United States Patent [19]

Woods

[11] **3,860,876**

[45] **Jan. 14, 1975**

[54] **MUSICAL APPARATUS**

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[22] Filed: **Nov. 24, 1972**

[21] Appl. No.: **309,153**

[52] **U.S. Cl.** **328/167,** 307/233, 330/107, 84/1.01

[51] **Int. Cl.** **H03k 1/16**

[58] **Field of Search** 328/167; 330/107, 109; 84/1.01, 1.16, 444; 307/233

[56] **References Cited**

UNITED STATES PATENTS

3,059,190	10/1962	Hafler	330/109 X
3,096,488	7/1963	Lomask	330/107 X
3,130,374	4/1964	Beres et al.	330/109 X
3,449,681	6/1969	Hafler	330/109 X

OTHER PUBLICATIONS

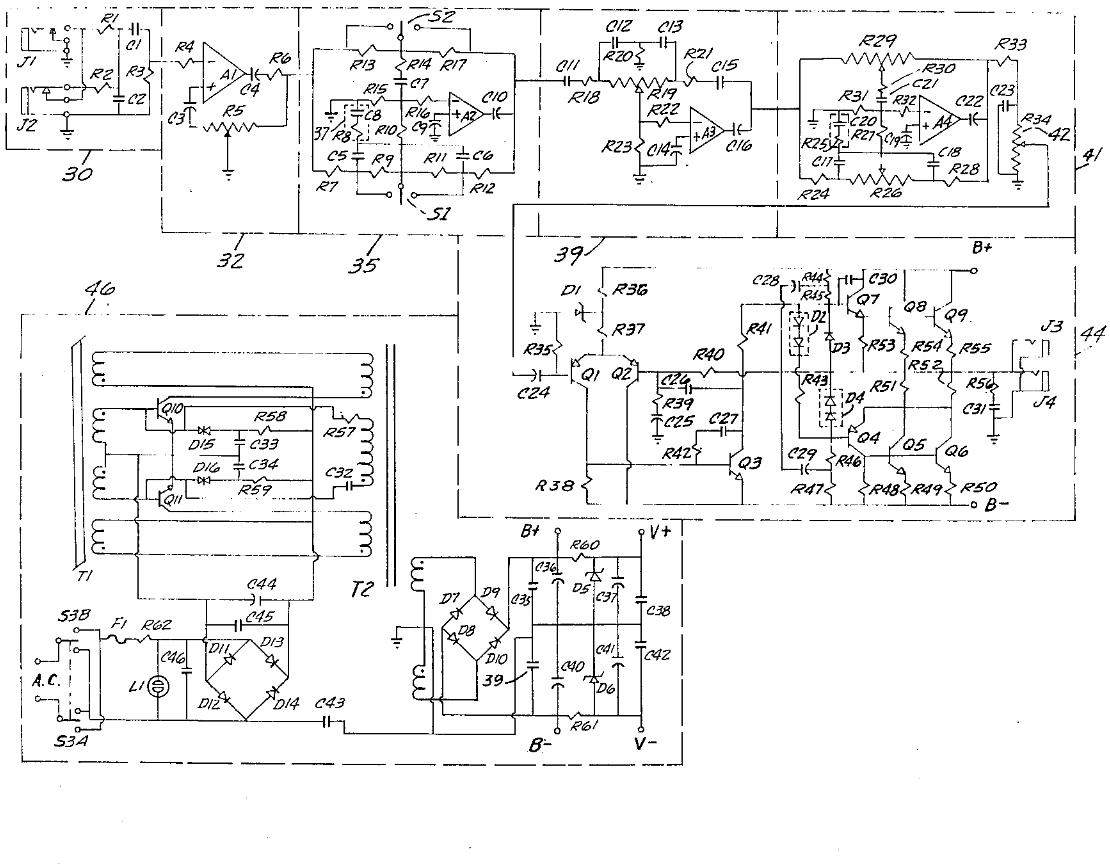
E. J. Gately, Jr., "The Wonderful World of Integrated Circuits", Audio, June, 1970, pgs. 36, 40 & 44.

Primary Examiner—John Zazworsky
Attorney, Agent, or Firm—Francis X. LoJacono, Sr.

[57] **ABSTRACT**

The present disclosure relates to apparatus for improving the tonal characteristics of a musical instrument in such a manner as to elicit excited responses from professional musicians; and more particularly, it teaches how the disclosed apparatus may be used for improving the tonal characteristics of a guitar. Variations of the apparatus permit the musician to achieve different special effects.

