Nov. 4, 1969 D. J. CAMPBELL 3,476,863

CONVERSION OF TONAL CHARACTER OF AURAL SIGNALS

Filed Oct. 7, 1965 5 Sheets-Sheet 1

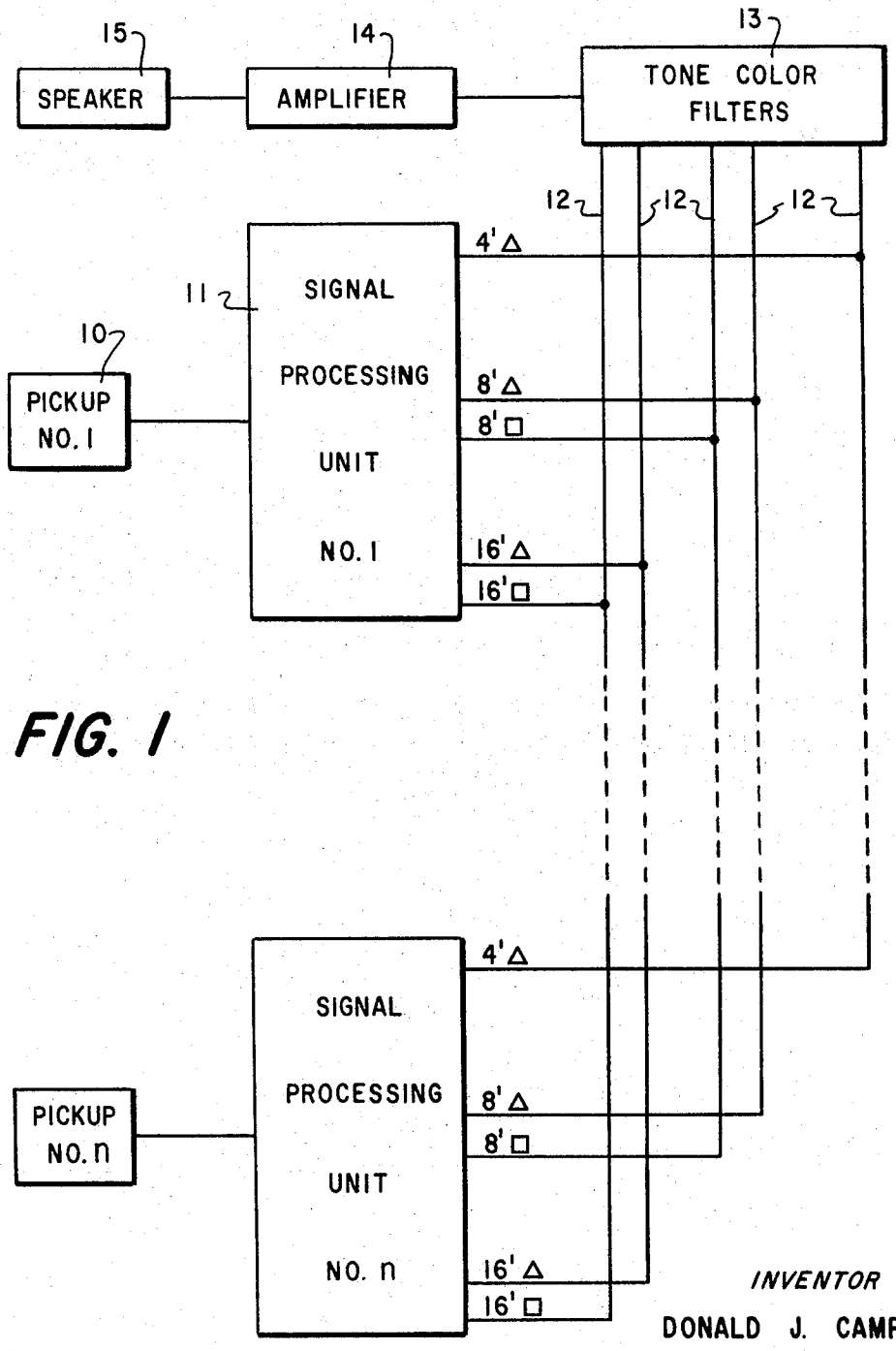


FIG. 1

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CONVERSION OF TONAL CHARACTER OF AURAL SIGNALS

