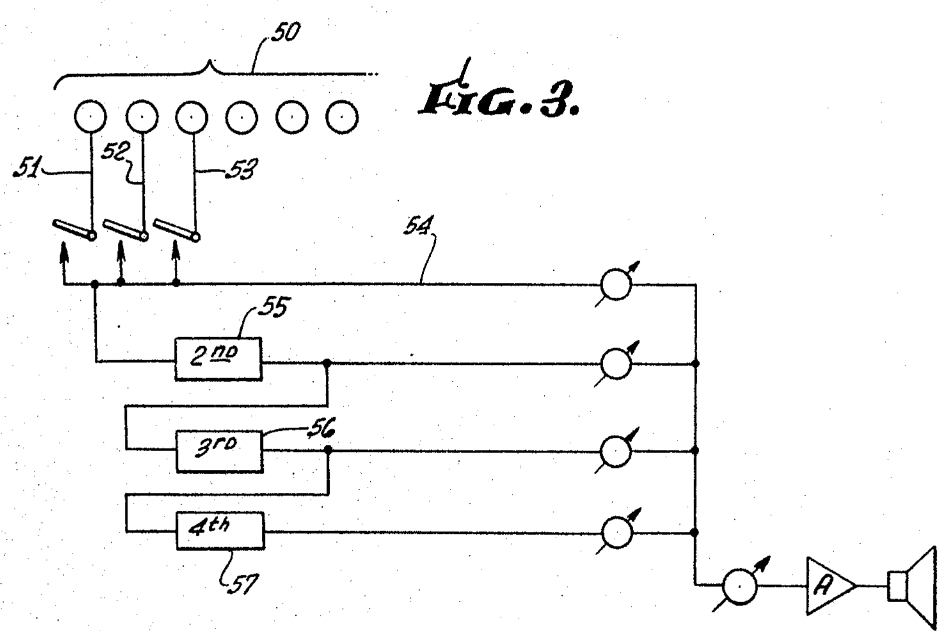


FIG. 3.



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ELECTRONIC ORGAN UTILIZING PROPORTIONAL FREQUENCY CHANGES FOR HARMONIC STRUCTURE

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U.S. Cl. 84—1.01 12 Claims

ABSTRACT OF THE DISCLOSURE

An electronic musical instrument produces composite tones from a single set of sine wave generators by the aid of proportional frequency changers. Bus leads corresponding to the harmonics connect with the audio output channel through circuit elements adjustable for shaping the output. The first set of bus leads connect to the sine wave generators through key switches to provide the fundamental and certain harmonics all on the well known "borrowing" principle. Bus leads of the second set (for example, for the 7th, 9th and higher order harmonics) connect to other bus leads through a proportional frequency changer. For example, the bus lead for the 7th harmonic may connect to the bus lead for the 8th harmonic through a proportional frequency changer that changes frequencies by the factor ⅞.

Brief summary of the invention

This invention relates to electronic organs, and particularly to electronic organs of the type in which sine wave generators are provided for each note of the musical range and in which harmonics are added by borrowing signals from sine wave generators for other notes. For example, the second, third, fourth, fifth, sixth and eighth harmonics of A_4 may be derived by borrowing, in selected amounts, signals from the sine wave generators for A_5, E_6 A_6, $C\#_7$, E_7 and A_7. The generators for A_5, A_6 and A_7 have frequencies that are precisely twice, four times and eight times the frequency of the generator for A_4, assuming that the generators are properly tuned. Accordingly, the octave harmonics are true. The generators for E_5, $C\#_7$ and E_7 have frequencies that are not exactly three, five and six times the frequency of A_4; yet they are sufficietly close to provide simulation. However, while the $C\#_7$ is commercially used for the fifth harmonic, its frequency is considerably sharp, and noticeable improvement could be obtained if the correct frequency were available.

Moreover, generators are not available that closely approach the seventh, eleventh, thirteenth and other harmonics, particularly the dissonant ones not available from notes of the tempered scale. Consequently, the typical organ of this type omits the seventh harmonic, and terminates the harmonic structure with the eighth. With a complete absence of dissonant harmonics not found at tempered scale frequencies, the character of voices containing these harmonics suffers greatly, often to the point of nonrecognition. Even the addition of one or two of the dissonant harmonics such as the seventh and eleventh results in marked improvements in simulating organ voices.

In my copending application Ser. No. 461,568, filed May 17, 1965, entitled, Complementary Harmonic System for Flute Type Organs, there is shown and described a system for solving this problem by providing a supplemental set of composite generators, one for each note. Each provides signals corresponding to the missing upper order harmonics. The provision of a second set of composite generators is costly; furthermore, the relative amplitude of the harmonics included in the composite generator cannot be controlled. The primary object of this invention is to provide a new and improved system for adding harmonics. Another object of this invention is to provide a system of this character which does not require any supplemental generator sets, but instead, one device for each harmonic added. To achieve these results, I provide a proportional frequency changing device for each added harmonics, the frequency changing device having a common input cooperable with generators for all of the notes of the organ.

