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[45] **May 16, 1972**

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[22] Filed: **Oct. 1, 1970**

[21] Appl. No.: 77,280

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 864,024, Oct. 6, 1969.

[52] U.S. Cl.....84/1.01, 84/1.16, 84/1.17 P

[51] Int. Cl. G01h 1/00

[58] **Field of Search**84/1.01, 1.14, 1.16, 1.17 P,
84/1.24

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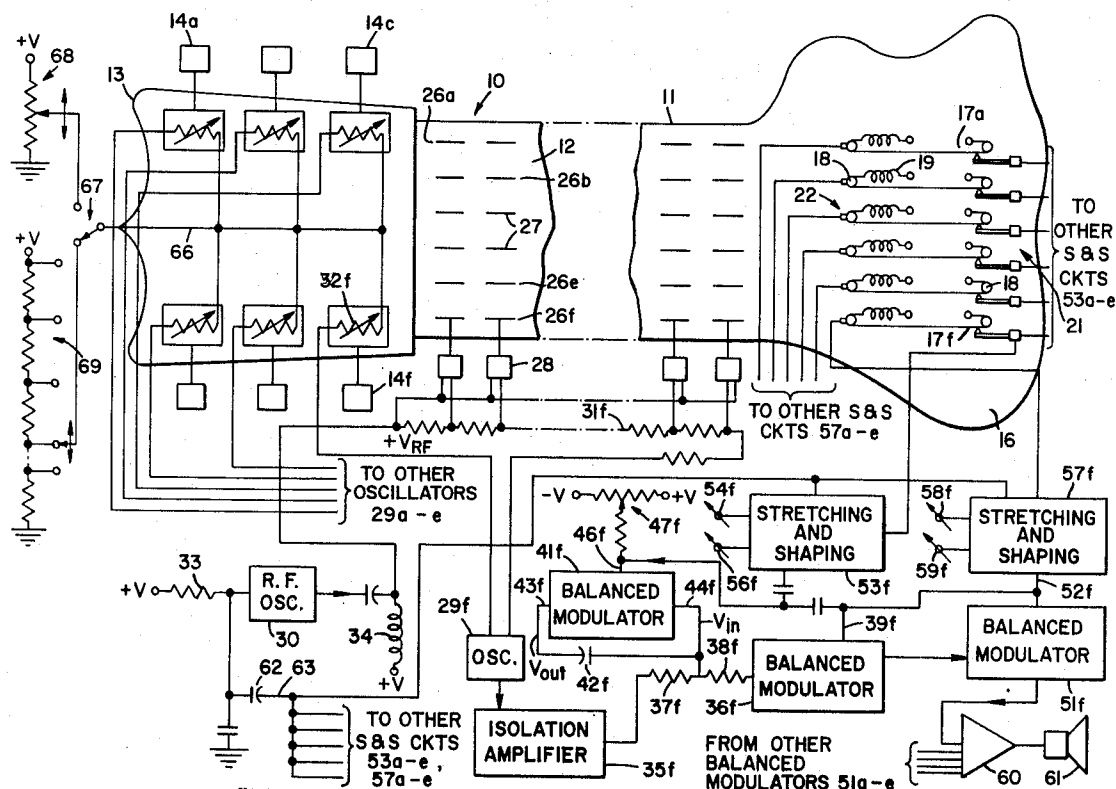
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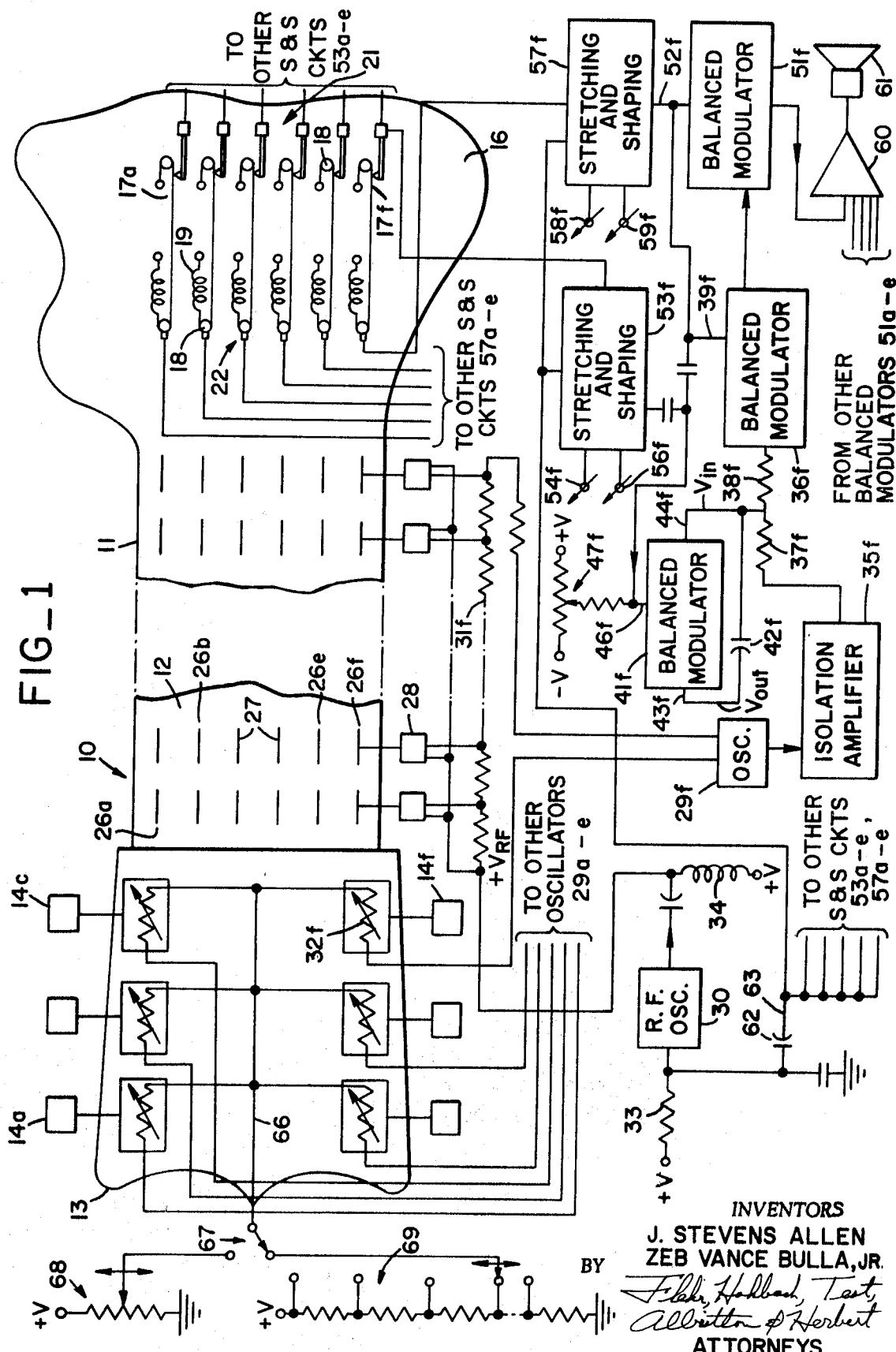
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[57] **ABSTRACT**