Filed Oct. 7, 1965 5 Sheets-Sheet 2

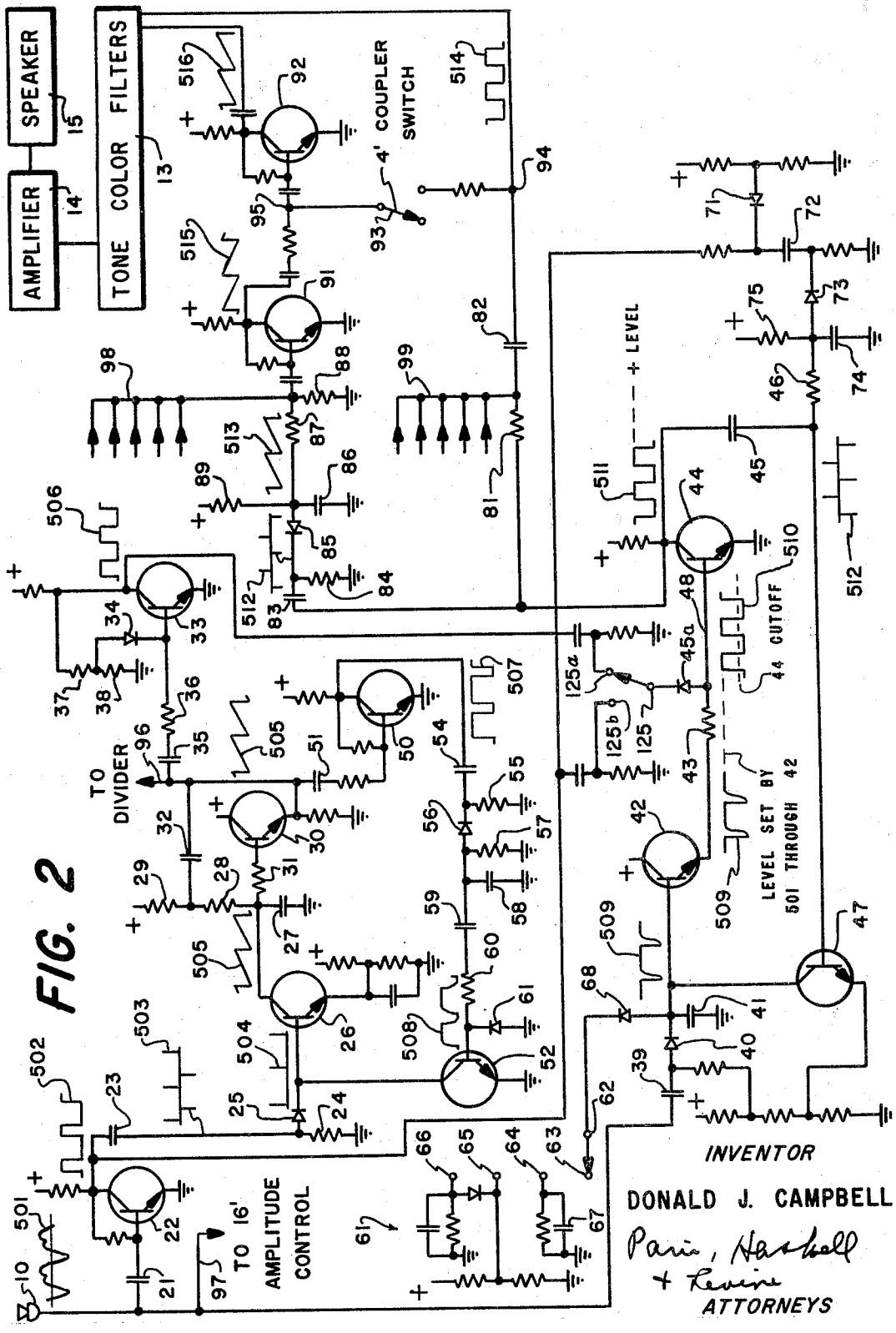


FIG. 2

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CONVERSION OF TONAL CHARACTER OF AURAL SIGNALS

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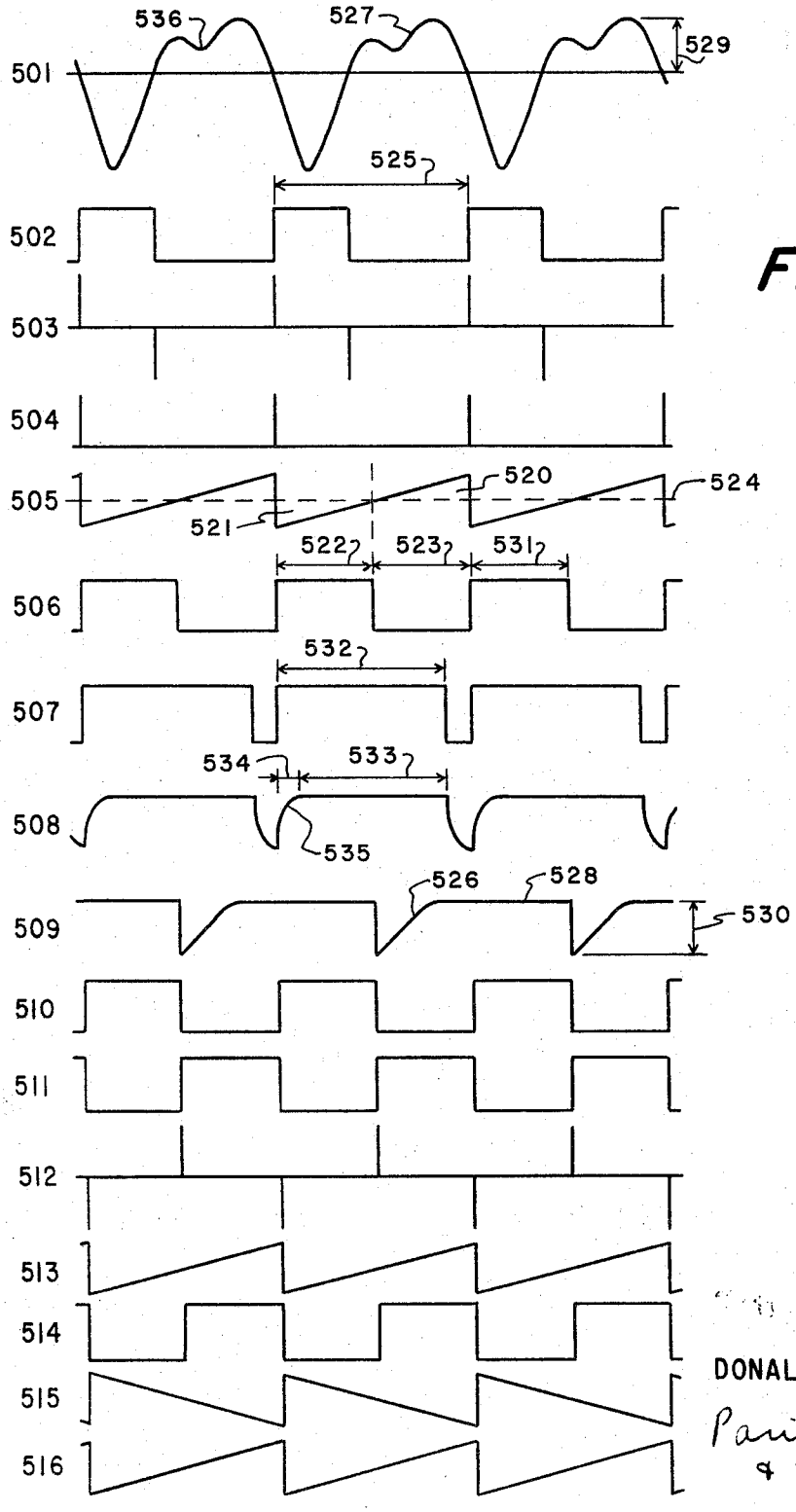