23 Claims, 12 Drawing Figures



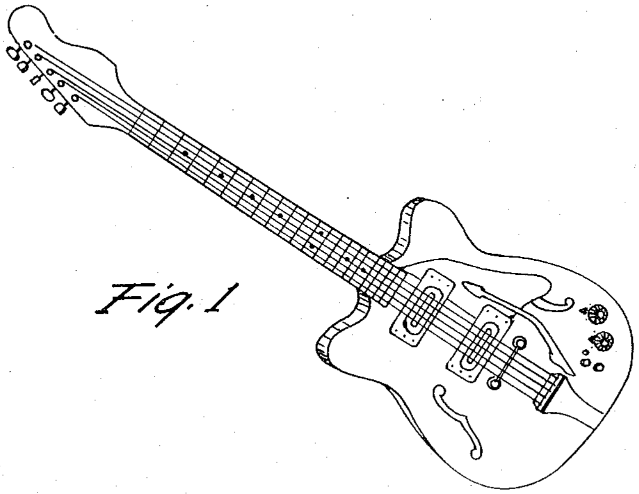


Fig. 1

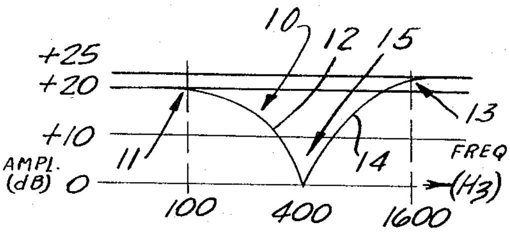


Fig. 2

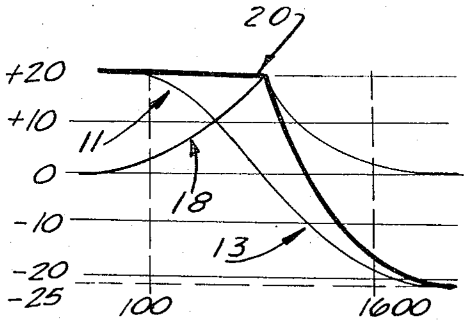


Fig. 5

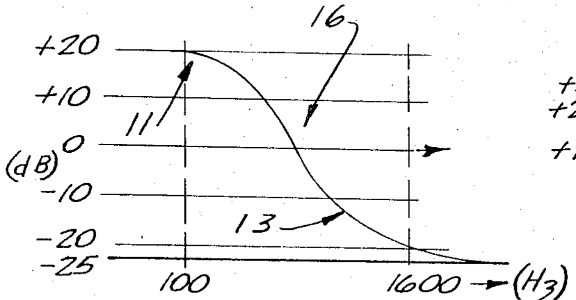


Fig. 3

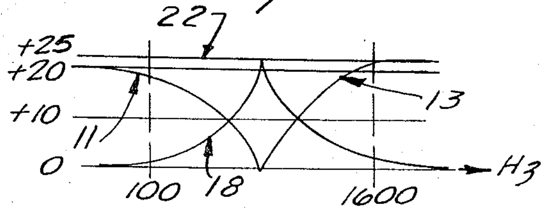


Fig. 6

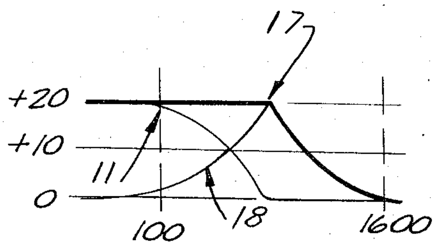


Fig. 4

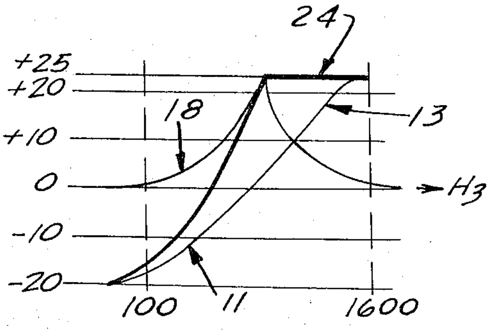
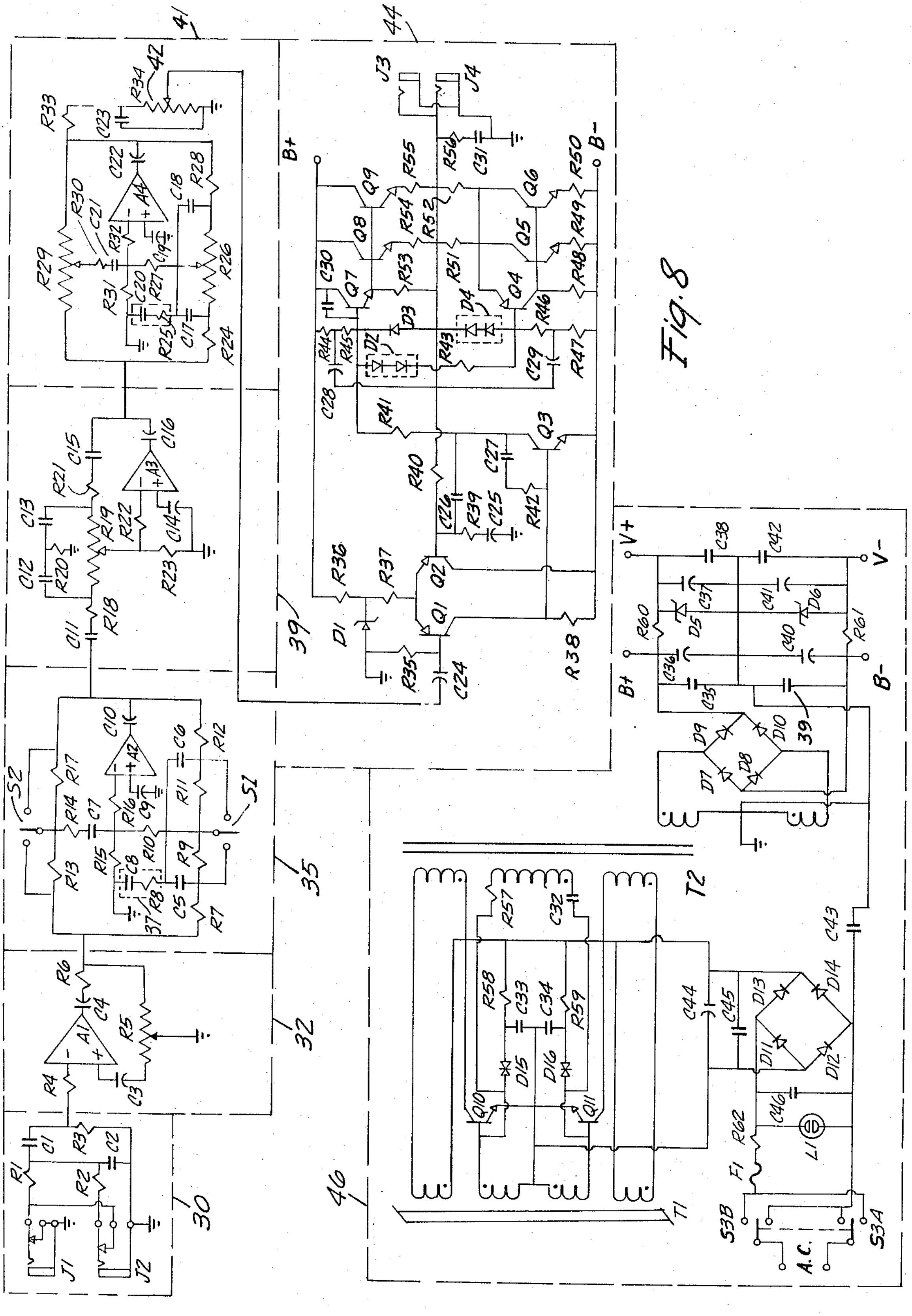


Fig. 7


J1
J2
R1
C1
R2
R3
C2
30
R4
A1
C3
C4
R5
R6
32
R7
C5
R8
C8
R9
R10
R15
37
R13
R14
C7
R16
C9
A2
C10
R11
C6
R12
R17
S1
S2
35
C11
R18
R19
R20
C12
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A3
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C35
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D7
D8
T2
R57
C32
R58
C33
C34
R59
D15
D16
Q10
Q11
C44
C45
C43
D13
D14
D11
D12
C46
L1
R62
F1
T1
S3B
S3A
A.C.
46