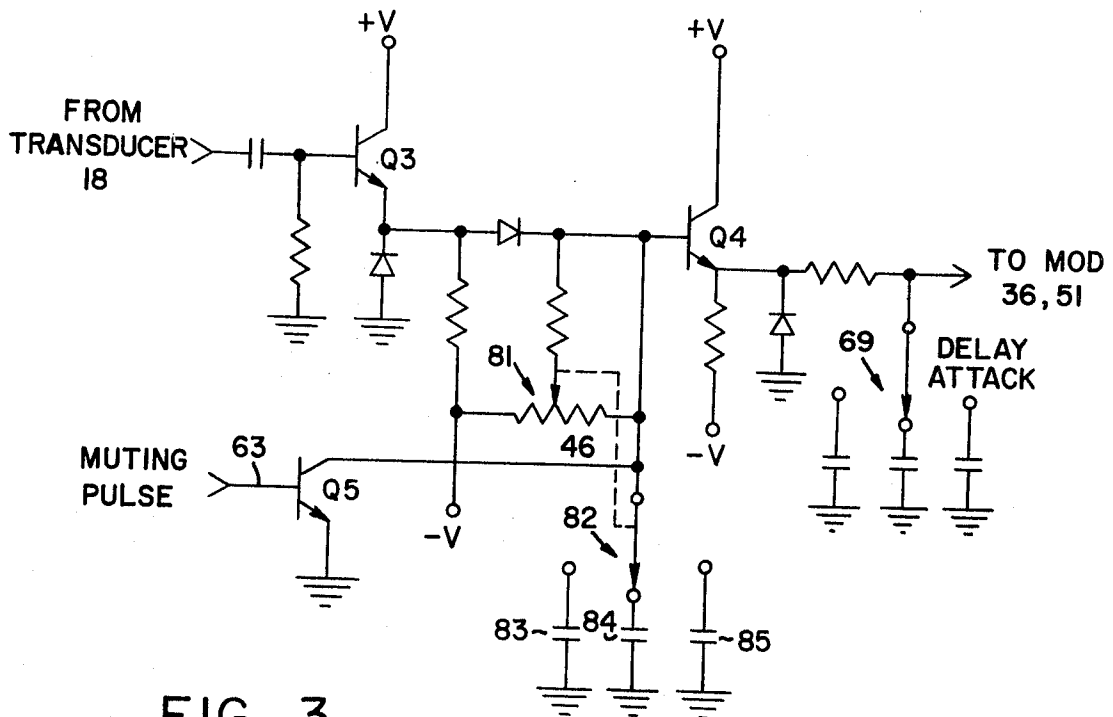
An electronic musical instrument in which the fingerboard of a guitar is replaced by capacitive touch contact switches simulating all of the fret positions of a string. The touch plates are coupled to various oscillators and the output frequency is amplitude modulated by a transducer produced output signal from a set of strings which are plucked. This output signal is stretched and shaped as desired to modulate the audio frequency signal and produce the final musical output.