FIG. 3

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CONVERSION OF TONAL CHARACTER OF AURAL SIGNALS

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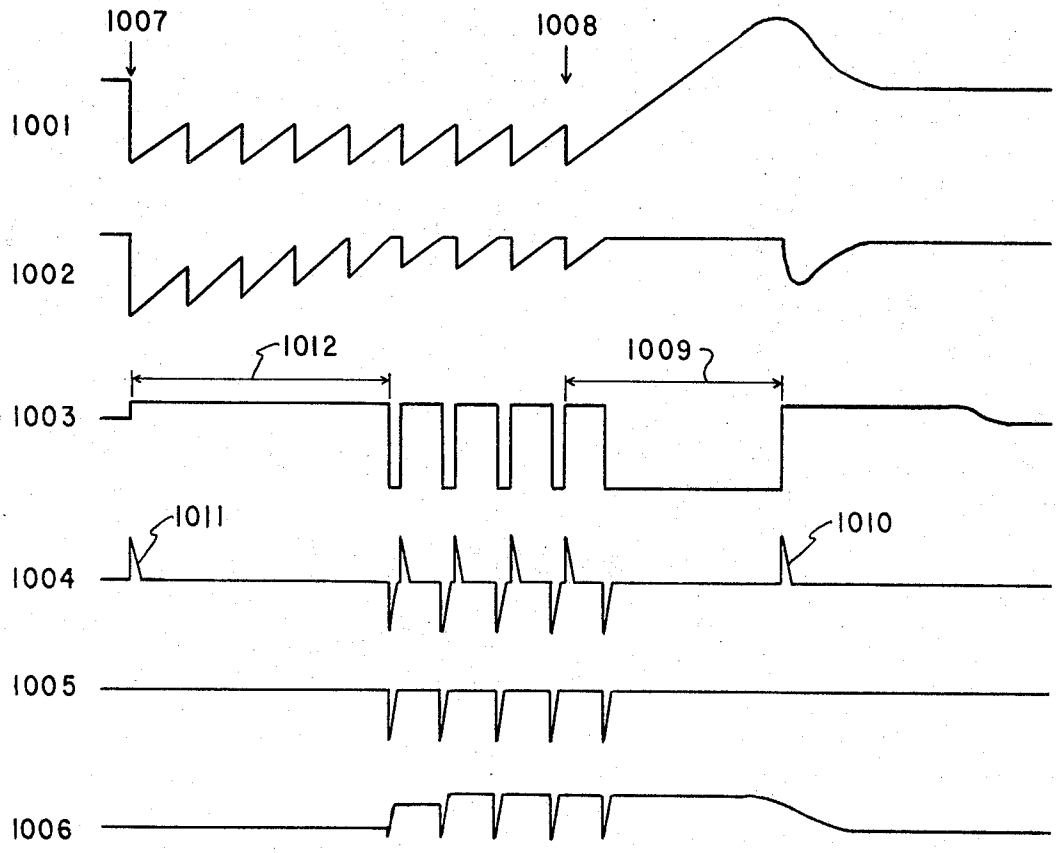


FIG. 4

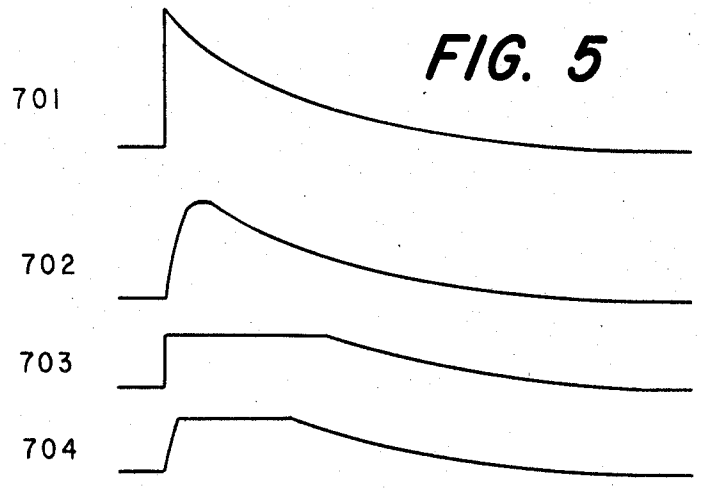


FIG. 5

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CONVERSION OF TONAL CHARACTER OF AURAL SIGNALS

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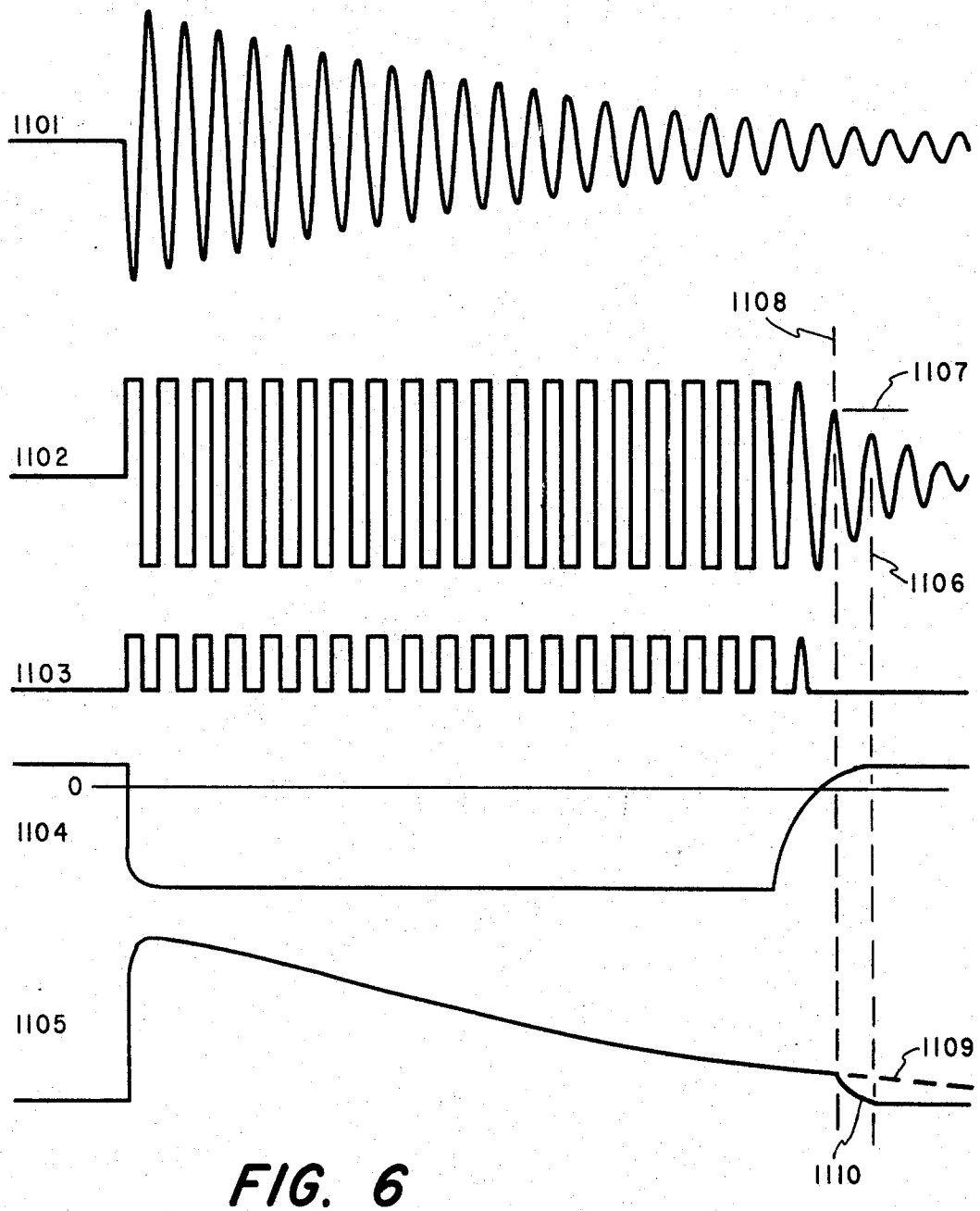


FIG. 6

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United States Patent Office 3,476,863
Patented Nov. 4, 1969

3,476,863

CONVERSION OF TONAL CHARACTER OF AURAL SIGNALS

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Filed Oct. 7, 1965, Ser. No. 493,773
Int. Cl. G10h 1/00; H03k 5/01
U.S. Cl. 84—1.01 30 Claims

ABSTRACT OF THE DISCLOSURE

A system for converting an aural input signal of one tonal character to an aural output signal of a different tonal character, including a circuit for determining the fundamental frequency of the input signal, a symmetrical waveform signal generator responsive to the fundamental frequency, and an amplitude control circuit for adjusting each cycle of the symmetrical waveform signal in accordance with the peak value of the corresponding cycle of the aural input signal.