Fig. 8

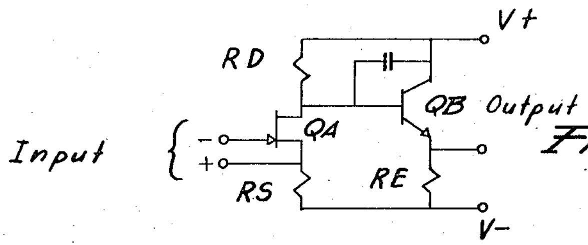

Fig. 9

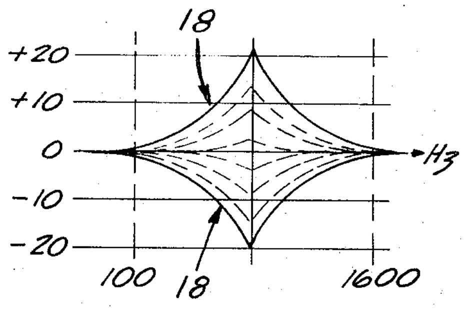

Fig. 10

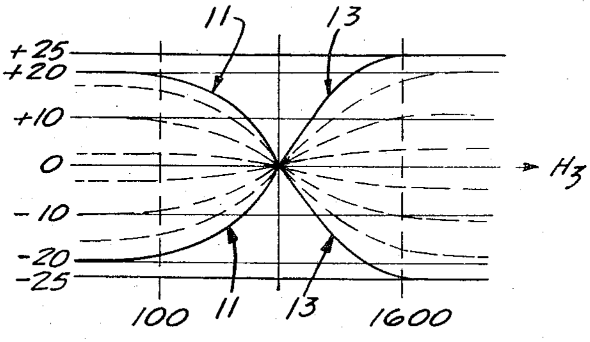

Fig. 11

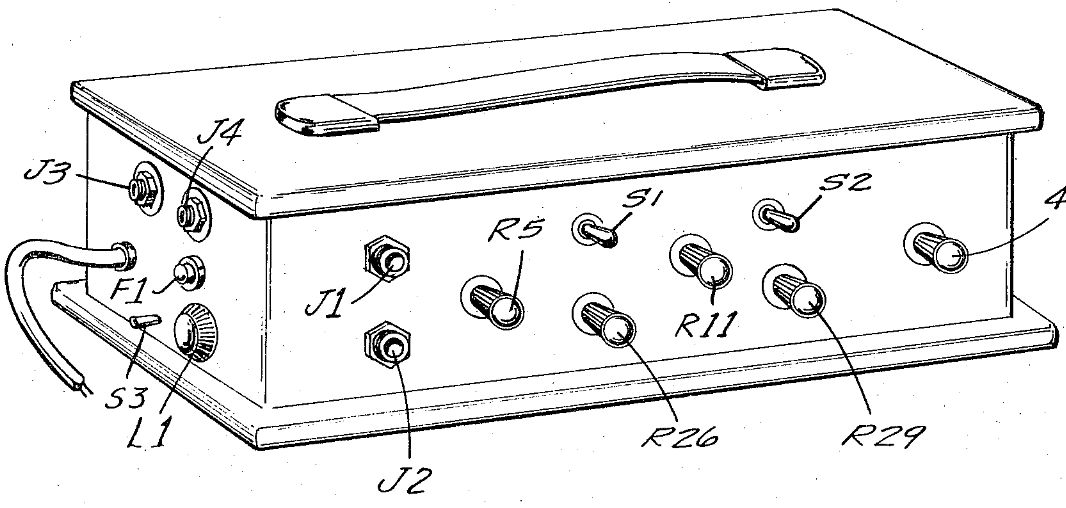

Fig. 12

MUSICAL APPARATUS

BACKGROUND

It is well known that a musical instrument produces a characteristic range of tones, these depending on a large number of different factors — in general, a large instrument producing deeper tones than a smaller instrument. Among the tone-modifying factors are, for example: the body size; the body shape; the particular mode of playing the instrument; and (in string instruments) the string tension, the string size, the type and location of the bridge, the body bracing, the shape and position of the sound holes, etc. Unfortunately, the relation between these various factors is extremely complex, and their interactions are not well understood.

Therefore, producing a good musical instrument is a work of art, of science, and of skill; and, since only a relatively few really good instruments are produced, they are both expensive and highly prized.

In general, a group of qualified musicians will agree upon a "good" instrument; but even so, a particular musician may not be completely satisfied with a given instrument — and the reason for this will be understood from the following discussion.

It is well known that a "pure" note — say as produced by a tuning fork — may be technically expressed as a "frequency" having a given number of vibrations per second. However, such a pure note — known as a "fundamental" is not very useful from a musician's point of view, because such a musical note needs a plurality of "harmonics" or "overtones" of higher frequencies to "fill out" the note and to produce a "tone."

Every different type of instrument — e. g., violin, trumpet, etc. — produces an individually characteristic combination of tones, i. e., fundamentals and harmonics. For this reason, it is possible to recognize a tone as originating from a violin, and to distinguish a violin tone from a trumpet tone. Furthermore, each individual instrument — whether it be a violin or a trumpet — differs somewhat from other instruments of its class, because each individual instrument has an individual structure that causes it to produce an individual combination of fundamentals and harmonics that differs from the combination of fundamentals and harmonics produced by the other instruments of its class.

As a result of these instrument tonal characteristics, each musician is constantly searching for a musical instrument that sounds "right" to him; and, while a good instrument generally sounds right to a number of different musicians, each musician may personally desire a slightly different combination of tones.

For ease of comprehension, the following explanation will be presented in terms of a guitar; although, it will be later realized that the discussion and disclosure apply to a wide range of musical instruments, and to other apparatus.

Of late, a much larger share of musical attention is being given to the guitar — partly because of the ease with which it may be played, and partly because a gifted musician is able to produce such a wide range of music thereon. As a result, the guitar now occupies a prominent place in entertainment — both as a solo instrument and as part of a musical group.

This trend toward wider use of the guitar has introduced two simultaneous problems, as follows. First of all, the volume of sound produced by an acoustical, hollow-body guitar tends to be too small compared to the sound volume of other musical instruments. Secondly, the tonal range of the guitar tends to be too limited. It became feasible to increase the tonal range of the guitar by introducing a so-called "family" of guitars — including bass guitars, intermediate-range guitars, tenor guitars, guitars with different numbers of strings, etc.

In order to produce improved bass tones, the bass guitar tended to grow in size with each new generation thereof, so that eventually the bass guitar became so large as to be unwieldy. It turns out that both of these problems (volume and size) may be simultaneously solved by a relatively simple solution, namely, by the use of an electronic sound system comprising a microphone, an electronic amplifier, and a loud speaker — the composite sound system increasing the volume, and disproportionately amplifying the bass notes.

One disadvantage of this electronic sound arrangement was that its microphone was unsightly. Another disadvantage was that it tended to limit the musician's on-stage mobility. Still another, more important, disadvantage was that the musician now tended to be limited by the characteristics of the electronic sound system; so that, often, the audience did not hear the tones that the musician felt were desirable.

Fortunately, with the advent of transistors and new materials, it became possible to build the amplifiers and the microphones (now known as "pick-ups") small enough so that they could fit into the hollow body of the guitar; although, the more powerful amplifiers are still placed on stage along with the musician.

It may thus be understood that — despite the miniaturized sound system — a musician, having found a musical instrument that comes close to satisfying his personal tonal requirements, is greatly disturbed when an electronic sound system — over which he has no control — distorts the tone from his musical instrument.

Due to the introduction of these electronic, transistorized amplifiers, it now became feasible to have the electronic amplifier — rather than the guitar — produce the desired bass tones; so that it was no longer necessary to build large, hollow-body, acoustical, bass guitars. As a result, the newest type of guitar is the so-called "solid-body" guitar, as illustrated in FIG. **1**. This type of guitar has a body that — instead of being hollow — is a block of wood about two inches thick, and of a suitable size and shape, a portion of the solid body being hollowed out to accommodate the necessary electronic components. Thus, with a suitable, miniaturized, electronic circuit, the solid-body guitar is able to minimize the need for the prior-art, large, hollow-body, acoustical, bass guitar. However, most professional musicians complained that the sound from these electronic guitars was "dead", "dull", or similarly described.

Thus, it becomes desirable to provide apparatus that improves the sound of a musical instrument.

OBJECTIVES AND DRAWINGS

FIG. **1** shows a pictorial view of a guitar;

FIGS. **2** – **7** show various waveforms representative of response curves that may be attained by the use of the subject apparatus;

FIGS. **8** and **9** show circuitry for the subject apparatus;

FIGS. 10 and 11 show families of waveforms representative of response curves that may be attained by the use of the subject apparatus;

FIG. 12 shows a pictorial view of how the subject apparatus may be packaged.

SYNOPSIS

Broadly speaking, the present disclosure teaches that a novel, "live" sound is produced by selectively amplifying and/or attenuating the fundamental tones and their harmonics in a specialized manner that produces a sharp differentiation between the fundamental frequencies and their harmonics. This result is attained, producing a lower range of frequencies that has a sharp "roll-off" portion, an upper range of frequencies that has a sharp "roll-on" portion, and a mid-range of frequencies that sharply separates the lower range of frequencies from the upper range of frequencies.