32 Claims, 8 Drawing Figures

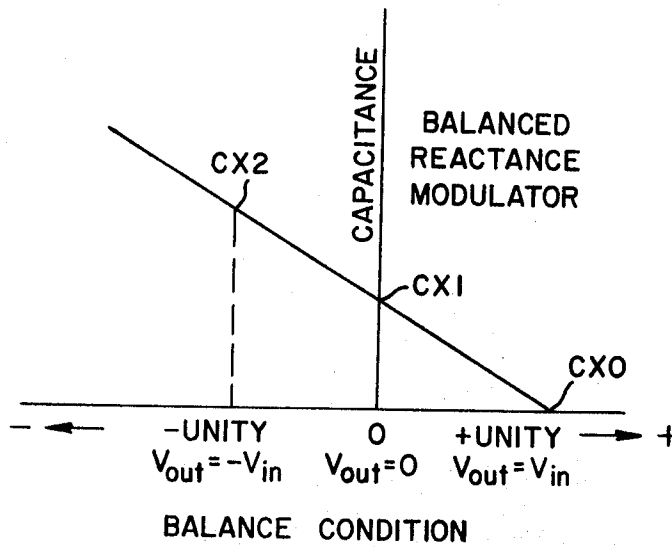




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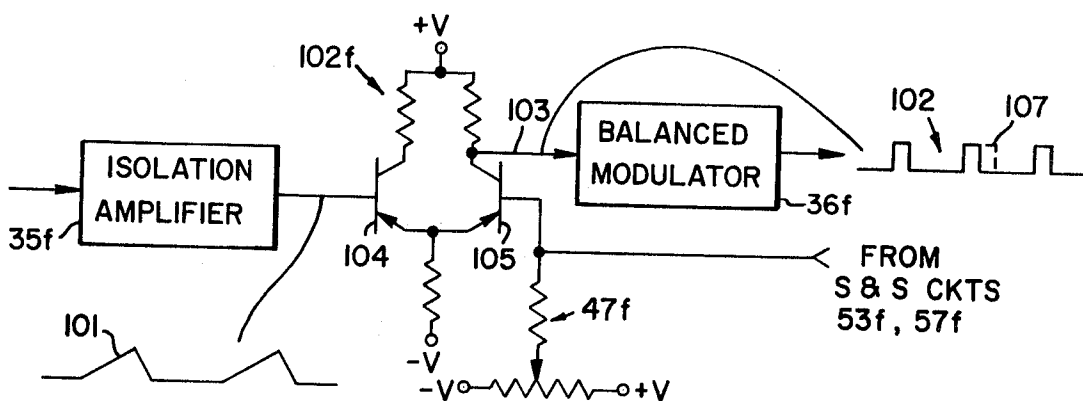


FIG_3

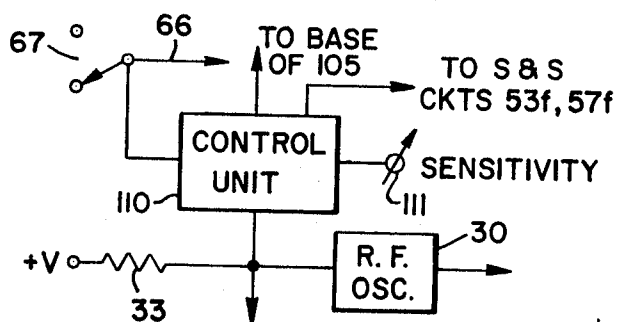


FIG_4

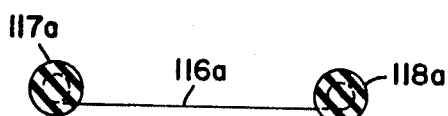
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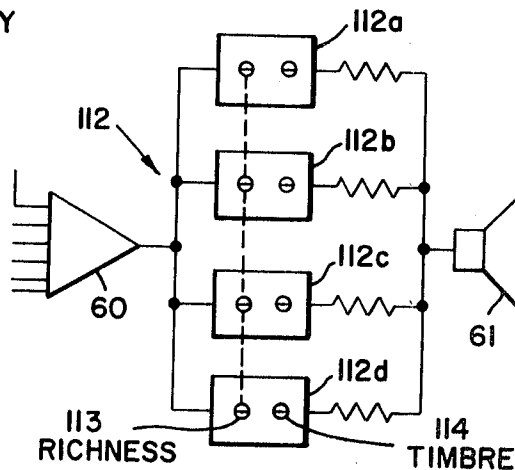
FIG_5



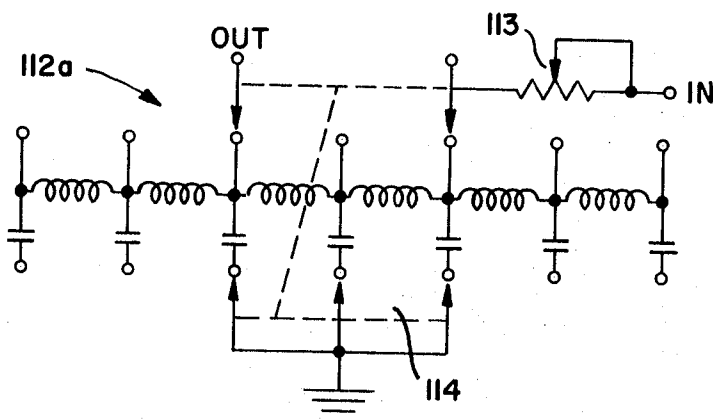
FIG_6



FIG_8



FIG_7



FIG_7A

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ELECTRONIC MUSICAL APPARATUS

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of copending application, Ser. No. 864,024, filed Oct. 6, 1969, in the names of J. Stevens Allen and Zeb Vance Bulla.