The present invention relates to the art of electronic music generation. More particularly, this invention is concerned with the conversion of an aural input of one tone color or timbre to an aural output having a different tone color or timbre, and/or a different pitch, or ampitude, or other characteristics. As used in the present specification and claims, unless otherwise indicated expressly or by context, the term "aural input" is intended to include not only the compressional sound wave per se, but also a corresponding electrical signal that may be generated concurrently with a sound wave, as for example by the use of an electromagnetic or other direct pick up as is employed with electric guitars.

In accordance with the general aspects of the present invention, an aural input signal is analyzed to obtain its fundamental frequency, and each cycle is analyzed to obtain its amplitude. Output waves of high harmonics content are then produced, for example square and sawtooth waves, which correspond in frequency to the fundamental of the aural input signal, and correspond cycle by cycle to the amplitude of the aural input signal. The resultant signals are then processed through well known tone color filters to obtain desired variations in the timbre of the signal, and thence are reconverted into an aural signal of desired tone color different from that of the aural input. Further, as will be readily apparent, the processing of the signal can include frequency doubling and dividing in order to change the pitch of the signal as desired.

The processing of an aural input signal as above described, may be used for example to convert a voice input to an instrumental output, convert an input from one instrument to an output having the tone color of a different instrument, and converting an input signal of one tone color and fundamental frequency to an output of a different tone color and same or different fundamental frequency, or same tone color and different fundamental frequency.

It is therefore among the objects of the present invention to provide: for the electronic processing of aural input signals to aural output signals; for the conversion of an aural input signal to waves of high harmonic content having the same fundamental frequency as the input, or multiples thereof, and corresponding in amplitude to the input signal, cycle by cycle; for the conversion of an aural input signal of one tone color to an aural output signal of another tone color; and for the conversion of an aural input signal of one frequency to an aural output signal of a multiple or fraction of the input frequency.

Other objects and advantages of the present invention will become apparent to those skilled in the art from a consideration of the following detailed description of one specific embodiment of the invention had in conjunction with the accompanying drawings, in which like numerals refer to like or corresponding parts, and wherein:

FIG. 1 is a block diagram of an overall system from aural input to aural output;

FIG. 2 is a schematic circuit diagram of a signal processing unit embodying the present invention; and

FIGS. 3, 4, 5, and 6 are waveform charts showing the various waveforms appearing in the processing unit of FIG. 2 in their relative time relationships.

Referring first to the block diagram of FIG. 1, it will be seen that a pickup unit **10**, which may be a microphone for transducing a voice or instrumental sound to an electrical signal, transmits the input signal to the processing unit **11**, where the signal is transposed into square and sawtooth waves related in frequency and amplitude to the input signal. The square and sawtooth wave outputs indicated as 4 foot, 8 foot and 16 foot outputs, are carried by busses **12** to appropriate tone color filters **13**. The outputs of the filters **13** are combined in amplifier **14**, and thence transmitted to output speaker **15**. Obviously, any number of pickups **10** may be provided, depending upon the number of inputs utilized, as indicated in FIG. 1 by pickups and processing units numbered *1* through *n*. Each processing unit may of course be identical, and consequently the detailed description of one such unit will be sufficient.

Processing unit **11** is shown in the schematic circuit diagram of FIG. 2. Many of the waveforms present in the operation of the circuit of FIG. 2 have been indicated thereon to facilitate an understanding of this circuit, and they have been numbered in accordance with the waveforms in the chart of FIG. 3.

The aural input signal represented by a waveform **501** is coupled from the pickup microphone **10** through capacitor **21** to the base of clipping amplifier **22**. The clipped and inverted waveform **502** constitutes the output of amplifier **22**, and it contains only frequency information of input waveform **501**. Waveform **502** is then differentiated by capacitor **23** and resistor **24** into waveform **503**, then rectified by diode **25** into waveform **504**. It will be observed that at this point in processing the input signal **501**, a trigger is provided for each negative going zero crossing of waveform **501**. The positive going crossings have been eliminated by the diode **25**.

Waveform **504** is converted to a sawtooth waveform **505** by the interaction of the transistors **26** and **30**, and the network of resistors **28** and **29** and capacitors **27** and **32**. Between trigger pulses of waveform **504**, transistor **26** is biased below cutoff, thereby causing capacitor **27** to be slowly charged through resistors **28** and **29**. Each trigger pulse of waveform **504** activates transistor **26** and causes capacitor **27** to be rapidly discharged therethrough, thus producing the sawtooth waveform **505**. The output of the sawtooth generator is converted to a low impedance through emitter follower transistor **30** and anti-oscillation resistor **31**. Bootstrap feedback capacitor **32** couples the output of emitter follower **30** to a point between resistor **28** and **29**, to increase the linearity of the waveform **505**.

The output **505** of emitter follower **30** is converted into a square wave, i.e. a rectangular wave symmetrical in time, by means of a squarer circuit comprising transistor **33** and diode **34**. When the linear sawtooth wave **505** is coupled through capacitor **35** into a load, the new D.C. level created depends on the nature of the load. If the load is linear and bilateral, the new level is **524** indi-

cated in FIG. 3, area **520** being equal to area **521**, and time **522** being equal to time **523**. A bilateral load is provided by diode **34** conducting during time **522** and transistor **33** conducting during time **523**. A linear load is insured by providing most of the load impedance in resistor **36**. These provisions result in level **524** being held at the conduction point of the base of transistor **33**. Thus transistor **33** conducts during time **523**, is cut off during time **522**, and square wave **506** is thereby produced at the output of transistor **33**. Feedback network **37** and **38** provides for transistor interchange and component tolerances. It will be observed that the symmetry of square wave **506** on the time axis is substantially independent of frequency. Also it should be noted that this symmetry of **506** is obtained despite any asymmetry that may exist in input waveform **501**. This result is had by utilizing only the negative going zero crossings of input waveform **501** as obtained at **504**, establishing frequency on that basis as in sawtooth waveform **505**, and then dividing the frequency period into two equal halves, as in square waveform **506**.

