

[54] VOLTAGE CONTROLLED CHORD ORGAN

[75] Inventor: David A. Bunger, Cincinnati, Ohio

[73] Assignee: D. H. Baldwin Company, Cincinnati, Ohio

[22] Filed: Dec. 30, 1971

[21] Appl. No.: 213,939

[52] U.S. Cl. 84/1.01, 84/1.03, 84/1.04

[51] Int. Cl. G10h 1/00

[58] Field of Search ... 84/1.01, 1.03, 1.19, DIG. 22,
84/1.08, 1.17, DIG. 7, DIG. 8, DIG. 18, DIG.
20

[56] References Cited

UNITED STATES PATENTS

3,359,358	12/1967	Brand et al.	84/1.08 X
3,548,066	12/1970	Freeman	84/1.03
3,560,628	2/1971	Plunkett	84/1.08
3,629,481	12/1971	Bunger	84/1.03
3,180,918	4/1965	Harmon	84/1.01
3,283,057	11/1966	Campbell	84/1.01
3,288,904	11/1966	George	84/1.01
3,546,355	12/1970	Maynard	84/1.03
3,567,838	3/1971	Tennes	84/1.03 X
3,624,265	11/1971	Yamada	84/1.19

OTHER PUBLICATIONS

J. Venn, "A Simple Electronic Chord Organ," Electronic Engineering, pages 421-425, July, 1961.

Primary Examiner—Stephen J. Tomskey

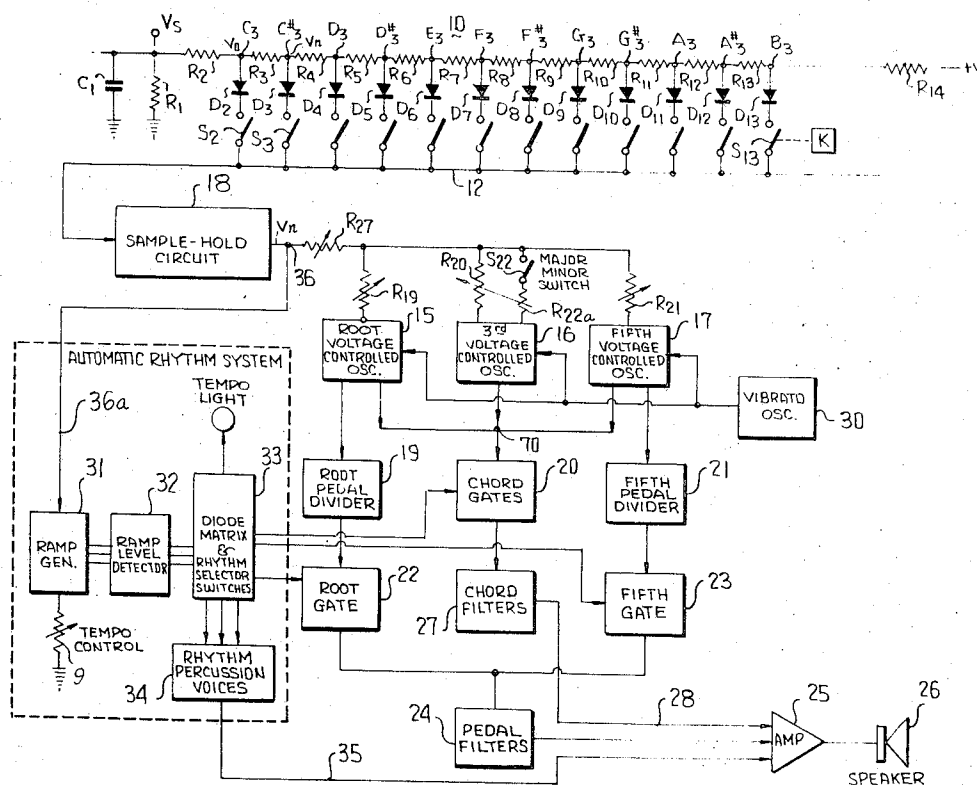
Assistant Examiner—U. Weldon

Attorney, Agent, or Firm—Hyman Hurvitz

[57] ABSTRACT

An electronic chord organ, in which voltage controlled oscillators are each supplied with the same voltage, the voltage being selected by actuation of keys of an organ keyboard, and the currents supplied to the individual oscillators being selected to sound a musical chord. The voltage controlled oscillators each receive voltages from a resistive voltage divider via a voltage sample and hold circuit, key switches applying voltage from selected points along the voltage divider via diodes to a common bus, the bus controlling the frequencies of all the oscillators, and the diodes serving to render only one key switch operable to apply voltage to the bus when plural ones of the key switches are simultaneously closed.