BACKGROUND OF THE INVENTION

The present invention is directed in general to an electronic musical apparatus and more particularly to musical apparatus of the stringed type.

With the advent of solid state electronics the use of electronic amplification for stringed instruments has been widespread. This amplification has also included echo or reverberation effects accomplished by introducing a time delay in one channel of amplification.

The present invention is directed in general to an electronic musical apparatus and more particularly to musical apparatus of the stringed type.

With the advent of solid state electronics the use of electronic amplification for stringed instruments has been widespread. This amplification has also included echo or reverberation effects accomplished by introducing a time delay in one channel of amplification.

However, except for the elimination of an acoustic sounding box, stringed instruments such as the guitar have been essentially unchanged in their basic construction. In other words, present amplified instruments have not provided a design in the music producing and amplification portions which have been truly integrated.

It is, therefore, a general object of the invention to provide an improved electronic musical apparatus in which the electronic portion is integrated with the music producing portion of the apparatus.

It is another object of the invention to provide apparatus as above which produces novel musical sounds and effects and greatly increases the versatility of standard stringed instruments when modified in accordance with the invention.

In accordance with the above objects there is provided electrical musical apparatus comprising transducer means adapted for actuation by a human hand. A plurality of touch actuated switch means are provided each corresponding to a predetermined audio frequency signal. Oscillator means are coupled to the switch means and are responsive to the selective actuation of any one of the switch means for generating an audio frequency signal corresponding to the switch means which has been actuated. Modulating means are coupled to the oscillator means and transducer means are responsive to the actuation of the transducer means concurrently with the actuation of one switch means for modulating the audio frequency signal.

FIG. 1 is a schematic representation of a musical instrument embodying the present invention along with a schematic block diagram illustrating the associated electronic portion of the invention;

FIG. 2 is a detailed circuit schematic of a portion of FIG. 1;

FIG. 3 is a detailed circuit schematic of another portion of FIG. 1;

FIG. 4 is a circuit characteristic useful in understanding the present invention;

FIG. 5 is a block diagram showing a modification of the circuit of FIG. 1;

FIG. 6 is a block diagram showing another modification of the circuit of FIG. 1;

FIG. 7 is a block diagram illustrating a modification of the output circuit of FIG. 1;

FIG. 7A is a detailed schematic of a block of FIG. 7; and

FIG. 8 is a cross-sectional view of a modification of the stringing arrangement of FIG. 1.

Referring first to FIG. 1, the present invention is shown in its preferred embodiment as a guitar 10 which, as will be explained in detail below, has been modified in accordance with the principles of the present invention. However, it should be

understood that the present invention is applicable to any stringed instrument. Guitar 10 includes typical portions such as a neck 11 with a fingerboard 12, a head 13 having tuning machines 14a-f and a table portion 16 having stretch strings 17a-f mounted around rubber studs 18 by springs 19. The strings are arranged so they may be plucked by fingers or a plectrum. Strings 17a-f do not extend over the fingerboard to the tuning machines 14a-f. Instead they are short and lie only on the table 16.

The displacement of the strings is picked up by two sets of piezoelectric transducers 21 and 22. The individual transducers are constructed similarly to photograph pickups. Transducer set 21 physically contacts strings 17 slightly in front of studs 18 to cause them to be primarily responsive to transverse mode vibrations of the strings. Transducer set 22 contacts portions of strings 17 which are wrapped around studs 18 and are thus primarily responsive to longitudinal mode vibrations.

As will be clearly apparent, the frequency of the musical signal is not dependent upon the strings; rather only the amplitude and partially the rise and fall duration of the musical sound is determined by the strings 17a-f. Moreover, by controlling the location at which the strings are plucked, the longitudinal or transverse modes can be emphasized to achieve special sound effects. For example, plucking near the transverse mode transducer 21 will produce a twanging effect.

Fingerboard 12 instead of having strings and being fretted to produce a variation in musical pitch consists of columns of touch plates 26a-f in the form of wire segments which correspond to or simulate the strings which would otherwise be in those column locations. In addition, each of the simulated string columns 26a-f correspond to the tuning machines 14a-f and may in fact be tuned in the same manner as a typical stringed guitar. More specifically, each touch wire column 26a-f is arranged in a straight line and each touch wire designated 27 simulates a specific fingering position of a string in the same physical location. Thus, the spacing and configuration of the touch wire 27 would be varied depending upon the type of stringed instrument being simulated. For example, with a classical guitar the touch wires 27 would be spaced farther apart because of the wider neck of that guitar as opposed to a "folk" type guitar with a narrower neck.