Having established a symmetrical waveform **506** equal in frequency to the fundamental frequency of the input signal, there remains to be established for each cycle of this waveform an amplitude corresponding to that of the corresponding cycle of the input signal. When controlling the amplitude of a square wave, it is not necessary to establish amplitude until one-half of a given cycle has occurred. This fact makes it possible to measure the peak of a controlling wave during each first half of the square wave cycle, to store this amplitude information, and then to use it to control the amplitude of each second half of the square wave. By clearing the storage element at the end of each cycle, the amplitude of each square wave cycle then becomes a function of the peak amplitude of the corresponding cycle of the controlling wave.

This function is accomplished by the amplitude control circuit comprising coupling capacitor **39**, diode **40**, storage capacitor **41**, emitter follower transistor **42**, resistor **43**, amplifier **44**, diode **45***a*, differentiating network of capacitor **45** and resistor **46**, and transistor **47**. The input waveform **501** is coupled through capacitor **39** to diode **40**, which passes only the positive going portions of waveform **501**, thereby trapping the positive peak voltage of **501** on storage capacitor **41**, indicated as waveform **509**. The emitter follower **42** passes this waveform through resistor **43** to point **48** where it is combined with waveform **506** coupled through diode **45***a*. Positive portions of waveform **506** are not passed by diode **45** to point **48**, hence during that portion of the cycle the positive plateau of waveform **509** controls the voltage at point **48**. The negative portions of waveform **506** are passed by diode **45** to point **48**, causing the voltage of waveform **509** to be dropped across resistor **43**, and bringing the voltage at point **48** below cut off value for the base of transistor **44**. Accordingly, waveform **510** is generated at point **48**, whose amplitude for each cycle is a direct function of the peak amplitude of waveform **501** for that cycle.

Considering the amplitude control circuit with more detailed reference to the waveforms in FIG. 3, it will be seen that waveform **501** charges capacitor **41** during the time **523**, resulting in the **526** portion of waveform **509**. Waveform portion **526** has substantially the same shape and amplitude as the portion **527** of waveform **501**, hence amplitude **530** of waveform **509** is substantially equal to amplitude **529** of waveform **501**. During time **523** square wave **506** is conducted to point **48** by diode **45***a* lowering the base of transistor **44** below cut off. During this time voltage of waveform **509** has no effect on the transistor **44** and is dropped across resistor **43**. Since diode **45***a* is cut off during the time **531**, the voltage of waveform **509** controls, establishing the amplitude of waveform **510** at the value **530**.

Waveform **510** applied to the base of amplifier **44** produces the desired square wave output signal embodied in waveform **511**. Waveform **511** is differentiated by capacitor **45** and resistor **46** into waveform **512**, and each positive going portion of waveform **511** produces a corresponding positive spike in waveform **512** triggering transistor **47** into momentary conduction to discharge storage capacitor **41**.

The foregoing description relates to the basic flow of a signal being processed in unit **11**. There remain several refinements to the processing unit that will now be described. It will be recalled that generation of the basic signal of the procesing unit, i.e., waveform **506**, depends upon negative going zero crossings of input signal **501**, producing one square wave cycle for each such zero crossing. These negative going zero crossings are registered in the spikes of waveform **504**. As illustrated in the drawings, input signal **501** has one negative going zero crossing per fundamental cycle. However, this input is usually a complex signal as illustrated by the secondary minimum at **536** in waveform **501** (see FIG. 3). As the amplitude of this input signal decreases, changes in the waveform may occur whereby a point will be reached where the minimum point **536** crosses the zero value, and there would thereby be produced a false or extraneous zero crossing which would immediately result in a doubling of the frequency of waveform **506**. To eliminate this occurrence, a blanking signal is generated to blank out waveform **504** for most of the period between spikes, when such extraneous zero crossings are likely to occur. The blanking circuit is embodied in the feedback path between capacitor **51** and transistor **52**.

Sawtooth waveform **505** is coupled through capacitor **51** to the base of transistor **50**. Transistor **50** and its associated circuitry responds to the sawtooth input in the same manner as squarer **33** to produce a wave output, except the load is designed to produce the rectangular waveform **507** unsymmetrical in time, instead of the symmetrical waveform **506**, with portion **532** extending for about 90% of the time period **525**. Waveform **507**, after passing through a resistance-capacitance-diode network appears as waveform **508** at the base of transistor **52**. The voltage level of portion **533** of waveform **508** is chosen to render transistor **52** conductive, and non-conductive or cut off at a value slightly below. As a result, the base of transistor **26** is blanked during the period **533** when transistor **52** is conductive. The shape and values of waveform **508** are selected to blank out the base of transistor **26** from approximately the 5% point to approximately the 90% point of the period **525**. The margins at either end of the blanking period are necessary to assure that the fundamental signal frequency zero crossings are not also blanked out. Otherwise, the base of transistor **26** would be driven positive by the true signal zero crossing spikes of waveform **504** and simultaneously negative by transistor **52**, and the system would not operate.

Network **54**, **55**, **56** and **57** eliminates transients **1010** and **1011** shown in the waveform diagram of FIG. 4. FIGURE 4 shows the operation of the blanking circuit under transient conditions, whereas, the above description and the waveform diagram of FIG. 3 shows its operation under steady state conditions. Waveform **1001** corresponds to sawtooth waveform **505** appearing at the output of transistor **30** when an input signal begins at instant **1007** and ends at instant **1008**. Waveform **1002** appears at the base of transistor **50**, and waveform **1003** corresponds to waveform **507** appearing at the collector of transistor **50**. Differentiating network **54**, **55** produces waveform **1004**, and diode **56** passes ony the negative portion thereof, producing waveform **1005** and eliminating transients **1010** and **1011**. These transients can cause frequency halving when notes are rapidly repeated; because if a second note begins during time **1009**, it is possible for a true or desired zero crossing to occur during the time waveform **504** would be blanked out by transient **1010**, and if just one desired or true zero crossing is blanked out the entire system must

operate at half frequency thereafter for the remainder of the note, rejecting each alternate true zero crossing as an extraneous zero crossing.

Waveform **1005** has a positive quiescent value which if coupled to transistor **52** would blank out the base of transistor **26** between notes and render the system unresponsive to the beginning of any note. However, passing waveform **1005** through capacitor **59** results in waveform **1006**, corresponding to waveform **508**, having a quiescent value of zero. Resistor **60** adjusts the impedance to produce a very low slope for portion **533** of waveform **508**, insuring effective blanking over the entire period of **533**. Diode **61** clamps the low value of waveform **508** to ground providing a more effective drive of transistor **52**.