26 Claims, 6 Drawing Figures



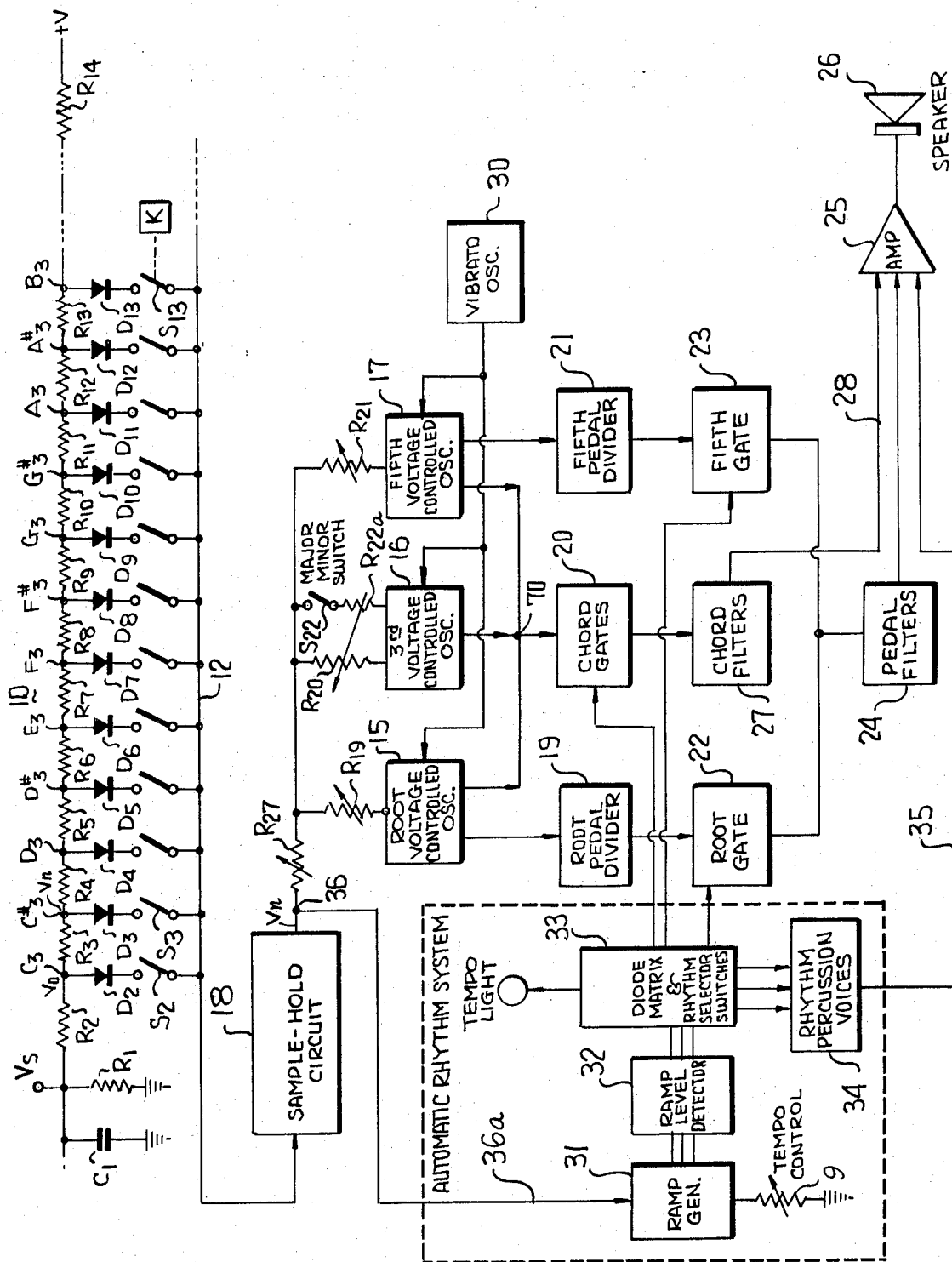


FIG. 1

FIG. 2

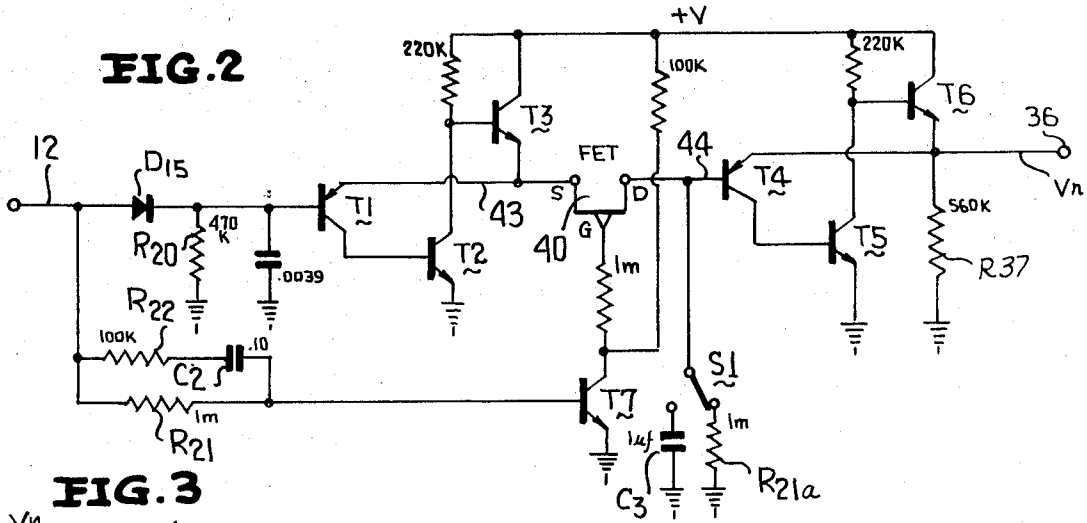


FIG. 3

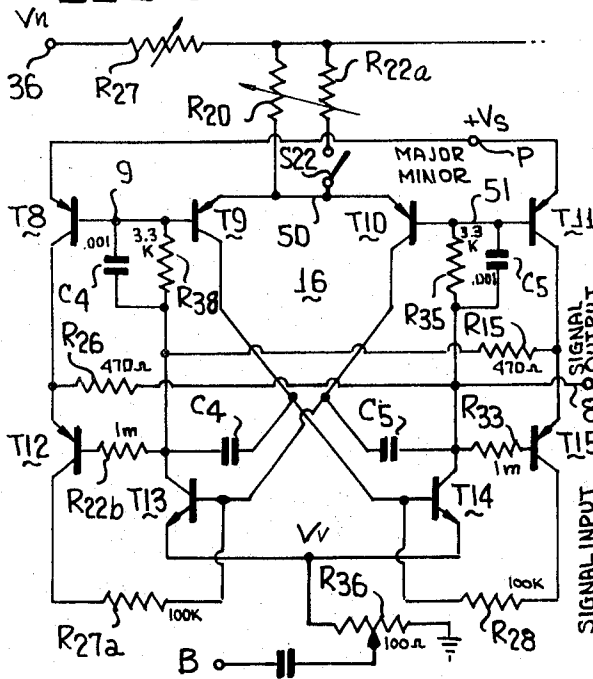


FIG. 4

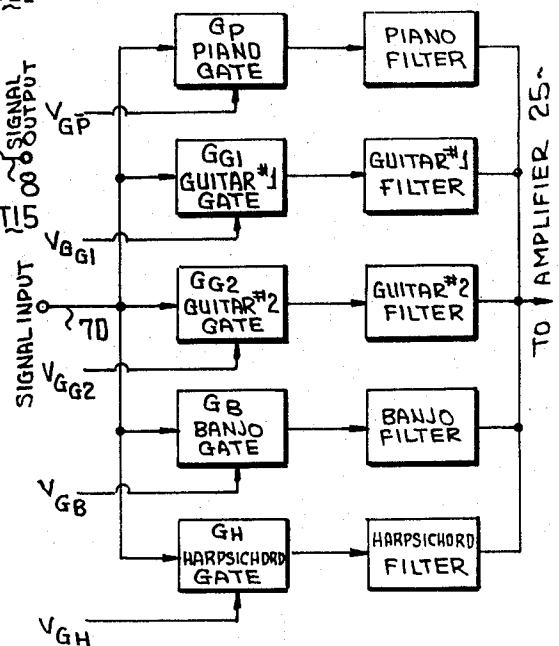


FIG. 5

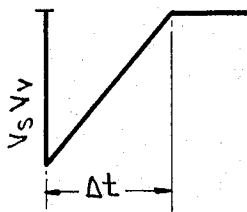
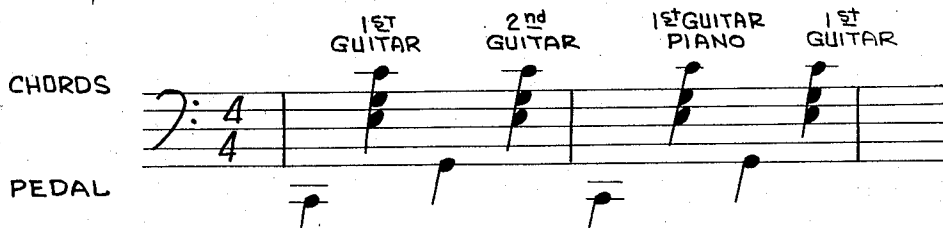


FIG. 6



VOLTAGE CONTROLLED CHORD ORGAN

BACKGROUND

Heretofore chords have been called forth by gating through to a common bus tone signal frequencies appropriate to a desired chord, the tone signals being supplied by oscillators or frequency dividers of the organ, which are also employed to provide accompaniment or solo tunes. The present system provides chord producing oscillators for chord production in an electric organ which are in addition to oscillators or frequency dividers otherwise employed in the organ. This is economically feasible since only three voltage controlled oscillators (VCO's) are required to play an entire gamut of triad chords. In the present system, the VCO's may be detuned slightly with respect to the normal organ generator, resulting in a chorus like effect when solo and chord are played together. Moreover, the chord, as a whole, can be shifted up and down in frequency, to provide chord glides, which is not feasible in conventional organs. The present system is arranged to play chords corresponding with the higher of two notes which are simultaneously played, whereas in prior art systems actuating two keys simultaneously to call for a chord, must serve to disable the chord playing circuitry, since the latter can be allowed to be responsive to only one playing key at a time. The economics of prior art systems is such that only one octave of notes is usually made available for chords. The present system is not so limited, but a large number of chords are available without appreciable increase in costs over those in any event involved in producing an octave of chords. The independence of the chord producing circuitry from the normal organ circuitry enables the chords and the solo voices to have diverse tone colors and to be each subject to vibrate independently of the other, or to vibrate at diverse rates or extents for the solo and chord voices.