An acceptable frequency changing device of this character is one in which a tape moves past a pickup head at an effective rate proportionately different from the rate at which it moves past a recording head.

Another object of this invention is to provide an inexpensive system of this character in which adjustments for maintaining tuning are readily accomplished.

This invention possesses many other advantages, and has other objects which may be made more clearly apparent from a consideration of several embodiments of the invention. For this purpose, there are shown a few forms in the drawings accompanying and forming part of the present specification. These forms will now be described in detail, illustrating the general principles of the invention; but it is to be understood that this detailed description is not to be taken in a limiting sense, since the scope of the invention is best defined by the appended claims.

Brief description of the drawings

FIGURE 1 is a digrammatic view of an electronic organ incorporating the present invention;

FIG. 2 is a diagrammatic view of a proportional frequency changer; and

FIG. 3 is a diagrammatic view of a modified form of the present invention.

Detailed description

In FIG. 1, a series of sinusoidal generators **10** is illustrated having frequencies corresponding to the fundamentals of the notes indicated by the legends adjoining the generators **10**. Also indicated in FIG. 1 are an output power amplifier **11** and a transducer **12**, indicated diagrammatically, in this instance, as a speaker.

In order to obtain a complex wave form at the output **11–12**, a borrowing system is provided. For this purpose, each key **13** has associated therewith a set of switches designated as S_1, S_2, S_3, S_4, S_5, S_6 and S_8. The key **13** and switches illustrated are for the note A_4, by way of example. The switch S_1, and by the aid of a connection **15**, is adapted to connect the generator **10** for A_4 to a bus bar B_1. This bus bar is connected to the input of the amplifier **11** via an adjustable control W_1, which may be a potentiometer, autotransformer, or any other suitable element. The bus bar B_1 is engaged by all of the switches S_1 for all of the keys typified by the key **13**. Accordingly, if the element W_1 is adjusted for substantial signal transmission, all of the fundamentals for the various notes will be operative.

The adjustable control element W_2 is adapted to determine the extent that second harmonics are present at the output. The second switches S_2 for each switch set cooperate with a single bus bar B_2 for this purpose. Thus the switch S_2 for the note A_4 by the aid of a lead **16**, when the key **13** is depressed, connects the A_5 generator **10** to the bus bar B_2. Similarly, the switch S_2 associated with the key for note G_4 (not shown) will connect with the generator for G_5.

The switches S_3, S_4, S_5, S_6 and S_8 for the A_4 group similarly connect by the aid of leads **17**, **18**, **19**, **20** and **21** to generators for E_6, A_6, $C^{\#}_7$, E_7 and A_7. Bus bars B_3, B_4, B_5, B_6 and B_8 are provided and serve as third, fourth, fifth, sixth and eighth harmonic bus bars, cooperable with switches for the other notes. Adjustable circuit elements W_3, W_4, W_5, W_6 and W_8 are likewise provided to control the relative strength of the third, fourth, fifth, sixth and eighth harmonics.

Generators for E_6, $C^{\#}_7$ and E_7 have frequencies corresponding quite closely to three, five and six times the frequency of the generator A_4. However, there are no generators in the set **10** having frequencies closely corresponding to the seventh, eleventh and other higher harmonics. In order to create seventh harmonics, the frequencies of all signals aplied to one of the bus bars, in this instance the eighth harmonic bus bar B_8, are proportionately changed. This is done by a proportional frequency changer **22**.

The frequency changer **22** is interposed in a lead B_7. One end of the lead B_7 connects to the bus bar B_8 at a place where the eighth harmonic appears in full strength, namely, in advance of the adjustable circuit element W_8. The other end of the lead B_7 connects via an adjustable circuit element W_7 to the amplifier **11** and transducer **12**. The frequency changer **22** serves to change the frequency of signals at its output connection **23** relative to its input connection **24**. In order properly to derive a seventh harmonic from the eighth harmonic bus bar B_8, the proportionate relationship is 7:8. For example, when the key **13** is depressed, a signal is applied to the input connection **24** via lead **21** that has a frequency of 3520 cycles per second. This signal is changed in frequency by a factor of ⅞, and accordingly appears at the output connection **23** as a signal of 3080 c.p.s., which corresponds to the seventh harmonic of A_4. The frequency changer includes suitable amplifiers so that the signal strength at the output connection **23** is restored to the same level as at the input connection **24**.