The present disclosure indicates that special sound effects are often desired for specific purposes, and that special conditions are often required for practicing; and it teaches how the apparatus may be modified to achieve such special sounds and conditions.

Basic Concept

I have discovered a new, previously-unknown concept that causes a musical instrument, such as a guitar, to produce a sound that thrills professional musicians, the comments being such as "brilliant," "live," and the like. Moreover, my inventive concept permits each individual musician to modify the sound in such a way that he is personally pleased. Furthermore, my inventive concept may be used with a relatively cheaply-made guitar, and may even be used to cause a given instrument to act selectively as a bass guitar, as a mid-range guitar, or as a tenor guitar.

Originally, it was believed that, in order to produce satisfactory bass-guitar sounds, it was merely necessary to have an electronic sound system capable of amplifying the bass notes. However, this arrangement has not proved satisfactory.

My basic concept, on the contrary, not only amplifies the bass notes, but also strongly aamplifies the treble notes — especially the lower-frequency harmonics — and, when desired, may even amplify or attenuate the intermediate notes. The resultant combination of fundamentals and harmonics produces bass sounds having tonal colors that far surpass those produced previously.

Response Curve of FIG. 2

The present inventive concept will be better from FIG. 2, which shows a response curve 10 that depicts the amount of amplication — measured in decibels (dB), and indicated to be increasing in a vertically-upward direction for each frequency (indicated to be increasing in a rightward direction). The audio frequency spectrum ranges, typically, from about 20 vibrations per second (Hertz, or Hz) to about 20,000 Hz. As indicated in FIG. 2, a lower bass range of frequencies — extending from about 20 Hz to about 400 Hz — is amplified in such a manner that the lower-range-amplification waveform 11 has a steep "roll-off" portion 12 that terminates or "anchors" at a given anchoring frequency such as 400 Hz; although, another anchoring frequency may be used. In general, the frequencies below the anchoring frequency may be considered to be the above-discussed fundamentals.

FIG. 2 also indicates that an upper treble range of frequencies — extending upwards of the anchoring frequency — is amplified in such a manner that the upper-range-amplification waveform 13 has a steep "roll-on" portion 14 that is also anchored at substantially the anchoring frequency. In general, the frequencies above the anchoring frequency may be considered to be the harmonics of the various fundamentals.

Thus, as indicated in FIG. 2, the fundamental and harmonic frequencies are strongly amplified, in order to give them a large enough emplitude to be incorporated into the overall sound of the guitar.

It should be noted, however, that since relatively few of the high-frequency, treble notes are produced in a bass guitar, the relatively-high amplification of the treble notes does not drown out the bass notes. Thus, the bass notes still predominate.

Attention is directed, in FIG. 2, to the "notch" 15 between the roll-off portion 12 and the roll-on portion 14, notch 15 in the response curve 10 indicating that there is a mid-range of frequencies that receives minimal amplification. It has been found desirable to have the notch 15 of such configuration that it permits sharply reduced amplification of the fundamental frequencies within two octaves below the anchoring frequency, and permits sharp amplification of the harmonics within two octaves above the anchoring frequency — the bass-range wavefore 11 and the treble-range waveform 13 flattening out beyond these limits.

It appears that the novel, aural results provided by my invention are due to the co-action of the steep, roll-off portion 12 and the steep, roll-on portion 14, and to the minimum amplification in the notch 15 — these factors combining to produce a sharp distinction between the fundamentals and the harmonics.

Response Curve of FIG. 3

There are some musical arrangements wherein a bass guitar is used primarily for rhythm and/or background — and, therefore, should not produce treble notes that might intrude upon the melody being played by other instruments. The present invention permits this result to be achieved by producing a response curve that causes the guitar to produce primarily bass notes, and not produce any appreciable amount of treble notes.

Such a response curve 16 is shown in FIG. 3, this result being achieved by using the previously-discussed, bass waveform 11 — but "inverting" the previously-discussed, treble waveform 13. In this way, the overall response curve 16 of FIG. 3 produces sound containing amplified bass tones and attenuated treble tones.

Thus, the present invention permits the output sound of a given bass guitar to be modified to produce a live bass sound or a bass rhythm sound.

Response Curve of FIG. 4

There are times when it may be desirable to amplify a greater range of bass notes; and the present invention permits this result to be achieved by producing a response curve such as indicated at 17 in FIG. 4. To produce such a response curve, the above-discussed, bass waveform 11 is used as explained above, along with a mid-range waveform 18. For reasons to be discussed later, this mid-range waveform 18 is preferably of such a configuration that it is an "inversion" of the notch 15 between the bass-range, roll-off portion 12 and the treble-range, roll-on portion **14** of FIG. **2**, having its peak at the anchoring frequency.

The result of using the bass portion **11** and the intermediate portion **18** is indicated in FIG. **4**, and produces the composite response curve **17** that equally amplifies all of the bass tones up to the anchoring frequency, as indicated by the horizontal bass portion of the response curve **17**, while gradually attenuating the treble notes.

Response Curve of FIG. 5

In some cases, it is desired that the response curve contain more bass notes but still fewer treble notes; and FIG. **5** shows a suitable response curve **20.** In obtaining curve **20,** the original bass-range waveform **11** is used in its amplifying mode; the original treble-range waveform **13** is used in its attenuating mode; and the intermediate-range curve **18** is used in its amplifying mode. As indicated by the composite response curve **20,** the bass notes are equally amplified for an extended bass range; whereas the treble notes are attenuated sooner and more severely than by the response curve **17** of FIG. **4.**

Response Curve of FIG. 6

There times when it is desirable to equally amplify all of the frequencies — such a situation arising, for example, in a musical group when volume is more desirable than individual tones. FIG. **6** shows a response curve **22** that achieves this result. Here, all three range waveforms **11, 13** and **18** are used in their amplifying modes; so that the composite response curve **22** is substantially flat and horizontal — indicating that all of the frequencies are amplified to a substantially-equal extent. This particular response curve **22** is possible because the mid-range waveform **18** substantially fills in the notch **15.**

Response Curve of FIG. 7

While the disclosed inventive concept has been presented in terms of a bass guitar, it — of course — has other uses. For example, if the individual waveforms **11, 13** and **18** are combined as indicated in FIG. **7,** they co-act to produce a response curve **24** that attenuates the lower frequencies, and strongly amplifies the higher frequencies.

Thus, the present invention provides a plurality of range waveforms that may be selectively combined in amplification and/or attenuating modes to provide various types of response curves.

THE ELECTRONIC CIRCUITRY

The above-described response curves, and others, may be formed by electronic circuitry such as is shown in FIG. **8.** For convenience of explanation, the disclosed circuitry will be divided into several separate stages — which, however, cooperate to produce the desired results.

The Input Network

As discussed above, various pick-ups convert the acoustical vibrations of the guitar into electrical signals of corresponding frequencies; and, depending upon the design of the pick-ups, some of them produce larger amplitude signals than others. In order to accommodate pick-ups of various types, the disclosed electronic circuit has an input network **30** that has two input jacks (J1 and J2). When these jacks are not being used, the jack circuits are short circuited to ground in order to minimize extraneous noise and the like.