Since the frequencies of the signals generated by the three oscillators of the present system all depend on the value of a single voltage, it is possible to sound chord and pedal accompaniment for a considerable time after the keys involved have been released. So, if a note were played, which called for a chord or accompaniment, the called for material would continue for perhaps 1 minute or for a desired number of musical measures after key release, or until a new note has been played. This capability allows the player to employ both hands on the solo manual, and to call for chord, base or accompaniment at intervals only which produces the semblance of smooth playing technique. The holding capabilities could be defeated when desired allowing the system to operate in a normal manner, that is, the chord and pedal would cease to sound upon key release. The voltage controlled oscillator employed provides frequencies which are insensitive of B+ supply and of temperature, and is per se novel.

SUMMARY

A triad-chord organ, or an accessory for such an organ, employing three chordally related oscillators all controllable by a single voltage, called forth by playing one or more keys of a keyboard, which has a sample and hold capability for the single voltage, provision for multiple accompaniment voices within a given rhythm, independence of pitch and wave form treatment as be-

tween the solo voices of the organ proper and the chords played by the accessory device, ability to shift frequency of the entire chord, at will, without affecting the organ proper, and providing for wipeout of the lower of a plurality of keys inadvertently played simultaneously.

DRAWINGS

FIG. 1 is a circuit diagram, largely in block and partly schematic, of a system according to the present invention;

FIG. 2 is a schematic circuit diagram of a sample and hold circuit, employed in the system of FIG. 1;

FIG. 3 is a schematic circuit diagram of a voltage controlled oscillator, utilized in system of FIG. 1;

FIG. 4 is a block diagram of gated tone color filters, employed in the system of FIG. 1;

FIG. 5 is a wave form diagram useful in explaining the operation of the present invention; and

FIG. 6 is a line of music indicating how a typical measure of accompaniment might proceed.

DETAILED DESCRIPTION

A resistance divider 10 comprises resistances R1 to R14, all in series between ground and a positive B+ voltage terminal V+. Each of resistance junctions R2, R3 to R13, R14 has a diode connected in the conductive direction and via a corresponding key switch, identified as S2-S13, respectively, to a common bus 12. A voltage V_s appears across R1, and the latter is bypassed by capacitor C1 to reduce transients. Closure of any one single switch of S2-S13 directs a dc voltage to bus 12, but closure of two or more switches simultaneously directs only a voltage to bus 12 corresponding with that which would have appeared had only the higher of the switches been closed. This occurs because closure of any switch reverse biases the diodes D2 to D13 of lower subscript than that which identifies the higher key switch.

The voltage divider 10 provides a series of voltages whose ratios correspond with that of the equally tempered musical scale.

$$f_n = f_o(2)^{n/12} \quad (1)$$

$$f_n = k(V_n - V_s) \quad (2)$$

$$f_o = k(V_o - V_s) \quad (3)$$

$$V_n - V_s = (V_o - V_s) 2^{n/12} \quad (4)$$

In the equations (1) - (4), V_n represents voltages taken along divider chain 10. V_o is the voltage at the junction of R2 and R3, and V_s the voltage at the junction of R1 and R2. Voltage V_s is one of the supply voltages for the voltage controlled oscillators (VCO's), 15, 16, 17 which generate a triad chord in response to voltage V_n and voltage V_s , the voltage across R1. If f_o is arbitrarily selected to represent note C3, then f_1 is C3 and f_{12} is C4, so that $f_{12} = f_o 2^{12/12} = 2 f_o$, or an octave relation exists between f_o and f_{12} .

The voltage on bus 12 is applied to VCO's 15, 16, 17 via a sample and hold circuit 18, which holds at its output a voltage applied to its input by a key closure, after

the key is released for a predetermined time or until a succeeding key is actuated.

The voltage at the output of sample and hold circuit 18, supplies voltage to VCO's 15, 16, 17 via common tuning resistance R27, in series with parallel tuning resistances R19, R20, R21. Variation of the resistances R19, R20, R21, enables tuning of the separate oscillators, variation of R27 allows tuning of all three oscillators simultaneously, and placing R22a in parallel with R20 when switch S22 is closed, translates the played chord from minor to major by adjusting the total resistance in series with VCO 16.

The output of VCO 15 is divided, usually by two, in root pedal divider 19 and also proceeds to chord gates 20, to which are also applied the outputs of VCO's 16, 17, so that chord gates 20 control the entire triad chord. The "fifth" voltage VCO 17 provides output for a fifth divider circuit 21 usually by two. The outputs of frequency dividers 19 and 21 are gated by gates 22 and 23, respectively. The outputs of gates 22 and 23 are fed to pedal tone color filters 24, the outputs of which proceed to amplifier 25 and thence to loudspeaker 26. The output of the chord gates 20 proceeds to chord tone filters 27, and these to amplifier 25 via lead 28. The VCO's 15, 16, 17 may be vibrato modulated in response to voltage supplied by a vibrato oscillator 30.

Any voltage appearing at the output of sample and hold circuit 18, which is sufficiently great to indicate that a key is activated is applied to enable operation of a ramp generator 31, the slope of which may be controlled by a tempo control resistance 9. Usually, a new ramp voltage will commence with each measure, but in some known systems two ramps per measure are utilized. The output ramp is sampled at pre-selected levels by a ramp level detector 32, which applies its timed output pulses to a diode matrix 33, which serves to distribute the spaced output pulses spatially to diverse tone sources 34 appropriate to percussive rhythmic accompaniment tones, and the sources 34 are connected to the input of amplifier 25 via lead 35.