Each touch wire 27 is coupled to an individual switch 28 which is activated when a finger of the player is placed on the wire. This action places a virtual capacitor in the associated circuitry in a well-known manner. FIG. 1 shows switches 28 coupled to only touch wire column 26f. However, all touch wires would be connected to their own touch sensitive switches.

Each column 26a-f of touch wires 27 and their associated touch-actuated switches 28 are associated with an oscillator 29. As shown in FIG. 1 the subscript of the oscillator 29f corresponds to the simulated string; namely 26f. Touch actuated switches 28 are coupled to oscillator 29f through a series of resistors 31f which includes a V_{RF} voltage supply on one end. V_{RF} is provided by a radio frequency oscillator 30 having an input power source +V coupled through a resistor 33. The output R.F. signal modulates a +V voltage supply which is a.c. isolated by a choke coil 34.

Oscillator 29f is also coupled to a corresponding tuning machine 14f which includes a variable resistor 32f which, as will be explained in detail below, controls the basic frequency of oscillation of oscillator 29f. The remaining tuning machines 14a-f would be coupled to their respective oscillators 29a-e (not shown). All of the oscillators 29a-f are respectively coupled to an isolation amplifier 35a-f which prevents the loading of the associated oscillators 29a-f by the subsequent circuits. Amplifier 35f is coupled into a balanced modulator 36f through series resistors 37f and 38f. The balanced modulator is of a type commercially available as a unit and produces no output in the absence of a modulating input on line 39f.

Harmonic control means are coupled between resistors 37f and 38f and include a balanced reactance modulator 41f having a capacitor 42f across its signal input, V_m , and output ter-

minals, V_{out} , 43f and 44f and a third modulation input terminal 46f coupled to a potentiometer 47f. Output terminal 44f is coupled between resistors 37f and 38f.

Potentiometer 47f provides either a null or zero input or is variable between +V and -V voltage as indicated. Such inputs when applied to modulating input control terminal 46f varies the gain of the modulator 41f and in turn the value of capacitor 42f is illustrated in FIG. 4. At 0 voltage gain ($-\infty$ dB) where $V_{out}=0$ the true value of the capacitor ($C \times 1$) is in the circuit; at unity gain inverted where $V_{out} = -V_{in}$ the effective value is doubled ($C \times 2$); and at unity gain not inverted where $V_{out} = V_{in}$ the value is zero ($C \times 0$).

Harmonic control is effected by variation in the effective value of capacitor 42f which smooths or integrates the triangular waveform output of oscillator 29 by attenuating its higher harmonics.

The audio signal from oscillator 29f and modulator 36f is coupled through and modulated by a series connected balanced modulator 51f having a modulation input 52f. The series cascading of the modulators forms a combined modulation characteristic which is logarithmic. Since the response of the human ear to sound is non-linear a logarithmic characteristic partially compensates for this nonlinearity. The above combination also produces a better null than a signal modulator.

Both modulators 36a-f and 51a-f are respectively responsive to the bowing or plucking of string means 17a-f to modulate the audio frequency signals from the oscillators 29a-f in accordance with the displacement of the strings 17a-f. Specifically, modulator 36f is responsive to signals from transducer set 21 which are coupled to its modulation input 39f through a stretching and shaping unit 53f. This unit modifies the output of transducer set 21 by stretching the output waveform, the amount of stretching being varied by a control 54f, and delaying the production of the signal by means of a delay attack control 56f.

Similarly, input 52f of modulator 51f is coupled to transducer set 22 through a stretching and shaping unit 57f having stretch and delay control 58f and 59f.

The final modulated outputs of all balanced modulators 51a-f are coupled to an amplifier 60 and speaker 61.

Means for muting the audio output of the apparatus is provided by the associated circuitry of R.F. oscillator 30. A capacitor 62 coupled to the +V power input of the oscillator is responsive to the change in power requirements when the touch activated switches are deactivated. The resultant change in stored charge is coupled through a conductor 63 to stretching and shaping circuits 53a-f, 57a-f causing these circuits in turn to disable the modulators 36a-f, 51a-f; in other words, zero modulation is produced on inputs 39a-f and 52a-f. Details of the muting circuit are shown in FIG. 3.

Several alternative schemes are also available for muting. For example, a threshold circuit may be placed in line 63 so that muting will occur only if a predetermined number of switches 28 are deactivated. For a more complete control arrangement each simulated string column 26a-f may have a separate R.F. oscillator 30 with individual muting controls.

Simultaneous tuning of all simulated strings (or a simulated "capo") is achieved in the present invention by connecting variable resistors 32a-f to a common junction 66 and varying the voltage level of the junction. This simultaneously shifts the frequencies of oscillators 29a-f by a common amount. An option switch 67 coupled to junction 66 to either a foot pedal operated continuous potentiometer 68 or a detented potentiometer 69. Foot pedal 68 may, of course, be detented if desired.