Input jack J1 is adapted to receive signals from a low-amplitude pick-up; and, when a plug from such a low-amplitude pick-up is inserted into jack J**1,** resistors R1 and R2 are effectively connected in parallel; so that the relatively-low-amplitude, pick-up signals encounter minimal resistance and appear at the output of network **30.**

Input jack J2 is adapted to receive signals from a high-amplitude pick-up; and, when a plug from such a high-amplitude pick-up is inserted into jack J2, resistors R1 and R2 are effectively connected to form a voltage divider; so that about half of the relatively-high-amplitude signal appears at the output of network **30.**

Thus, the input network **30** produces a desired-amplitude, output signal, regardless of whether the input signal had a high or low amplitude.

The Voltage Amplifier

It so happens that many of the music audiences have become accustomed to a distortion produced by earlier amplifiers operating at high gain; and these audiences have come to expect certain musical selections to contain this distortion. As a result, it becomes desirable for the musician to be able to produce such a distortion when he deems it advisable; and the disclosed electronic circuitry of FIG. **8** contains a distortion amplifier **32** for achieving this function.

It may be seen that voltage amplifier **32** has an amplifier A**1** that has two inputs, an output, and an internal, "feedback" circuit that feeds a portion of the output back into the input — the feedback being "negative" in that it tends to counteract the input.

The voltage amplifier **32** functions as follows. When the slider of potentiometer R5 is at its rightmost position, the output signal is fed directly to ground, so that no signal is applied to subsequent circuitry. On the other hand, when the slider of the potentiometer R5 is at its leftmost position, the feedback is attenuated by the resistance of the potentiometer which bypasses RS of FIG. **9,** so that the feedback signal has very little effectiveness — permitting maximal gain of the amplifier.

FIG. **9** shows a typical schematic diagram of amplifier A**1.** As shown, it comprises a drain resistor RD, a source resistor RS, an emitter resistor RE, a field-effect transistor (FET) QA which has a voltage characteristic that resembles the characteristics of prior-art, vacuum tubes, and a bi-polar transistor QB having a characteristic that is typical of a transistor. The circuit of FIG. **9** is such that the negative feedback assures minimal amplifier gain to preclude overloading; but, when the amplifier is driven hard by placing the potentiometer R5 of FIG. **8** at its leftmost position, amplifier **32** tends to produce a voltage-type distortion similar to that produced by prior-art, tube-type amplifiers. In this way, the voltage amplifier **32** acts as a distortion control.

The Fixed, Waveform Generator

As was pointed out previously, it is desirable to produce a bass-range waveform **11** as discussed in connection with FIGS. **2 - 7**; and such waveforms may be produced by a fixed, waveform-generating circuitry, indicated at **35** of FIG. **8.** This circuit produces the fixed waveforms **11** and **13** in the following manner.

The Bass Circuitry, "Neutral"-Switch Setting

Directing attention first to the lower portion of the circuitry indicated at **35**, it will be noted that this circuitry contains a single-pole, three-position switch **S1**, switch **S1** being shown in its "neutral setting." In this neutral setting, the circuit operates as follows.

The incoming signal (from the voltage amplifier **32**) contains, it will be recalled, a plurality of various frequencies that correspond to the various notes produced by the pick-up of the guitar. The incoming signal traverses an input path — comprising circuit elements **R7, R9, C5, R10** and **R16**; and it is then applied to the input terminal of amplifier **A2** — which may be generally similar to amplifier **A1**, previously described. The input signal is thus amplified by amplifier **A2**; and appears at the output terminal of amplifier **A2**. A feedback path — comprising circuit elements **C10, R12, R11, C6, R10,** and **R16** — applies a feedback signal to the input terminal of amplifier **A2**.

Typically, **R7** equals **R12**; **R9** equals **R11**; **R9** equals 10 × **R7**; **R11** equals 10 × **R12**; **C5** equals **C6**; **R15** provides a resistive path to ground for proper return of the negative input terminal of **A2**; **R16** is for suppression of radio signals; **C9** bypasses the positive input terminal of amplifier **A2** for maximum open-loop gain of **A2** throughout the audio-frequency range; **C10** provides a low-impedance path for output and feedback signals through the audio-frequency spectrum.

Since corresponding circuit elements of the input path and of the feedback path are substantially equal, the applied input signal is identical — at all frequencies — to the applied feedback signal. Thus, the fixed, waveform-generating circuit **35** has a gain of zero decibels. For convenience, this gain is designated as a "unity" amplification; and is depicted as a straight horizontal line at zero dB of FIGS. **2** – **7**, this straight horizontal line indicating that all of the frequencies are amplified equally.

Digression

It is well known that an electronic circuit element known as a "capacitor" tends to transmit progressively higher frequencies in progressively greater amounts — that is, it is "frequency sensitive;" and this characteristic is used in the present circuit.

The Bass Circuit, "Boost"-Switch Setting

When switch **S1** is placed in its leftmost or "boost setting," the bass-range waveform **11** is generated as follows. When switch **S1** is at its boost setting it shorts out **C5** and **R9**; so that the effective input path now comprises only **R7, S1, R10,** and **R16**, this being a relatively-low-resistance, resistive (non-frequency-sensitive) path. The feedback path still comprises **C10, R12, R11, C6, R10,** and **R16**; so that this feedback path's impedance varies inversely with frequency for signals below 400 Hz. As a result, the input signal is larger than the feedback signal for frequencies less than 400 Hz; and the overall gain of the amplifier **A2** is boosted up to 20 dB for frequencies less than 100 Hz, as indicated at waveform **11** of FIGS. **2** and **4**.

For input frequencies greater than 100 Hz, capacitor **C6** exhibits an ever-decreasing resistance to the feedback signal; so that, for these higher frequencies, progressively larger feedback signals are applied to amplifier **A2** — in this way, decreasing its overall gain for frequencies in the 100 – 400 Hz range, and resulting in the roll-off portion **12** of FIGS. **2** – **6**, which reaches zero dB at the anchoring frequency of about 400 Hz.

In order to achieve an even steeper roll-off portion **12**, use is made of a waveform-shaping network **37** comprising **R8** and **C8**, this shaping network permitting the input-signal path and the feedback-signal paths to be equal, resulting in unity gain and a characteristic notch at 400 Hz.

The Bass Circuit, "Cut"-Switch Setting

When switch **S1** is placed in a rightmost, or its "cut setting", the bass-range waveform **11** is generated in an inverse from (See FIG. 7), as follows. With switch **S1** at its cut setting, it shorts out **C6** and **R11**; so that the effective feedback path now comprises only **C10, R12, S1, R10,** and **R16** — this being a relatively-low-resistance, non-frequency-sensitive path. The input path still comprises **R7, R9, C5, R10,** and **R16**; so that the input path has a progressively-larger impedance for frequencies below 400 Hz than the feedback path. As a result, the applied feedback signal is larger than the applied input signal; and the overall gain of amplifier **A2** is severely reduced, or cut, for frequencies up to about 100 Hz.

For frequencies greater than about **100** Hz, capacitor **C5** of the input-signal path exhibits an ever-decreasing-impedance to the input signal; so that, for these higher frequencies, progressively-larger input signals are applied to the amplifier **A2** — in this way, increasing its overall gain for frequencies in the 100 – 400 Hz range, and resulting in the inverted roll-off portion **12** of FIG. **7**.

In order to maintain the steeper roll-off portion **12**, waveform-shaping network **37** permits unity gain at 400 Hz, as discussed previously.