In operation, depressing of a key closes a corresponding one of key switches S2 to S13. If more than one keyswitch is actuated at any given time, only the keyswitch pertaining to the higher frequency tone will preset voltage to bus 12, because diodes D2-D13 will disable the lower frequency switches of S2-S13 by back biasing the associated diodes D2-D13. The impedance matching between the resistor divider chain 10 and the sample and hold circuit 18 is such that the V_n 's along the resistor chain 10 are unaffected by closure of any switch S2 to S13, and V_s is a fixed voltage. The switch closure may be momentary but in such case sample and hold circuit 18 will extend the voltage which had momentarily existed on bus 12, in normal playing until a further key is actuated, or for a predetermined amount of time. We may therefore assume that, in normal playing a voltage V_n will appear, at point 36, for at least part of a musical measure, and usually for one or more measures, regardless of whether a key is held down throughout or whether the key is only momentarily depressed.

Voltage V_n and voltage V_s establish the tone signals generated by VCO's 15, 16, and 17. The outputs of the oscillators 15, 16, 17 are commonly applied to chord gates 20, which are turned on and off by the diode matrix 33 at positions of the ramp voltage output of generator 31 which are established by (1) the pick-off points

selected by level detector 32 and (2) the selection of those pick-off points made by diode matrix 33. The rate of charge of the ramp voltage is established by resistance 9 and this establishes the tempo, which the player follows.

The divided outputs of VCO's 15 and 17, provided by root note and fifth note dividers 19 and 21, respectively, are gated through by gates 22 and 23, tone filtered by pedal filters 24, and acoustically radiated. Gates 22 and 23 are also timed by diode matrix 33, and the latter also controls rhythm percussion voices 34.

A wide variety of rhythmic patterns may be available in the present system, in terms of (1) the number of pick-off points provided in ramp level detector 32 and (2) the complexity of diode matrix 33. The pick-off points establish times or temporal points within a measure, the matrix 33 applies these temporal points to the several gates and voices available on a selective basis.

The automatic rhythm system of the present system is per se old, and well known. Therefore, its circuitry is not herein explained or illustrated in detail. Reference is made to U. S. Pats. to D. Campbell, No. 3,522,358 and of M. Harris, Ser. No. 27,258, now U. S. Pat. No. 3,629,480, and the mode of operation thereof, as well as typical rhythms which may be employed.

SAMPLE AND HOLD CIRCUIT

Referring to FIG. 2, when no keyswitch is closed no voltage is present on bus 12. The base of T1 is referenced to ground through the 470K resistor R20. T1 and T2 are in conduction due to the emitter current of T3 flowing into the emitter of T1 and from the collector of T1 to the base of T2. Lead 43 will bias itself to two diode drops above ground or about 1 volt. With no keyswitch closed T7 has no base current causing T7 to be cut off. This allows the gate of the F.E.T. 40 to be referenced to +V reverse biasing the gate and causing the F.E.T. 40 to be off or open. Thus the base of T4 is referenced to ground through switch S1 and the 1M resistor R21. The operation of T4, T5 and T6 is exactly the same as that of T1, T2 and T3. Thus point 36 will bias itself two diode drops above ground. When a keyswitch is closed a voltage will appear at the base of T1. The value of this voltage depends upon which of keyswitches S2-S13 is closed. The value of the voltage at the base of T1 will be two diode drops below the voltage value established by the resistor divider network R1 through R14 of the respective keyswitch closed. Transistors T1, T2 and T3 will adjust so that lead 43 is one diode drop above the reference potential at the base of T1. Since a keyswitch is closed T7 will be saturated due to base current flowing through the 1m base resistor R21. Resistor R22 and capacitor C2 in the base circuit of T7 is a speed up circuit for saturating T7 quickly upon closure of a keyswitch. With T7 saturated the gate of the FET 40 is referenced to ground forward biasing the gate and causing the FET 40 to turn on. With the FET 40 on, the voltage at lead 43 appears at lead 44 causing terminal 36 to be one diode drop above the voltage at lead 43 due to the regenerative action of T4, T5, and T6. The output point 36 is thus two diode drops above the voltage at the base of T1 and the frequency determining voltage source for the three VCO's is equal to V_n .

With S1 in series with R21a as soon as the played note is released point 36 will immediately settle to about 1 volt. Diode D15 could be eliminated and the

frequency control voltage source for the VCO's could be taken from lead 43, but sample and hold capability is then lost. The remainder of the circuitry could be eliminated. With S1 in series with capacitor C3 the circuit operates in the same manner except now the capacitor is charged to the reference voltage present at lead 44. When the played note is released the FET turns off leaving the reference voltage charge present on the capacitor C3 holding the output voltage at point 36 at the correct voltage. Due to the leakage current of T4 the charge on the capacitor will gradually increase but at a slow enough rate that no objectionable frequency drift will occur over the length of desired holding time from when the key was released. As soon as a new key is played the capacitor C3 will quickly charge through T3 or discharge through T1 and T2 depending on whether the new reference voltage is higher or lower than the previous reference voltage, and will attain its new correct voltage. It should be noted that output terminal 36 will be at the same voltage as the voltage on the divider chain of the selected keyswitch Vn. For example, if note C3 were played Vo less two diode drops due to D2 and D15 is applied to the base of T1. Terminal 36 is two diode drops above the voltage at the base of T1 due to the base-emitter diodes of T1 and T4. Thus Vo will appear at terminal 36.