Similarly, when the key corresponding to the note G_5 (783.99), for example, is depressed, the key switch S_8' applies a signal corresponding to the eighth harmonic of G_5, namely, 6271.92 c.p.s., and as derived from the generator G_8. The proportional frequency changer **22** likewise operates upon this signal to reduce it by the factor of ⅞, and a signal 5487.93 c.p.s. appears at the output connection **23** which corresponds to the seventh harmonic of G_5. In a like manner, the frequency changer **22** operates upon all signals applied to the eighth harmonic bus bar B_8 thus to derive seventh harmonics.

A proportional changer **25** in a like manner cooperates with the bus bar B_8 to create eleventh harmonics. Accordingly, the operating ratio of the frequency changer **25** is $^{11}/_{8}$. Additional frequency changers **26**, etc. may be provided for the thirteenth and other harmonics in a like manner. By deriving the signal from a close harmonic, the ratio of each frequency changer is kept as close as possible to unity.

If desired, each frequency changer could be serially associated with the others, as indicated for example by the dot-and-dash lead **27**. Thus, if the frequency changer **26** were connected serially with the frequency changer **25** instead of to the bus bar B_8 as indicated by the lead **28**, the ratio of operation of the frequency changer **26** could be $^{13}/_{11}$ rather than $^{13}/_{8}$.

Each of the leads B_7, B_{11}, B_{13}, etc. is controlled by the respective adjustable elements W_7, W_{11}, W_{13}, etc., whereby the harmonic structure of a tone may be synthesized. An adjustable circuit element **29** associated with the amplifier **11** may be linked to a swell pedal proportionately to control the volume of the composite tone.

One of the frequency changers **22** is illustrated diagrammatically in FIG. 2. The frequency changer includes a recording head **30** cooperable with the input connection **24**. A high speed tape **31**, wire or other recording medium is transported past the recording head **30** at high speed. In this instance, the tape is shown as of endless form cooperable with idler pulleys **32**, **33** and **34** and a drive pulley **35**. The drive pulley **35** is operated at a selected set speed by a motor **36** and a variable ratio drive **37** adjustable preferably through a continuous range. The motor **36** may be of a synchronous type. Optionally, the speed of the tape **31** may be regulated by a variety of known means.

Promptly after passing the recording head **30**, the tape **31** moves past a pickup head **38**. This pickup head has a substantially circular or cylindrical periphery at which a series of equiangularly and closely spaced pickup elements **39** are exposed for cooperation with the tape **31**. The pickup head **38** is mounted for rotation so as to move tangent to the tape **31**, and it is operated at a selected set speed by the aid of a motor **40** and a variable ratio drive **41** similar to the drive **37**. The motor **40** may likewise be of the synchronous type. Optionally, the speed of the head **38** may be regulated by other known means.

The pickup elements **39** connect in parallel to the output connection **23**, as by the aid of a slip ring structure **42**, shown as a single wire for convenience. This slip ring structure **42** may be of the type shown and described in my prior Patent No. 3,014,192, issued Dec. 19, 1961, and entitled Mercury Slip Ring Assembly. Interposed in the lead is an amplifier **43** having a gain set or otherwise adjusted so as to balance the amplitude of the signal in the output connection **23** relative to its amplitude in the input connection **24**.

The pickup head 38 is rotated, in this instance, in a counterclockwise direction so that the peripheral speed of the pickup head realtive to the tape **31** is ⅞ of the speed of the tape **31** past the recording head **30**. Since the speed of the tape **31** relative to the pickup head **38** is only ⅞ of what it is relative to the recording head **30**, the frequencies of the signals are scaled to produce seventh harmonics.

In the present instance, the pickup head is shown as the rotatable element. In practice, either the recording head **30** or the pickup head **38** could be movable in order to create different rates of motion of the tape relative to the heads.

Each pickup element moves into operative relationship with the tape as the adjoining element moves out of operative relationship. In effect, stretched segments of the tape are joined together, and other segments are operatively omitted. The omitted segments occupy an extremely short space of time relative to the progress of the music. The discontinuities are not perceived. The tape **31** moves at high speed such that the lag between the playing of the note and the creation of the tone at the output is likewise imperceptible.

The frequency changers **25** and **26** are identical except that the pickup heads will rotate at different speeds and in order to increase the frequencies, in the opposite direction relative to the tape. In these instances, the tape is effectively compressed, and partially repeated. Again discontinuities are not perceived. Apparatus of this general character is available commercially from Gotham Audio Corporation of New York. An erasing head **44** is located in advance of the recording head **30**.