Time **1012** is the delay between the beginning of a note and the beginning of operation of the blanking circuits. This delay does not cause any difficulty since the need for blanking always commences sometime after the beginning of a note in the type of musical or input signal under consideration. Moreover, time delay **1012** is actually an advantage in many instances where the note begins with a speaking tone or a beginning transient with contains a high portion of aperiodic components, non-harmonic components or components having a rapid shift in frequency. In these instances, delay period **1012** gives the signal time to stabilize before blanking begins, which otherwise could result in the blanking circuit following a false frequency, or otherwise malfunctioning.

With respect to capacitor **58** in the blanking feedback network, it merely functions to produce the margin time **534** afforded by the rounded portion **535** of waveform **508**.

For certain types of aural inputs to the signal processing unit **11**, as for example where the input signal is of the less complex variety, i.e., is nearly sinusoidal in form, the refined system embodying the sawtooth generator, its blanking circuit, and squarer circuit may not be essential. In such instance the clipped and inverted output waveform **502** obtained at the collector of transistor **22** may be applied directly through the diode **45***a* to point **48** in the amplitude control circuit, whereupon the cycle by cycle amplitude control is obtained in the same manner as above-described. For this purpose a switch **125** is provided. When it is closed to contact **125***a*, the aural input signal is processed through the refined circuitry including the sawtooth generator, its blanking circuit, and squarer circuit. However, when the switch **125** is closed to contact **125***b*, the output of transistor **22**, waveform **502**, is coupled directly to the diode **45**. Obviously, if desired, a processing unit of lower performance characteristics could be built, providing only the direct coupling of waveform **502** to the diode **45***a*, omitting the sawtooth generator, its blanking circuit, and the squarer circuit.

As previously indicated, it is one of the principal purposes of the present invention to take a musical input of one character and convert it to a musical output of another character, as for example converting the music of one instrument to that of a different instrument. To accomplish this objective successfully, it is essential that one be able to select the envelope of the signal during the processing operation, to correspond with that musical value desired at the output. This operation is exemplified and embodied in the networks **16** and selector switch **62**. When switch **62** is in the position **63**, the output signal **511** is not affected, and it follows the amplitude envelope of the input signal **501**. If the input were a plucked string, the output envelope would be the same, and is illustrated as envelope **701** of FIG. 5. The switch position **64** produces an amplitude envelope for output waveform **511** shown in envelope **702**, which has a more gradual beginning and is not as percussive as that of envelope **701**. The gradual beginning is caused by capacitor **67** requiring time to charge through diode **68** and thus lowering level **530** at the beginning of a note. Switch position **65** results in the envelope **703** having a flat top and sounding organlike. The flat top is caused by diode **68** being returned to a fixed voltage so that level **530** never exceeds that voltage value. Switch position **66** produces the amplitude envelope **704**, which is a combination of envelopes **702** and **703**. It is contemplated that when the aural input of the processing unit is an expressive musical source, position **63** would most likely be used in order to permit the expressiveness of the source to be reflected in the output. One or another of the switch positions **64**, **65**, and **66** would most likely be used to vary the musical expression of the output when the input is provided by an instrument having a fixed amplitude envelope, such for example as a guitar.

A further feature of the present processing system is a minimum input amplitude cut off circuit. Because the signal to noise ratio becomes sufficiently low to cause erratic operation of the sawtooth wave generator **26**, **27**, **30**, it is desirable to provide a cut off circuit operable when the input signal amplitude falls below a certain value. This result is accomplished by taking the squared input signal as waveform **502** at the collector output of transistor **22**, limiting it by means of diode **71** to a certain maximum value, passing this signal through diode **73**, and integrating the resultant rectified relatively negative value of the signal on capacitor **74**. So long as the waveform **502** obtains an amplitude value in excess of the limiting threshold established by diode **71**, the relatively negative value thereby established on capacitor **74** biases the transistor **47** below its cut off value. However, when the amplitude value of waveform **502** falls below the limiting threshold of diode **71**, capacitor **74** moves positive, changing the bias on the base of transistor **47** to a conducting value, thereby blanking the base of transistor **42** and rendering the amplitude control circuit inoperative and cutting off any output from the present processing unit.

Operation of this threshold cut off circuit is explained in greater detail with reference to the waveform chart of FIG. 6. Waveform **1101** is selected to represent an input waveform, and waveform **1102** is the corresponding squared wave appearing as the output of transistor **22**. At the time point **1106**, the amplitude of waveform **1102** becomes too small for reliable operation of the succeeding stages. Waveform **1103** is that appearing at the negative side of diode **71** resulting from the clipping action of the diode by voltage **1107** at the positive side of diode **71**. Voltage **1107** is selected so as to reduce the value of waveform **1103** to zero at time **1108**, shortly before time **1106**. Waveform **1103** is passed by capacitor **72** and rectified by diode **73**, producing waveform **1104** at the capacitor **74**. Resistor **75** is selected to provide a positive quiescent value on the base of transistor **47**, causing it to conduct and short out the signal on the base of transistor **42**, thus preventing the amplitude control circuit from passing any signal. When the peak value of the input signal **1101** is such as to provide a peak value for waveform **1102** greater than the voltage value **1107**, the voltage integrated on the capacitor **74** is maintained at a point where transistor **47** is cut off, permitting the amplitude control circuit to operate normally, as previously described. Accordingly, waveform **1105** is the amplitude envelope of the output signal waveform **511**, in which portion **1110** reflects operation of the present threshold cut off circuit, and portion **1109**, in dotted line, is the tail end of envelope **1105** which would contain aperiodic signals if it were not eliminated by the present threshold cut off circuit.

Pursuant to the foregoing description there is obtained at the output of transistor **44** a symmetrical square waveform signal **511**, having a frequency equal to the fundamental frequency of the input signal **501** (or **1101** in FIG. 6), and whose amplitude is a cycle by cycle function of the input signal amplitude which of course may be modified when desired by the envelope shaping networks **61**. Waveform **511** is dropped in amplitude across resistor **81**

and coupled through capacitor **82** as square waveform **511** to the appropriate tone color filter units **13**.

Simultaneously, square waveform **511** is differentiated by capacitor **83** and resistor **84** to provide waveform **512**. The negative spikes of this waveform are passed by diode **85** to a sawtooth generator comprising the resistance capacitance network **86**, **87**, **88** and **89**. Between negative spikes of waveform **512**, capacitor **86** charges to a positive value, and then is suddenly discharged by a negative spike from waveform **512**, thus forming the sawtooth waveform **513**. This waveform is then inverted by amplifier **91** to waveform **515**, and again inverted and amplified by amplifier **92** to waveform **516**. Waveform **516** is then passed to the appropriate tone color filter unit **13**.

By appropriate filtering of square waveform **514** and sawtooth waveform **516**, a signal of desired tone color is obtained, as is well understood in the art, and this resultant signal is then amplified at **14**, and passed to the output speaker **15** to provide an aural output.