It is important that there are balanced diode drops because then any variations in the diode drops due to temperature changes will be minimized. A voltage from the terminal 36 is also fed into the ramp generator of the automatic rhythm section via lead 36a. The ramp generator will start and continue to run whenever voltage above a minimum 1 volt level appears on output terminal 36, but otherwise will not run.

Summarizing the action of the Sample and Hold Circuit, with zero voltage at lead 12, indicating no key actuation, T3 is conductive since its base is referenced to its collector at V+. T3 supplies current to the emitter of T1, which is conductive and supplies current to the base of T2 which also conductive. Lead 43 will then be two diode drops above ground. T7 is cut-off since base current equals zero, leaving the gate of FET 40 at +V and the FET itself open or off.

The base of T4 is grounded when FET 40 is off, through R21a. T6 is conductive and supplies emitter current to T4 and base current to T5, so that T4, T5 are conductive. Vn is taken across resistance R37 in series with the emitter of T6. Since T3, T1, T2 are the same as T6, T4, T5, respectively, in relationship and interconnection, Vn will be two diode drops above ground, like lead 43.

If we now assume that a key switch is closed, bus 12 will receive a voltage Vn less one diode drop. D15 will provide a further diode drop, so that the base of T1 is two diode drops below Vn, while lead 43 is one diode drop above the base of T1.

But, whenever a keyswitch is closed, T7 is saturated, which grounds the gate of FET 40, turning on the latter. The voltage lead of 43 now appears at the base of T4. Terminal 36 is at the voltage of the base of T4 plus one diode drop. When the played key is released, T7 cuts off and Vn goes to two diode drops, above ground.

In the description of operation to date, with no hold, S1 was assumed to be in the position illustrated, i.e., connected to R21. If connected to C3 hold action occurs, C3 providing the memory, but it is subject to

some charge via the base of T4, so that its charge will slowly increase.

As soon as a new key is pressed, C3 will charge further through T3 or discharge through T1, T2, depending on whether its voltage was lower or higher than that which appears on lead 43 due to the new key actuation.

The object of the system is to have the voltage on lead 36a equal to Vn on the divider chain. When a key is depressed Vn less two diode drops appears on the base of T1. But lead 36 is two voltage drops above the T1 base, so that Vn will appear at lead 36.

Referring to FIG. 3, supply voltage Vs at point P is connected to the emitter of transistors T8 and T11. Frequency reference voltage is supplied from point 36 to the emitter of transistors T9 and T10 via R27 and R20. When a frequency reference voltage Vn greater than Vs appears at point 36 the VCO will provide an output signal. Assuming no key switch is closed and one volt is present at point 36, the following conditions exist. T8, T12, and T13 are off and T11, T14 and T15 are on. Since T11 is on +Vs is applied to the collector of T13 via R15 and the bases of T8 and T9 via R38. This is obtained by a momentary circuit through R27, R20, T9, T15, and T14 which causes T14 to latch. Since the emitter and base of T8 are referenced to the same voltage T8 will be off. T12 will be off because its base is referenced to Vs via R22b, R15 and T11 and its emitter is referenced to ground via R26 through T14 which is saturated and through R36 which is connected to ground. Thus the emitter base junction of T12 is reversed biased insuring that transistor is in an off state. Since T12 is off no base current can be supplied to T13 via R27a. Since one volt is present at point 36 the collector of T10 can supply no base current to T13. These two conditions insure T13 to be off. Since T14 is saturated the base emitter junction of T11 is forward biased from Vs through R35, T14 and R36 to ground. This holds T11 on and supplies Vs to the emitter of T15. T15 is on because its base-emitter junction is forward biased from Vs at its emitter through R33, T14 and R36 to ground. T15 being on provides base current for T14 from Vs via R28 and insures T14 to be saturated. Thus the assumed set of conditions are seen to be a stable state for the VCO 16. When voltage is applied at 36 greater than Vs current will flow through R27 and R20 to lead 50. This turns T10 on and lead 50 will be clamped to one diode drop above lead 51. Since lead 51 is one diode drop below Vs, lead 50 is clamped to Vs. T9 will be off because its base is also at Vs. The collector of T10 supplies current to the base of T13 and linearly charges C5 since T10 acts as a constant current source. The value of charging current is determined by the difference in potential between points 36 and 50 divided by the series resistance of R27 and R20. When C5 is charged to a voltage level sufficient to overcome the base emitter drop of T13, T13 will turn on. Normal multi-vibrator action is now initiated. The collector of T13 goes from Vs to Vv. This negative voltage transient is transferred across C4 and drives the base of T14 to -Vs+Vv. T14 turns off and its collector quickly rises to Vs. In order for the collector of T14 to rise quickly to Vs, C5 must be charged to Vs quickly. This is accomplished by a heavy charging current through R26. Since T13 is now on T8, T9 and T12 turn on and T10, T11, T14 and T15 turn off. T13 is held in saturation by current via R27a and the opposite stable condition from that previously described now exists. Since the current

flowing from point 36 through R27, R20 can no longer flow through T10, base current for T13 to remain in saturation must be supplied via T12 and R27a. The current that initially flowed through T10 now switches and flows through T9 to linearly charge C4 from $-V_s + V_v$ to a voltage level which will turn T14 on to continue multivibrator action.