In the form of the invention illustrated in FIG. 3, the set of generators **50** are each provided with but one lead, as at **51**, **52**, **53**, etc., and only a fundamental bus bar

54 is provided. The second, third, fourth and other harmonics are created by proportional frequency changing devices **55**, **56** and **57** that all derive signals directly or indirectly from bus bar **54**. The third harmonic frequency changer **56** derives a signal from the second harmonic frequency changer, and the fourth harmonic frequency changer derives a signal from the third harmonic frequency changer, etc. In this manner, the speed ratios are 2:1, 3:2, 4:3, 5:4, etc. Only a single key contact is required for harmonic structure purposes.

The inventor claims:

1. In an electronic organ: a set of substantially sine wave generators for the notes of the organ; an audio output channel; a bus lead connectible with said audio output channel; keys for the notes; a key switch for each note and operated by the corresponding key for operatively connecting the corresponding generator to said bus lead; a proportional frequency changer having an input operatively connected to said bus lead and an output operatively connected to said audio output channel, said frequency changer having a predetermined characteristic proportionality constant to provide signals corresponding to a certain harmonic of all signals applied to said bus lead.

2. The combination as set forth in claim **1** in which each of said frequency changers includes a recording head, a pickup head and a record medium transportable relative to said heads, one of said heads being rotatable whereby the rate of movement of the medium relative to one head differs from its rate of movement relative to the other head by a selected ratio, and means for rotating said rotatable head.

3. In an electronic organ: a set of substantially sine wave generators for the notes of the organ; an audio output channel; a bus lead connectible with said audio output channel; keys for the notes; a key switch for each note and operated by the corresponding key for operatively connecting the corresponding generator to said bus lead; a set of proportional frequency changers each having an input operatively connected directly or indirectly to said bus lead, and each having an output operatively connected to said audio output channel, said frequency changers having predetermined characteristic proportionality constants to provide signals corresponding to certain different harmonics of all signals applied to said bus lead.

4. The combination as set forth in claim **3** in which each of said frequency changers includes a recording head, a pickup head and a record medium transportable relative to said heads, one of said heads being rotatable whereby the rate of movement of the medium relative to one head differs from its rate of movement relative to the other head by a selected ratio, and means for rotating said rotatable head.

5. In an electronic organ: a set of substantially sine wave generators for the notes of the organ; a set of bus leads corresponding to the fundamental, second, third, fourth, fifth, sixth and eighth harmonics; keys for the notes; a set of key switches for each note and operated by the corresponding key and cooperable respectively with the bus leads; connection means between the key switches and those generators corresponding substantially to the fundamental, second, third, fourth, fifth, sixth and eighth harmonics of the corresponding note; said connections being arranged so that each bus lead transmits corresponding harmonics; a set of proportional frequency changers having inputs connected directly or indirectly to the bus leads, each frequency changer having a predetermined characteristic proportionality constant to provide the seventh, eleventh, thirteenth and other harmonics; and an audio output channel connected to said bus leads and to the outputs of said frequency changers.

6. The combination as set forth in claim **5** in which each of said freqency changers includes a recording head, a pickup head and a record medium transportable relative to said heads, one of said heads being rotatable whereby the rate of movement of the medium relative to one head differs from its rate of movement relative to the other head by a selected ratio, and means for rotating said rotatable head.

7. The combination as set forth in claim **1** together with an adjustable circuit element interposed between said bus lead and said audio output channel, and another adjustable circuit element interposed between said frequency changer and said audio output channel; said adjustable circuit elements being operative to scale the signals transmitted, thereby to form tone characteristics.

8. The combinaion as set forth in claim **7** in which each of said frequency changers includes a recording head, a pickup head and a record medium transportable relative to said heads, one of said heads being rotatable whereby the rate of movement of the medium relative to one head differs from its rate of movement relative to the other head by a selected ratio, and means for rotating said rotatable head.

9. The combination as set forth in claim **3** together with an adjustable circuit element interposed between said bus lead and said audio output channel, and additional adjustable circuit elements respectively interposed between said frequency changers and said audio output channel; said adjustable circuit elements being operative to scale the signals transmitted, thereby to form tone characteristics.

10. The combination as set forth in claim **9** in which each of said frequency changers includes a recording head, a pickup head and a record medium transportable relative to said heads, one of said heads being rotatable whereby the rate of movement of the medium relative to one head differs from its rate of movement relative to the other head by a selected ratio, and means for rotating said rotatable head.

11. The combination as set forth in claim **5** together with an adjustable circuit element interposed between each of said bus leads and said audio channel, and between the outputs of said frequency changers and said audio output channel; said adjustable circuit elements being operative to scale the signals transmitted, thereby to form tone characteristics.

12. The combination as set forth in claim **11** in which each of said freqency changers includes a recording head, a pickup head and a record medium transportable relative to said heads, one of said heads being rotatable whereby the rate of movement of the medium relative to one head differs from its rate of movement relative to the other head by a selected ratio, and means for rotating said rotatable head.

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