The circuit shown in FIG. 2 is the processing circuit for an 8 foot pitch, or the reference footage having the same pitch as the input signal. To obtain the next higher octave, or 4 foot pitch, the 4 foot coupler switch **93** is closed connecting the square wave output channel **94** and point **95** in the sawtooth output channel. On closing switch **93**, waveforms **514** and **515** are added, and with waveform **515** chosen to have a peak amplitude twice that of waveform **514**, the output of the sawtooth channel is a sawtooth wave of double the frequency of waveforms **515** or **514**. This frequency doubling action is more fully explained in my copending application, Ser. No. 474,892, filed July 26, 1965, and entitled Frequency Doubler and Coupler for Electronic Music Generation Systems.

In addition, to obtain the next lower octave, or a 16 foot pitch, the waveform **505** is frequency divider, as indicated at **96**, and then processed in the the same manner as indicated in the present circuit by utilizing the input signal **501** as the amplitude control therefor, as indicated at **97** in FIG. 2.

Where multiple processing units are used, with a separate aural input for each such unit, their respective sawtooth and square wave outputs may be combined into the sawtooth and square wave output channels of the present circuit, as indicated at **98** and **99**.

Thus, pursuant to the present invention there is provided a system for processing an aural input of one tone color, to obtain an aural output of a different character, wherein the output is related in cycle by cycle correspondence to the frequency and amplitude of the input. It is understood, of course, that the specific embodiment herein disclosed is presented only for purposes of illustrating the invention, and that modifications and variations will be apparent to those skilled in the art. Accordingly, such modifications and variations as are embraced by the spirit and scope of the appended claims are contemplated as being within the purview of the present invention.

What is claimed is:

1. In a system for converting an aural input signal of one tonal character to an aural output signal of a different tonal character:

(a) a processing unit comprising means for detecting a single fixed reference point in each cycle of the fundamental frequency of said input signal;

(b) said detecting means comprising means for generating a pulse for a selected direction of zero crossing for each cycle of the fundamental frequency of said input signal;

(c) said processing unit further including means responsive to said detecting means for generating a blanking signal extending from shortly after a given detecting means pulse to shortly before the next succeeding detecting means pulse to blank out extraneous detecting means zero crossing pulses that may occur during a latter portion of a complex aural input tone; and

(d) means responsive to said detecting means for generating one cycle of a square wave signal for each of said detected fixed reference points in cycle-for-cycle correspondence with the cycles of said input signal.

2. In a system for converting an aural input signal of one tonal character to an aural output signal of a different tonal character:

(a) a processing unit comprising means for detecting a single fixed reference point in each cycle of the fundamental frequency of said input signal, said detecting means comprising:

(1) means for clipping the input signal to obtain the fundamental frequency thereof,

(2) means for differentiating the clipped signal to obtain pulses definitive of zero crossings of the input signal, and

(3) means for rectifying the differentiated signal to obtain those pulses definitive of only one selected direction of zero crossing; and

(b) means responsive to said detecting means for generating one cycle of a symmertical waveform signal for each of said detected fixed reference points in cycle for cycle correspondence with the cycles of said input signal.

3. A system according to claim **2**, said generating means comprising,

(1) a sawtooth waveform generator producing one cycle in response to each of said rectified pulses, and

(2) a square waveform generator responsive to the sawtooth generator and providing a linear and bilateral load therefore producing one symmetrical square waveform cycle in response to each sawtooth waveform cycle.

4. In a system as set forth in claim **3**, said unit further including a second rectangular waveform generator responsive to said sawtooth waveform generator and providing a linear and non-bilateral load therefor producing one non-symmetrical rectangular waveform cycle in response to each sawtooth waveform cycle, means for coupling the output of said rectangular waveform generator to the output of said rectifying means during a portion of the cycle of said non-symmetrical rectangular waveform to blank out extraneous pulses that may appear in the output of said rectifying means between successive pairs of rectifying means output pulses definitive of zero crossings of the fundamental frequency of said input signal, as may occur during a latter portion of a complex aural input tone.

5. In a system as set forth in claim **3**, said unit further including an amplitude control circuit comprising means for detecting the peak value of a given half of each cycle of said input signal, and means for combining said detected peak value with the corresponding cycle of said square waveform to provide a second symmetrical square waveform in cycle by cycle synchronism with the first mentioned symmetrical square waveform and having an amplitude corresponding with the peak value of the corresponding input signal cycle.

6. In a system as set forth in claim **5**, said unit further including means for varying the amplitude envelope of a series of said second symmetrical square waveform cycles in accordance with a selected function.

7. In a system as set forth in claim **5**, said unit further including means responsive to the amplitude of said clipped input signal for reducing to zero the amplitude of said second symmetrical square waveform when the amplitude of said clipped input signal falls below a selected value.

8. In a system as set forth in claim **7**, said unit further including a first output channel coupling said second symmetrical square waveform to tone color filter means, a second output channel including means for converting said second symmetrical square waveform to a corresponding sawtooth waveform and coupling it to tone color filter means, and means for converting the outputs of said tone color filter means to sound.

9. In a system for converting an aural input signal of one tonal character to an aural output signal of a different tonal character:

(a) a processing unit comprising means for detecting a single fixed reference point in each cycle of the fundamental frequency of said input signal;

(b) said processing unit further including an amplitude control circuit comprising means for detecting the peak value of a given half of each cycle of said input signal;

(c) means responsive to said detecting means for generating one cycle of a symmetrical waveform signal for each of said detected fixed reference points in cycle for cycle correspondence with the cycles of said input signal; and

(d) means for combining said detected peak value with the corresponding cycle of said symmetrical waveform to provide a second symmetrical waveform in cycle-by-cycle synchronism with the first mentioned symmetrical waveform and having an amplitude corresponding with the peak value of the corresponding signal cycle.

10. In a system as set forth in claim 9, said symmetrical waveform signal generating means being a square waveform generating means, and said second symmetrical waveform being a square waveform.

11. In a system as set forth in claim 10, said detecting means comprising means for generating a pulse for a selected direction of zero crossing for each cycle of the fundamental frequency of said input signal.

12. In a system as set forth in claim 9, said detecting means comprising means for generating a pulse for a selected direction of zero crossing for each cycle of the fundamental frequency of said input signal.

13. In a system as set forth in claim 9, said unit further including means responsive to said detecting means for generating a blanking signal extending from shortly after a given detecting means pulse to shortly before the next succeeding detecting means pulse to blank out extraneous detecting means zero crossing pulses as may occur during a latter portion of a complex aural input tone.

14. In a system as set forth in claim 13, said symmetrical waveform signal generating means being a square waveform generating means, and said second symmetrical waveform being a square waveform.