If the voltage at point 36 is defined as V_n and it has been shown that the voltage at point 50 is V_s the charging current flowing through T9 or T10 is determined by

$$I = V_n - V_s / R_{27} + R_{20} \quad (5)$$

the wave form of the voltage at the base of T13 or T14 looks like that of FIG. (5)

$$Q = C v \quad (6)$$

$$dq/dt = C dv/dt \text{ or } i = c \Delta v / \Delta t \quad (7)$$

$$f = 1/T \quad T = 2 \Delta t \quad (8)$$

$$f = \frac{1}{2} \Delta t \quad (9)$$

$$I = C V_s - V_v / \Delta t \quad \Delta t = C(V_s - V_v) / I \quad (10)$$

therefore

$$f_n = I / 2c(V_s - V_v) = V_n = V_s / (R_{27} + R_{20}) (2c) (V_s - V_v) \quad (11)$$

It can be seen that the frequency of the VCO is directly proportional to I.

It has previously been stated that

$$f_n = K(V_n - V_s) \quad (12)$$

It now becomes apparent why V_s enters into the equation and that

$$K = 1 / R_{27} + R_{20} (2c) (V_s - V_v) \quad (13)$$

Equation (11) states that if the major-minor switch S22 was opened R20 would increase in value and f_n would decrease. The value of the ganged pot R22a must be selected so that $\Delta f_n = 1$ semitone. Thus when S22 is opened the 3rd VCO will go from a major 3rd to a minor 3rd frequency. If no vibrato signal is applied at point B from oscillator 30, V_v can be ignored because R36 is extremely small compared to that of R27 and R20. R20 is used to tune the 3rd VCO to the correct frequency with respect to the other two VCO's. R27 is used to vary the frequency of all three VCO's equally. It can be shown that $V_n = V / K_1$ $V_s = V / K_2$ looking at the resistor divider chain or

$$f_n = \frac{\frac{v}{k_1} - \frac{v}{k_2}}{(R_{27} + R_{20}) \left(2c \frac{v}{k_2} \right)} = \frac{\frac{k_2}{k_1} V - V}{(R_{27} + R_{20}) (2cV)} \quad (14)$$

where V is the supply voltage for the entire system.

$$\frac{df_n}{dV} = \frac{(R_{27} + R_{20}) (2cV) \left[\frac{K_2}{K_1} - 1 \right] - V \left[\frac{K_2}{K_1} - 1 \right] (R_{27} + R_{20}) (2C)}{(R_{27} + R_{20})^2 (2cV)^2} \quad (15)$$

defining

$$(R_{27} + R_{20}) (2c) (K_2 / K_1 - 1) = K_3 \quad (16)$$

$$df_n / dV = V k_3 - V k_3 / (R_{27} + R_{20})^2 (2cV)^2 = 0 \quad (17)$$

which shows that the frequency of the VCO is independent of supply voltage variations. It can also be seen from the equation for f_n that c is the only fixed value component which effects f_n . Considering the equation 11, where a vibrato signal is applied to point 7, V_v cannot be considered to be 0. It can be seen from the above that

$$df_n / dV_v = [(v_n - v_s) (R_{27} + R_{20}) 2c / (R_{27} + R_{20})^2 (2c)^2 (V_s - V_s)^2] [(V_n - V_s) / (R_{27} + R_{20}) 2c (V_s - V_v)^2] \quad (18)$$

$$df_n / dV_v = [K_4 (V_n - V_s) / (V_s - V_v)^2] df_n = [k_4 (V_n - V_s) / (V_s - V_v)^2] dV_v \quad (19)$$

% frequency modulation is defined as df_n / f_n
Therefore

$$\frac{df_n}{f_n} = \frac{\frac{k_4 (V_n - V_s)}{(V_s - V_v)^2}}{\frac{V_n - V_s}{k (V_s - V_v)}} = k_4 k \left(\frac{dV_v}{V_s - V_v} \right)$$

This equation states that the rate of change of f_n versus V_v is independent of V_n , which implies that a constant percentage frequency variation of f_n can be obtained by varying V_v completely independent of V_n . This is essential for the frequency modulation or vibrato to be a musically useful effect. The root and fifth VCO's are circuitwise, and operate like the 3rd VCO 16 and therefore are individually neither illustrated nor described.

When a voltage V_n is present at 36, R19 is adjusted to provide the correct frequency for the root VCO. R20 is adjusted to provide the correct frequency for the fifth VCO. Once this is done V_n can be varied or R27 can be varied and the frequency relationship among the three VCO's will remain correct, although their pitches will vary.

GATES

With reference to FIG. 4, the output of the three VCO's are summed and connected to the input 70 of a set of chord gates. A chord gate is provided for each tone color chord filter.

Vgp, Vggl, etc. represent trigger inputs to the gates, derived from diode matrix 33. The gates are normally off. When the gate receives a trigger input it will turn on quickly and then decay exponentially. Each gate

may have a different decay rate. The gates pass their respective signals to the appropriate filters and hence to the amplifier and speaker system.

Different combinations of voices will be used for different rhythms. For example, a Dixie Land rhythm might use the piano and banjo. A Latin type rhythm might use the two guitar voices.