Special effects can be achieved by feeding an a.c. signal to the junction 68 in effect modulate the tuning voltage. Also either or both tuning potentiometers may be ganged with other electronic musical apparatus embodying the present invention to in effect allow an entire band to easily tune to various musical keys.

In operation, the electronic musical apparatus of the present invention is initially tuned by varying the knobs on tuning machines 14a-f. Oscillators 29a-f, in effect, produce the fundamental mode frequencies which would be produced by unfretted strings. Movement of the finger up the fingerboard 12 along a given column of touch segments 27 gradually cuts out resistors of resistor string 31 to increase the frequency of oscillation of oscillator 29 in the same manner and proportion as an actual string which is fretted. More specifically, for example, the oscillator 29 vibrates at the fundamental frequency of the string which it represents and then as the touch segments 27 are activated it will increase in frequency in accordance with the touch segment corresponding to that fret position.

The use of simulated tuning machines 14a-f and touch wire columns 26a-f, in the same location as they would be for an actual stringed guitar, makes adaptation to the electronic musical apparatus of the present invention extremely easy for the experienced player of an actual stringed instrument.

The specific audio frequency signal or combination of frequency signals which are applied to the modulators 39 and 51 by oscillators 29a-f are modulated by the displacement of the strings 17a-f. This displacement is represented as an electrical waveform which can be stretched in time by means of stretching adjustments 54, 58 or the delay attack controls 56, 59 to achieve special effects. The outputs of stretching and shaping circuits 53f and 57f are also coupled to the input terminal 46 of balanced reactance modulator 41 to cause the harmonic content of the audio output to vary in accordance with the modulation signal.

FIG. 2 shows greater details of a touch-sensitive switch 28 along with oscillator 29f. The capacitance produced when the finger touches the touch plate 27 is shown by a virtual capacitor 70. This capacitor is coupled into the switch 28 between diodes 71 and 72 through a d.c. blocking capacitor 73 which guards against shocks to the player of the apparatus and also protects the diodes and transistors against accidental grounding. Diode 72 is coupled to the base of a transistor Q1 and diode 71 to the emitter of Q1. The emitter of Q1 is also coupled through a d.c. blocking capacitor 74 to the radio frequency oscillator 30. This may be of a frequency of from 1 to 75 megahertz and provides for operation of the touch-sensitive switch in a manner well-known in the art. The collector of Q1 is coupled to a resistor string 31f coupled in turn to oscillator 29f; more specifically to the emitter of a unijunction transistor Q2.

A capacitor 76 is also coupled to the emitter of Q2 and provides the basic free-running frequency of the oscillator. One of the input terminals of Q2 is grounded and the other connected between series connected resistors 77 and 78. These resistors are also coupled to the respective tuning machine resistors 32a-f (in this case 32f) to vary the biasing of Q2 to determine the oscillation frequency of oscillator 29f in combination with capacitor 76. More specifically, the discharge point of capacitor 76 is determined by Q2 and its charging rate is determined by the number of resistors in resistor string 31f. The fewer in number of resistors the faster the charging rate; therefore, the higher the frequency the higher the pitch. Oscillator 29 because of the above construction produces a sawtooth type output. In addition, the use of a unijunction type transistor allows the frequency of oscillation to be linearly varied with the above change in resistance.

The output of oscillator 29f is coupled to an isolation amplifier in the form of a field effect transistor whose purpose is to prevent the loading of the oscillator by the subsequent balanced modulators.

A typical stretching and shaping circuit is shown in greater detail in FIG. 3. The output from transducers 21 or 22 is coupled into a transistor Q3 which is coupled to waveshaping circuits which include a potentiometer 81 and a switch 82 which may be switched between three capacitors 83, 84 and 85. The potentiometer and switch may be joined together as shown by the dashed line 46 which will in effect be the stretch switches

54, 58 of FIG. 1. The output of waveshaping circuit 81, 82 is coupled into the base input of a transistor Q4. The emitter output of Q4 is coupled to a switch 86 which also includes three capacitors to provide for delay of the signal which is then coupled to balanced modulators 36, 51.

The shaping circuit of FIG. 3 may be elaborated on and modified extensively. For example, resonant circuits and feedback circuits may be used when desired.

In order to achieve a greater degree of harmonic control of the output of oscillator 29, a variable symmetry chopper circuit may be used in place of balanced modulator 41f and capacitor 42f. Such a modification of the circuit of FIG. 1 is illustrated in FIG. 5 where the output of an isolation amplifier 35f, which is in the form of a triangular waveshape 101, is coupled to a variable symmetry chopper 102f. This chopper is driven by the oscillator 29f and produces a pulse type output 102 on an output line 103 which is coupled to balanced modulator 36f.

Chopper 102f is actually in the form of a saturated differential amplifier and includes transistors 104 and 105 having their emitters coupled together and to a negative voltage source and their collectors coupled through resistors to a common positive voltage source. A Schmitt trigger circuit may alternatively be used. However, the base input of transistor 105 is coupled to potentiometer 47f along with the outputs of stretching and shaping circuit 52f and 53f to vary the point on the waveshape 101 at which the chopper clips. This causes a variation in the symmetry of the pulse train 102 as illustrated by the dashed outline 107. In other words, the actual pulse width of pulse train 102 is varied in accordance with the control input voltage on the base of transistor 105 to provide pulses of variable width.