In actuality, the inverted, bass-range waveform **11** of FIG. **7** is obtained by minimal amplification; but — by electronically repositioning the zero dB base line — the inverted, negative-going, bass-range waveform may be considered to be "negatively" amplified, or attenuated. It will be noted that the roll-off portion **18** is still substantially anchored at the anchoring frequency.

The Treble Waveform, "Neutral"-Switch Setting

Referring again to the fixed, waveform generator **35** of FIG. **8**, it will be noted that the upper portion thereof also contains a similar switch **S2**, this portion of the fixed, waveform generator producing the treble-range waveform **13**. This portion of the circuitry functions as follows. With switch **S2** at its neutral setting, the incoming signal traverses an incoming path comprising **R13, R14, C7,** and **R16**; and the feedback signal traverses a feedback path comprising **C10, R17, R14, C7,,** and **R16**. Since corresponding circuit elements of the input path and the feedback paths are equal, the applied input signal is identical to the feedback signal at all frequencies. Thus, for a neutral-switch setting, the amplifier **A2** has a gain of zero decibels.

The Treble Circuit, "Boost"-Switch Setting

With switch **S2** at its leftmost or "boost setting," the circuit functions as follows. This switch setting shorts out **R13**, forming the input path **S2, R14, C7,** and **R16** — and permits a large input signal to be applied to amplifier **A2**. Thus, input-path elements **R14** and **C7** are placed in parallel with the bass-input paths **R7, R9, C5,** and R10. This parallel arrangement causes the feedback signal traversing R17 to be effectively shorted into the relatively low resistance of R6 of the voltage amplifier 32, rendering the effect of feedback through R17 negligible. Thus, negative feedback is applied through R12, R11, C6, and R10. Therefore, for treble signals, the input signal is larger than the feedback signal; and the gain of amplifier A2 increases with frequency from 400 to 1600 Hz, as shown at 13 of FIG. 2.

The action of feedback capacitor C7, as discussed above, now produces a roll-on characteristic 14 for waveform 13. Moreover, the waveform-shaping network 37 again permits unity gain at 400 Hz with the characteristic notch, thus steepening the roll-on portion 14 in the portion of the spectrum just above 400 Hz.

The Treble Circuit, "Cut"-Switch Setting

When switch S2 is placed in its rightmost or "cut setting", the reverse condition applies. With R17 shorted out by switch S2, R14 and C7 are placed in parallel with the feedback path R12, R11, C6, and R10. This causes the input signal traversing R13 to be effectively shorted into the low-output impedance of A2, rendering the effect of the input signal negligible. Thus, the input signal is applied through R7, R9, C5, R10, and R16. The relatively large feedback signal and the small input signal co-act to produce minimum amplification.

As discussed above, the action of feedback capacitor C7 produces a roll-on characteristic. Moreover, the waveform-shaping network 37 again permits unity gain at 400 Hz with the characteristic notch, thus steepening the roll-on portion 14 in the portion of the spectrum just above 400 Hz.

In the above-described manner, the fixed, waveform generator 5 is able to produce boosted and attenuated bass and treble waveforms — each of these being fixed in shape and amplitude, having a common anchoring frequency, and having substantially identical roll-off and roll-on characteristics whose slopes average plus or minus 12 dB per octave.

The Mid-Range, Waveform Generator

The discussion of FIG. 4 pointed out that a mid-range waveform 18 is desirable in order to achieve selective response curves; and such a mid-range waveform may be generated by a mid-range, waveform generator 39 of FIG. 8. As shown, the output from the fixed, waveform generator 35 is applied to the input of the mid-range, waveform generator 39, the operation being as follows.

In the mid-range generator 39, R22 is a radio-frequency suppressor; R23 is a return path to ground for the input electrode of amplifier A3; and C14 and C16 have negligible reactance over the audio-frequency range.

The input signal path comprises C11, R18 and C12, R20; whereas the feedback path comprises C16, C15 and R21, R20 — a potentiometer R19 being connected across C12 and C13. Corresponding elements of the input signal path and of the feedback signal path are equal; and, when the slider of potentiometer R19 is placed at its mid-point, the feedback signal is equal to — and cancels — the input signal. Thus, for a mid-point setting of potentiometer R19, there is a unity gain for each frequency.

The Mid-Range, Waveform Generator, "Boost" Setting

When the slider of potentiometer R19 is at its leftmost or "boost setting", the slider of the potentiometer picks up the full input signal, and applies it to amplifier A3 (which may be similar to those discussed above). Capacitor C11 and resistor R18 control the roll-on characteristic by allowing the input signal to increase with increasing frequency. The boost setting of potentiometer R19 permits the "full-bridged-tee" configuration — comprising R19, R20, C12 and C13 — to become part of the feedback path; so that maximum feedback signal is attenuated at the anchoring frequency, displaying the characteristic peak at 400 Hz of FIGS. 4 through 7.

The Mid-Range, Waveform Generator, "Cut" Setting

When the slider of the potentiometer R19 is at its rightmost or "cut setting", the slider of the potentiometer picks up the full feedback signal, and applies it to amplifier A3. C15 and R21 control the roll-off portion by allowing the feedback signal to increase with increasing frequency.

With the slider of potentiometer R19 at its "cut setting", the above-described, full-bridged tee (R19, R20, C12, and C13) becomes part of the input signal path; so that maximum input signal is attenuated at the anchoring frequency.

Thus, the mid-range waveform 18 of FIGS. 4 – 7 has a roll-on portion, a roll-off portion, and a peak (and notch) at the anchoring frequency.

The Mid-Range, Waveform Generator, Variable

The above explanation has indicated how the mid-range, waveform generator 39 is capable of producing a positive, amplified, mid-range waveform 18; and a negative, attenuated, mid-range waveform 18. Since these waveforms 18 are obtained by extreme settings of potentiometer R19, it will be readily apparent that intermediate potentiometer settings will generate a family of mid-range waveforms, indicated by the dotted lines of FIG. 10. Thus, the variable, mid-range, waveform generator is capable of selectively amplifying the mid-range waveform while substantially maintaining the positioning of the mid-range waveform, this amplification being idependent of the lower-range and upper-range waveforms.

Variable, Waveform Generator

As indicated in the introductory passages, it is often desirable for the musician to be able to change — not only the type of notes produced by the sound system — but to also be able to change the amplitude of these various notes, and the relative response of their harmonics.

FIG. 8 shows a variable, waveform generator 41 that is substantially the same as the fixed, waveform generator 35 previously discussed — the difference being that the variable, waveform generator 41 uses potentiometers R26 and R29 instead of the switches S1 and S2, respectively.

The operation of the variable, waveform generator 41 is substantially the same as that of the fixed, waveform generator 35; that is, when the potentiometers R26 and/or R29 are at their extreme leftmost or rightmost settings, the variable, waveform generator 41 produces substantially the same fixed waveforms **11** and **13** previously discussed. However, as the potentiometers R**26** and R**29** are placed at intermediate settings, the resultant waveforms have their amplitudes and shapes varied to produce a family of waveforms, indicated by the dotted lines of FIG. **11.** The solid-line representations **11** and **13** indicate the previously-discussed, fixed waveforms, these forming the "envelope" of the family of curves.

Thus, the variable, waveform generator **41** is able to produce any of the family of waveforms indicated — in this way, selectively amplifying the lower-range and/or the upper-range waveforms while substantially maintaining the anchoring frequency.