15. A system for converting an aural input signal of one tonal character to an aural output signal of a different tonal character, including:

(a) a processing unit comprising means for detecting the fundamental frequency of said input signal;

(b) means responsive to said detecting means for generating a symmetrical waveform signal in cycle-for-cycle correspondence with the cycles of said input signal;

(c) amplitude means responsive to the amplitude of said input signal to adjust the amplitude of said symmetrical waveform signal; and

(d) means for selectively varying the harmonic content of said symmetrical waveform signal.

16. A system according to claim 15, including means for converting the resultant signal to sound.

17. A system according to claim 15, including means for varying the amplitude envelope of a series of cycle of said symmetrical waveform signal in accordance with a selected function.

18. In a system for converting an aural signal of one tonal character to an aural output of a different tonal character, means for determining the fundamental frequency of said signal, means for generating a symmetrical waveform signal of said frequency, and means for varying the amplitude of each cycle of said symmetrical waveform signal in accordance with the peak value of the corresponding cycle of said aural signal.

19. In a system for converting an aural signal of one tonal character to an aural output of a different tonal character:

(a) means for determining the fundamental frequency of said signal;

(b) means for generating a symmetrical waveform signal of said frequency;

(c) means for varying the amplitude of each cycle of said symmetrical waveform signal in accordance with the peak value of the corresponding cycle of said aural signal;

(d) means for selectively varying the harmonic content of said symmetrical waveform signal; and

(e) means for converting the resultant signal to sound.

20. In a system as set forth in claim 19, means for varying the amplitude envelope of a series of cycles of said symmetrical waveform signal in accordance with a selected function.

21. In a system for converting an aural input signal of one tonal character to an aural output signal of a different tonal character, a processing unit comprising means for converting an aural input signal to a signal substantially rectangular in waveform and having a frequency equal to the fundamental frequency of said input signal, an amplitude control circuit including means for detecting the peak value of a given half of each cycle of said input signal, and means for combining said detected peak value with the corresponding cycle of said rectangular waveform signal to provide a resultant signal in cycle by cycle synchronism with the input signal and having an amplitude corresponding with the peak value of the corresponding input signal cycle.

22. In a system for converting an aural signal of one tonal character to an aural output of a different tonal character, means for determining the fundamental frequency of said signal, means for determining the peak amplitude value of each aural signal cycle, and means responsive to the first two means for producing a signal having a frequency equal to the fundamental frequency of the aural signal and each cycle having an amplitude related to said peak amplitude of the corresponding cycle of said aural signal.

23. A system for converting an aural input signal of one tonal character to an aural output signal of a different tonal character, a processing unit comprising means for detecting the fundamental frequency of said input signal, means responsive to said detecting means for generating a symmetrical waveform signal in cycle for cycle correspondence with the cycles of said input signal, and amplitude means responsive to the amplitude of said input signal to adjust the amplitude of said symmetrical waveform signal.

24. In a system for converting an aural input signal of one tonal character to an aural output signal of a different tonal character:

(a) a processing unit comprising means for converting an aural input signal to a signal substantially rectangular in waveform and having a frequency equal to the fundamental frequency of said input signal;

(b) an amplitude control circuit including means for detecting the peak value of a given half of each cycle of said input signal; and

(c) means for combining said detected peak value in synchronism with each cycle of said rectangular waveform signal to provide a resultant signal having an amplitude corresponding with the peak value of the corresponding input signal cycle.

25. A system for converting an aural input signal of one tonal character to an aural output signal of a different tonal character:

(a) a processing unit comprising means for detecting the fundamental frequency of said input signal;

(b) means responsive to said detecting means for generating a symmetrical waveform signal in cycle-for-cycle correspondence with the cycles of said input signal;

(c) amplitude means responsive to the amplitude of said input signal to adjust the amplitude of said symmetrical waveform signal; and

(d) said processing unit further including means responsive to said detecting means for resetting said amplitude means extending for only a portion of a cycle of said symmetrical waveform signal.

26. A system for converting an aural input signal of one tonal character to an aural output signal of a different tonal character:

(a) a processing unit comprising means for detecting the fundamental frequency of said input signal;

(b) said detecting means comprising low pass filter means for said input signal to obtain the fundamental frequency thereof;

(c) means responsive to said detecting means for generating a symmetrical waveform signal in cycle-for-cycle correspondence with the cycles of said input signal;

(d) said generating means comprising a first sawtooth waveform generator producing one cycle in response to each cycle of the fundamental frequency;

(e) amplitude means responsive to the amplitude of said input signal to adjust the amplitude of said symmetrical waveform signal; and

(f) a second sawtooth waveform generator responsive to the symmetrical waveform signal and producing one sawtooth waveform cycle in response to each symmetrical waveform cycle.

27. A system for converting an aural input signal of one tonal character to an aural output signal of a different tonal character:

(a) a processing unit comprising means for detecting the fundamental frequency of said input signal;

(b) means responsive to said detecting means for generating a symmetrical waveform signal in cycle-for-cycle correspondence with the cycles of said input signal; and

(c) amplitude means responsive to the amplitude of said input signal to adjust the amplitude of said symmetrical waveform signal, said amplitude means further comprising

(1) means for detecting the peak value of a given half of each cycle of said input signal, and

(2) means for combining said detected peak value with the corresponding cycle of said symmetrical waveform to provide a second symmetrical waveform in cycle-by-cycle synchronism with the first mentioned symmetrical waveform and having an amplitude corresponding with the peak value of the corresponding input signal cycle.

28. A system as set forth in claim **27**, including a first output channel coupling said second symmetrical waveform to tone color filter means, a second output channel including means for converting said second symmetrical waveform to a corresponding sawtooth waveform and coupling it to tone color filter means, and means for converting the outputs of said tone color filter means to sound.

29. An amplitude control circuit comprising means for detecting the peak value of a given half of an input signal, symmetrical waveform means responsive to said input signal to provide a first symmetrical waveform having a frequency octavely related to the fundamental frequency of said input signal, and means for combining said detected peak value with the corresponding cycle of said first symmetrical waveform to provide a second symmetrical waveform in cycle by cycle synchronism with said first symmetrical waveform and having amplitude corresponding with the peak value of the corresponding signal cycle.

30. A circuit as set forth in claim **29**, wherein said first symmetrical waveform signal generating means being a square waveform generating means, and said second symmetrical waveform being a square waveform.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,476,863 Dated November 4, 1969

Inventor(s) D. J. Campbell

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 1, line 28, change "ampitude" to -- amplitude --;

Col. 5, line 63, change "16" to -- 61 --;

Col. 7, line 35, after "is" insert -- fed to a --;

Col. 8, line 21, change "symmertical" to -- symmetrical --;

Col. 9, line 63, change "cycle" to -- cycles --.

SIGNED AND
SEALED
JUL 7 1970

(SEAL)
Attest:

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Commissioner of Patents