In accordance with well known Fourier analysis a change in width will change the harmonic content of the pulse train 102 with a greater width producing lower harmonics and the narrower width producing a higher ratio of upper harmonics. Thus, by variation of the pulse width the harmonic content of various stringed instruments can be approximated. Moreover, since the control input to the base of transistor 105 is also coupled to the output of the stretching and shaping circuits 52f and 53f a variable harmonic content can be produced during the plucking of a single string. This can produce, for example, a familiar twanging sound.

Another variation in circuitry which allows the user of the musical apparatus to supply a tremolo or vibrato is illustrated in FIG. 6. Here the RF oscillator 30 is shown with its input current being supplied from a positive voltage source through resistor 33. Variation of the skin pressure produced by the finger on one of the touch plates 27 shown in FIG. 1 causes a change in the input current of the RF oscillator and the voltage on resistor 33. Further in accordance with the invention a control unit 110 along with a sensitivity control 111 is coupled to resistor 33 and to the line 66 which controls the tuning of the musical apparatus of the present invention. As discussed previously, the tuning controls modify the frequency of oscillation of the oscillators 29a-f. Since control unit 110 feeds back a portion of the voltage across resistor 33, variation of this voltage will also cause a concomitant change in the tuning voltage to thus produce the desired vibrato effect in response to a variation of the skin pressure on the touch plates. The amount of tremolo or vibrato is controlled by sensitivity control 111.

Similarly, control unit 110 may be coupled to choppers 102a-f and to stretching and shaping circuits 53a-f, 57a-f to provide for special effects modulation.

Further control of the audio output of the musical apparatus of the present invention is provided by the use of a filtering circuit at the output of amplifier 60 and the input of loudspeaker 61. Filtering means 112, as illustrated in FIG. 7, includes four filter components designated 112a through 112d each having a richness control 113 and timbre control 114. The richness controls in the preferred embodiment are ganged together. FIG. 7A shows a typical filter 112a which includes a

plurality of π sections each having an inductor and two capacitors. The timbre control 114 ties to ground the capacitors of two π sections and bridges across the inductors of these π sections to provide input and output terminals which are respectively coupled to the amplifier 60 and loudspeaker 61. However, the input terminal has series connected to it a potentiometer 113 which is actually the richness control. In practice, potentiometer 113 has a maximum impedance substantially equal to the characteristic impedance of the filter 112a. Since the output terminal of the filter is not terminated there will be a mismatch at the output and a variation of richness control 113 from its characteristic impedance value causes a mismatch in the input to provide reflections. This provides additional richness in the output signal of loudspeaker 61. Additional variation in timbre is achieved by moving the ganged switch 114.

Although four filters 112a-d are shown in FIG. 7, additional filters may be used and ganged as desired to produce different sound effects.

Furthermore in addition to the use of filters between amplifier 60 and loudspeaker 61 the same type of filters may be used at the several inputs to amplifier 60 to individually change the characteristic of the audio frequency signal output from the balanced modulators 51a-f.

FIG. 8 shows a modification of the stringing arrangement of FIG. 1. Here the string 116 is coupled directly to two rubber grommets 117a and 118a. Tension may be provided by a cylindrical wedge (not shown) in either of the grommets. This construction may be desirable for some applications over the spring type construction shown in FIG. 1 where a spring 19 is used.

It is apparent from the foregoing description that many different types of sound effects which may be produced by the present invention involve the manipulation of several control knobs. Thus, the present invention contemplates the use of matrix cards or similar type devices for presetting the controls.

Thus, the present invention provides an improved electronic musical apparatus where the fingerboard of the stringed instrument is actually simulated by capacitive-type touch switches allowing greater ease of playing. This also provides more accurate frequency output of the instrument and allows for greater versatility and production of different types of sound effects from the instrument so modified. In addition, the use of strings merely for modifying the amplitude and rise and fall time etc. of the output frequencies again allows a greater versatility in the sound quality of the instrument.

What we claim is:

1. Electronic musical apparatus comprising, string means adapted for bowing or plucking, a plurality of discrete touch actuated switch means for simulating the fingerboard of a stringed musical instrument each of said switch means corresponding to a predetermined audio frequency signal, oscillator means coupled to said switch means and responsive to the selective actuation of any one of said switch means for generating said predetermined audio frequency signal corresponding to the switch means which has been actuated, transducer means in proximity to said string means responsive to the physical displacement of said string means; and modulating means coupled to said oscillator means and transducer means and responsive to the actuation of said string means into vibration concurrently with the actuation of said one switch means for modulating said audio frequency signal.

2. Electronic musical apparatus as in claim 1 where said switch means include fixed wire segments for forming virtual capacitors when a human finger is placed in proximity with a segment.

3. Electronic musical apparatus as in claim 1 where said switch means include touch actuating means arranged in a straight line corresponding to the various fingering positions of a string in the same physical location.