Combination of Waveforms

The disclosed circuitry is such that the various waveforms may be selectively combined; that is, certain waveforms may be amplified, other waveforms may be attenuated, still other waveforms may be left untouched — and all of these waveforms may be added together algebraically. That is, the attenuated portions may be substracted from the amplified portions — and vice versa — to provide a plurality of response curves of various shapes. In fact, when the maximal output of the fixed waveform generator is added to the maximal output of the variable, waveform generator, the overall response curve may have an amplitude that may be twice as large as either; and combinations and adjustments of these two waveforms with the mid-range waveform can produce response curves that may vary from a positive, double-amplitude to a negative, double-amplitude, composite, waveform.

The volume control **42** adjusts the ultimate amplitude of the composite, response curve.

Throughout this discussion, resistors R**8**, R**20**, and R**25** of the fixed, waveform generator **35**; the mid-range, waveform generator **39**; and the variable, waveform generator **41**; respectively, are shown to be of fixed value. However, these resistors may be replaced by variable resistances for external controls to give sharper or flatter roll-on and roll-off portions than displayed in FIGS. **2**-**7** and FIGS. **10** and **11.** This modification would be advantageous in that the musician would be allowed even greater control over the coloring of his sound.

Pre-Amplifier

The term "pre-amplifier" is frequently applied to a combination of electronic devices — such as the input network **30**; the fixed, waveform generator **35**; the mid-range, waveform generator **39**; and the variable, waveform generator **41.** In general, a pre-amplifier — despite its discussed amplification — handles only small-magnitude, electrical signals; and may, therefore, be made quite small. As a result, such a pre-amplifier may be made as a small, separate unit; and, when so desired, may be physically positioned at a location that is different from the rest of the apparatus. This will be discussed later.

The Power Amplifier

As discussed above, the pre-amplifier produces a relatively-low-amplitude, composite, electrical, output signal that corresponds to the desired response curve; but, in order to produce an appreciable volume that may be heard by a large audience, the output of the preamplifier must be further amplified — and such further amplification is generally achieved by means of a "power amplifier." Such a power amplifier, **44,** is shown in FIG. **8.** Here, the composite output from the pre-amplifier is applied to the input of power amplifier **44** — which may take any of a number of forms. In the illustration, the input stage of the power amplifier **44** comprises a differential amplifier made up of two transistors, Q**1** and Q**2,** the output of the differential amplifier being applied to a transistor Q3 that, in turn, drives two sets of cascaded transistors Q4, Q5, Q6 and Q7, Q8, Q9 — this arrangement being desirable to avoid overloading and distortion. Negative feedback is applied from the amplifier output to the base of Q2 (non-inverting input) via R**40.** The composite output of the two sets of transistors is applied to one or more output jacks J**3** and J**4,** which receive the plugs from suitable loudspeakers.

It has been found that transistorized circuits are unable to withstand short circuits or prolonged overloads, so a protective, current-limiting circuit is incorporated into the circuit of the power amplifier **44** to protect it against momentary overloads or short circuits.

It will be noted that transistor Q7 is driven by a current source formed by R**44**, R**45**, and C**28**; and that transistor Q4 is driven by a current source formed by R**46**, R**47**, and C**29.** For excessive, positive, current peaks, diodes D2 act to shunt the excessive current away from the base electrode of Q7; whereas, for excessive, negative, current peaks, diodes D3 and D4 act to shunt the excessive current away from the base electrode of Q**4.** In this way, symmetrical, positive and negative, current limiting is achieved for excessive currents ranging from overloads to short circuits.

The disclosed protection circuitry is important, for the safety of transistors Q4 - Q9, and also — since the power supply is all solid state — for avoiding unbalanced currents in transformer T**2.** Moreover, the disclosed current-limiting arrangement obviates the need for a power "shut-down" circuit — such a shut-down circuit being inadvisable, since its transient "spikes" produce unacceptable sound-quality deterioration. A fuse F1 protects the circuit against prolonged short circuits and overloads.

In this way, the output signal from the power amplifier corresponds to the desired response curve, as determined by the settings of the various controls of the pre-amplifier, and has the desired power to energize the loudspeakers.

The Power Source

It is well know that active electronic devices, such as transistors, require a so-called "DC" power source which is most conveniently obtained from a "converter" that converts the readily-available, 60-Hz power to the desired DC. Such a converter **46** is shown in FIG. **8.** As indicated, the converter receives AC power, a double-pole, reversing switch S3 being used to assure minimal hum. The AC power traverses a fuse F1; and a suitable pilot lamp L1 is used to indicate when the circuit is energized. The 60-Hz, AC power is then applied to a full-wave rectifier D**11** -D**14** that provides a DC voltage that energizes an oscillator comprised of transistors Q**10** and Q**11.** This oscillator produces a square-output waveform of a very high frequency — typically 30,000 Hz. This very-high-oscillation frequency has been selected in order to provide minimal audio interference, since its frequency is ultrasonic — i.e., well above the highest frequency heard by the human ear. Thus, these ultrasonic oscillations do not produce any sound that may disturb the listener or the musician, in live performance or in a recording studio.

In the present case, it is desirable that the oscillator begin operation immediately, and continue to oscillate; and this result is assured by the use of two trigger-pulse generators comprising, respectively, **R58, C33, D15** and **R59, C34, D16.** The operation of these trigger-pulse generators is such that each periodically produces an individual trigger pulse that is applied to respective bases of the transistor Q10 and Q11 of the oscillator. Thus, each trigger-pulse generator periodically triggers its associated transistor into operation; so that the oscillator immediately begins its operation, and continues its oscillation.

In order to further assure immediate and continuous operation of the oscillator, each of the trigger-pulse generators has a frequency that is slightly different from the other; and neither of these is a multiple of the frequency of the oscillator — i.e., all three are non-synchronous. Such a non-synchronous arrangement assures that the oscillator will not be locked out; it will always receive effective trigger pulses.

The output of the oscillator is, in turn, applied to a second, full-wave rectifier D7 –D10 that converts the ultrasonic, oscillator output to another DC voltage, transformers T1 and T2 improving the efficiency. Since the disclosed circuitry requires two different DC voltages, the DC output from the second, full-wave rectifier D7 – D10 is applied to a smoothing-and-filtering network that provides a first, ±38-volt, DC source; and a second, ± 15-volt, DC source — these different DC voltages B and V being applied to the power amplifier and to the pre-amplifier, respectively.

Packaging

FIG. 12 illustrates a typical packaging of the disclosed apparatus, the cabinet having been designed to act as a base for the various electronic components, and to act as a "heat sink" that dissipates the heat into the air. One early model was about eleven inches long, about three inches high, about seven inches deep, weighed about five pounds, and had a power rating of about one-hundred watts RMS, into four ohms.

The left side of the cabinet has a power cord for plugging into a wall receptacle; and has an on-off power switch S3, a pilot light L1, and a fuse F1. The left side of the cabinet also contains two output jacks, J3 and J4.

The front of the cabinet has the operating controls, namely: two input jacks J1 and J2; a distortion control R5; a first, three-position switch S1 for the bass-range, fixed, waveform generator; a second, three-position switch S2 for the treble-range, fixed, waveform generator; a first control R26 for the bass-range, variable, waveform generator; a second control R29 for the treble-range, variable, waveform generator; a control R19 for the mid-range, variable, waveform generator; and a volume control **42.**

In use, the apparatus of FIG. 12 is electrically connected between the musical instrument and the loudspeakers by means of the various jacks and plugs; and the unit is then placed conveniently for the musician — who may then adjust the various controls to his satisfaction relative to the instrument, the accoustics of the area, the type of musical number, the audience, etc.