4. Electronic musical apparatus as in claim 1 where said modulating means includes waveshape modifying means for modifying the output of said transducer means.

5. Electronic musical apparatus as in claim 1 including tuning means for said oscillating means located in a position corresponding to the tuning machine of the simulated finger-board.

6. Electronic musical apparatus as in claim 1 where said plurality of switch means include a common radio frequency oscillator for generating an alternating signal which charges virtual capacitors formed by touching a predetermined portion of said switch means.

7. Electronic musical apparatus as in claim 1 where said switch means includes means coupled to said modulating means and responsive to the deactivation of said switch means to disable said modulating means.

8. Electronic musical apparatus as in claim 1 where said modulating means includes first and second series coupled balanced modulators said modulators providing a logarithmic modulation characteristic.

9. Electronic musical apparatus as in claim 1 where said transducer means includes first transducer means primarily responsive to longitudinal mode vibrations of said string means and includes second transducer means primarily responsive to transverse mode vibrations of said string means.

10. Electronic musical apparatus as in claim 1 where said transducer means includes piezoelectric elements mechanically coupled to said string means.

11. Electronic musical apparatus as in claim 1 including harmonic control means coupled to said oscillator means for modifying the harmonic content of the audio frequency signal output of said oscillator means said harmonic control means including variable integration means.

12. Electronic musical apparatus as in claim 11 where said variable integration means comprise a capacitor coupled across a balanced modulator said modulator including variable gain control means to vary the effective capacitance value of said capacitor.

13. Electronic musical apparatus as in claim 11 where said harmonic modulator is coupled and responsive to said transducer means.

14. Electronic musical apparatus as in claim 11 where said oscillator means produce sawtooth type signals and said variable integration means attenuate high harmonics of said sawtooth signals.

15. Electronic musical apparatus as in claim 1 including tuning means for said oscillator means said tuning means being coupled to a common junction and together with means for varying the voltage level of said junction to simultaneously vary the frequencies of the audio frequency signals generated by said oscillator means.

16. Electronic musical apparatus as in claim 15 where said means for varying said voltage level includes a potentiometer.

17. Electronic musical apparatus as in claim 15 together with foot pedal means for controlling said potentiometer.

18. Electronic musical apparatus as in claim 15 where said means for varying said voltage level includes continuous potentiometer means and detented potentiometer means and option switch means for selecting one of said potentiometer means.

19. Electronic musical apparatus as in claim 1 where said oscillator means includes at least one unijunction transistor.

20. Electronic musical apparatus comprising, transducer means adapted for actuation by a human hand, a plurality of touch actuated switch means each including a fixed wire segment for forming a virtual capacitor with a human finger, each

of said switch means corresponding to a predetermined audio frequency signal, oscillator means coupled to said switch means and responsive to the selective actuation of any one of said switch means for generating an audio frequency signal corresponding to the switch means which has been actuated; and modulating means coupled to said oscillator means and transducer means and responsive to the actuation of said transducer means concurrently with the actuation of said one switch means for modulating said audio frequency signal.

21. Electronic musical apparatus as in claim 20 where said modulating means includes harmonic control means coupled to said oscillator means for modifying the harmonic content of the audio frequency signal output of said oscillator means said harmonic control means including a variable symmetry chopper driven by said oscillator means for producing a pulse type output signal having a variable pulse width.

22. Electronic musical apparatus as in claim 21 together with control means coupled to said chopper for varying said pulse width.

23. Electronic musical apparatus as in claim 21 where said chopper includes a saturated differential amplifier.

24. Electronic musical apparatus as in claim 21 where said oscillator means produces sawtooth type signals and said chopper clips said sawtooth signals to produce said pulse type output signal.

25. Electronic musical apparatus as in claim 21 where said chopper is coupled and responsive to said transducer means for varying the pulse width of said output signal.

26. Electronic musical apparatus as in claim 20 where said touch actuated switch means includes means responsive to the skin pressure of a finger on a wire segment of said switch means for modifying the frequency of said audio frequency signal of said oscillator means.

27. Electronic musical apparatus as in claim 26 where said touch actuated switch means includes a radio frequency oscillator for generating an alternating signal which charges virtual capacitors formed by said finger touching said wire segment said radio frequency oscillator having an input current proportional to said skin pressure said switch means also including control means responsive to said input current for proportionately modulating said frequency of said audio frequency signal.

28. Electronic musical apparatus as in claim 20 together with filtering means having an input coupled to the modulated output of said modulating means and an output to audio transducer means.

29. Electronic musical apparatus as in claim 28 where said filtering means has a frequency filtering characteristic which is variable to provide control of the timbre of said audio frequency.

30. Electronic musical apparatus as in claim 29 where said filtering means includes a plurality of π sections comprising an inductor and two capacitor legs together with switching means for coupling said input and output to any two adjacent π sections at any one time for providing said variation of said filtering characteristic.

31. Electronic musical apparatus as in claim 28 together with impedance means coupled to said input of said filtering means having an impedance different from the characteristic impedance of said filtering means.

32. Electronic musical apparatus as in claim 31 where said impedance means is variable to provide for control of the richness of said audio frequency.

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