As indicated above, the pre-amplifier of FIG. 8 may be made small enough to be placed in the body of the guitar; and some musicians prefer this location, as they may then make the various adjustments unobtrusively — even during the performance of a musical selection. In this case, the installation would appear as indicated in FIG. 1, this illustration showing a guitar with a pre-amplifier located within the guitar body.

Where desired, the entire apparatus may be incorporated into the speaker enclosure. Due to the tremendous reduction in size and weight over present-day systems, the entire package may be incorporated into an appropriately hollowed out solid-body or hollow-body guitar. Alternatively, it may be incorporated into an electric piano, an electric organ, etc. All or part of the disclosed system may also be applied to Hi Fi, tape recorders, cassettes, television, automobile entertainment systems, etc.

It will be realized that the disclosed system requires only one channel for any instrument; whereas, prior-art systems often required bass channels, treble channels, etc.

Moreover, the amount of amplification and/or attenuation is readily controlled by the musician, who may choose to strongly emphasize the bass tones, emphasize the treble tones, and/or mix in small amounts of intermediate tones. In this way, the musician has complete control over the tone produced by his instrument; and, since the disclosed amplifier is capable of producing over one-hundred watts, the musician does not need the prior-art, electronic, sound system with its built-in shortcomings.

Distortion Control

In the past, if a guitarist desired to practice a musical selection that required the distortion discussed above, this meant that he had to turn the volume control up to its maximal setting; and this tended to disturb everyone in the neighborhood. The disclosed invention permits this type of distortion practice without the prior-art disturbance, by using the following technique.

The volume control **42** is first turned down to provide a minimal volume of sound; and the distortion control R5 is then turned up until the desired distortion is obtained. At this time, the volume control is readjusted. The distortion control and the volume control are thus substantially independent of each other.

In this way, the desired amount of distortion is obtained; but the overall volume of sound is low enough not to cause any disturbance.

SUMMARY

The disclosed invention has many advantages over prior-art arrangements. First of all, the disclosed apparatus provides new, live sound that thrills musicians. The new, live sound is achieved by selectable use of controllable, bass-range waveforms, treble-range waveforms, and mid-range waveforms. The ultimate sound is totally under the control of the musician. A separate distortion control is provided. A separate volume control is provided. Distortion effects may be practiced without undue disturbances. The apparatus is designed to withstand momentary short circuits. Thus, it provides a versatile, solid-state, musical apparatus having superior sound, combined with small size and light weight.

I claim:

1. Apparatus for performing a filtering and selective amplifying function on an applied waveform or signal having a particular frequency range to produce a response curve having a given frequency spectrum, comprising:

means for generating a lower-range waveform having a roll-off portion that is anchored at a given anchoring frequency, and for independently and selectively amplifying said lower-range waveform while substantially maintaining said anchoring frequency;

said roll-off portion having a relatively-steep configuration;

means for generating an upper-range waveform having a roll-on portion that is anchored at substantially said anchoring frequency, and for indenpendently and selectively amplifying said upper-range waveform while substantially maintaining said anchoring frequency;

said roll-on portion having a relatively-steep configuration;

means for combining said lower-range waveform and said upper-range waveform to produce said desired response curve;

said response curve having a peak-shaped notch that is substantially centered at said anchoring frequency.

2. The invention of claim 1, wherein said anchoring frequency is substantially 400 Hz.

3. The invention of claim 1, wherein said selective amplification includes positive and negative amplification.

4. The invention of claim 1, including means for independently distorting said response curve.

5. The invention of claim 1, including means for distorting said response curve, and means for controlling the ultimate amplitude of said response curve.

6. The invention of claim 1, wherein said means for generating said lower-range waveform comprises a fixed waveform generator.

7. The invention of claim 1, wherein said means for generating said lower-range waveform comprises a variable waveform generator.

8. The invention of claim 1, wherein said means for generating said lower-range waveform comprises a fixed waveform generator and a variable waveform generator;

means for combining the outputs of said fixed and variable waveform generators for producing said response curve.

9. The invention of claim 1, wherein said means for generating said upper-range waveform comprises a fixed waveform generator.

10. The invention of claim 1, wherein said means for generating said upper-range waveform comprises a variable waveform generator.

11. The invention of claim 1, wherein said means for generating said upper-range waveform comprises a fixed waveform generator and a variable waveform generator;

means for combining the outputs of said fixed waveform generator and said variable waveform generator to produce said response curve.

12. The invention of claim 1, wherein:

said means for generating said lower-range waveform comprises a fixed waveform generator and a variable waveform generator;

said means for generating said upper-range waveform comprises a fixed waveform generator and a variable waveform generator;

means for combining the outputs from said fixed and said variable waveform generators.

13. The invention of claim 1, wherein said roll-off portion of said lower-range waveform has an original slope of about twelve decibels per octave.

14. The invention of claim 1, wherein said roll-on portion of said upper-range waveform has an original slope of about twelve decibels per octave.

15. The invention of claim 1, wherein said roll-off portion of said lower-range waveform is substantially similar to said roll-on portion of said upper-range waveform.

16. The invention of claim 1, including means for generating a peak-shaped, mid-range waveform having its peak positioned at substantially said anchoring frequency;

means for independently and selectively amplifying said mid-range waveform while substantially maintaining said positioning of said mid-range waveform.

17. The invention of claim 16, wherein said peak-shaped, mid-range waveform is shaped substantially similarly to said notch of said response curve.

18. The invention of claim 17, including means for combining said mid-range waveform with said lower-range waveform and said upper-range waveform.

19. The invention of claim 18, wherein said waveform-generating means comprises electronic circuits.

20. The invention of claim 19, including a power amplifier having a dual-clipping, safety action;

said dual-clipping, safety action comprising means for clipping both the positive-going and the negative-going waveforms of said power amplifier.

21. Apparatus for performing a filtering and selective amplifying function on an applied waveform or signal having a particular frequency range to produce a musical-instrument response curve having a given frequency spectrum, comprising:

means, comprising a fixed waveform generator and a variable waveform generator, for generating a lower-range waveform having a roll-off portion that is anchored at a given anchoring frequency, and for independently and selectively amplifying said lower-range waveform while substantially maintaining said anchoring frequency;

said roll-off portion having a relatively-steep configuration;

means, comprising a fixed waveform generator and a variable waveform generator, for generating an upper-range waveform having a roll-on portion that is anchored at substantially said anchoring frequency, and for idependently and selectively amplifying said upper-range waveform while substantially maintaining said anchoring frequency;

said roll-on portion having a relatively-steep configuration;

said response curve having a peak-shaped notch that is substantially centered at said anchoring frequency;

means for generating a peak-shaped, mid-range waveform having its peak positioned at substantially said anchoring frequency, and for independently and selectively amplifying said mid-range waveform while substantially maintaining said positioning of said mid-range waveform;

said peak-shaped, mid-range waveform being shaped substantially similarly to said notch of said response curve; and

means for combining the outputs from said waveform generators.

22. The invention of claim **21**, wherein said roll-off portion of said lower-range waveform is substantially similar to said roll-on portion of said upper-range waveform.

23. The invention of claim **21**, including means for independently distorting said response curve, and means for independently controlling the ultimate amplitude of said response curve.

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