The outputs of the root and fifth VCO's are also fed into frequency dividers 19 and 21. This is done to obtain an octave lower frequency range for pedal bass accompaniment. The outputs of the dividers are fed into the root and fifth gates. These gates operate similarly to the chord gates and derive their respective triggers from the matrix 33. An example of a Swing rhythm which might be programmed is illustrated in FIG. 6 of the drawings, which is for a C major chord with C,G pedal when the C key is depressed.

Typical values of resistances R1-R14 are as follows.

R1 =	50.000
R2 =	20.001
R3 =	1.190
R4 =	1.260
R5 =	1.335
R6 =	1.414
R7 =	1.498
R8 =	1.589
R9 =	1.682
R10 =	1.781
R11 =	1.888
R12 =	2.000
R13 =	2.119
R14 =	192.246

These values are based on the assumption that $V_s = 5.0$ V and $V = 28.0$ V.

I claim:

1. An electronic organ, comprising a voltage tunable tone signal oscillator system, said oscillator system including at least one oscillator, a plurality of organ keys arranged in an array, a resistive voltage divider, means for applying voltage to one end of said voltage divider, means for connecting the other end of said voltage divider to a point of reference potential, taps taken from said voltage divider, a separate two contact key switch operable by each of said keys, said key switches each having one of said contacts connected to a different one of said taps, a common bus line of substantially zero resistance, means connecting all the others of said contacts to said common bus line, and control means connecting said common bus line to energize said at least one oscillator, said taps being so selected that said at least one oscillator oscillates at pitches which vary as $f_o^{n/12}$, where n is an integer including zero identifying said key switches and f_o is the lowest frequency called forth by actuating said keys, and separate diodes connected in series with each of said key switches, said diodes being poled to be highly conductive of current from said resistive voltage divider through said switches.

2. The combination according to claim 1, wherein V_n is the voltage of the n th tap of said voltage divider and

wherein V_o is the voltage of the o th tap, and wherein a further voltage divider extends between said o th tap and said point of reference potential, said further voltage divider having a voltage V_s at its division point, and wherein the resistors of said resistive voltage divider and of said further voltage divider are selected to provide voltages according to the equation

$$K(V_n - V_s) = (V_o - V_s) (2)^{n/12},$$

wherein K is a constant, V_s is a supply voltage for said multivibrator oscillator, V_o is a reference voltage and V_n is a frequency determining voltage.

3. The combination according to claim 2, wherein said oscillator system includes three oscillators connected respectively to said common line via diverse tuning resistances selected to control said three oscillators to produce the notes of a musical chord.

4. The combination according to claim 3, wherein said oscillators produce root frequency, third frequency and fifth frequency, respectively, and wherein is included switch means for at will adjusting that one said diverse resistance which controls the frequency of said third frequency so as to provide at will either a major or a minor chord.

5. The combination according to claim 4, wherein is further provided a variable resistance in series commonly only with said diverse resistances taken in parallel, and means for varying said variable resistance to effect a common frequency variation of all said oscillators.

6. The combination according to claim 5, wherein is included a sample and hold circuit connected to said common bus line, said sample and hold circuit including means for producing and storing a voltage equal to V_n for at least the time normally required to play a measure of music, said means for producing and storing a voltage equal to V_n being included in said control means, and means for applying said a voltage equal to V_n to said at least one oscillator in frequency controlling relation to said at least one oscillator.

7. The combination according to claim 6, wherein said sample and hold circuit includes an input lead, a power lead, a first NPN transistor having a collector connected directly to said power lead, said first NPN transistor having a base, a bias resistance connected between said power lead and said base of said first NPN transistor, a second NPN transistor connected collector to emitter from said base of said first NPN transistor to ground, a third PNP transistor having its emitter connected directly to the emitter of said first NPN transistor, its collector connected to the base of said second transistor and its base connected to said input lead, a FET having a source electrode, and a drain electrode and a gate electrode, means connecting said source electrode to the emitters of said first and third transistors, a fourth NPN transistor having a grounded emitter, a base connected to said input lead and a collector connected to said gate electrode, a connection directly from said power lead to said collector of said fourth transistor, a fifth NPN transistor having its collector connected directly to said power lead and its base connected via a bias resistance to said power lead and its emitter connected to ground via a load resistance, a sixth NPN transistor having its collector emitter circuit connected between said base of said fifth NPN transistor and ground, a seventh PNP transistor having its col-

lector connected to the base electrode of said sixth transistor and its emitter connected to the emitter of said fifth transistor, said drain electrode being connected to the base of said seventh transistor, and selective means connecting said drain electrode via a resistance or a store capacitance to ground, and means biasing the base of said first transistor to ground.

8. The combination according to claim 6, wherein said sample and hold circuit includes a voltage input line, a voltage output line, means including a FET for coupling said lines, means maintaining said FET non-conductive in absence of at least a predetermined voltage on said input lead, means for rendering said FET conductive when said input lead acquires a greater than said predetermined voltage, a storage capacitor connected between said output line and ground, and means for charging said capacitor when the voltage of said input lead exceeds the voltage of said output lead and for discharging said capacitor via said FET when said output lead exceeds the voltage of said input lead.

9. The combination according to claim 6, wherein said sample and hold circuit includes a storage capacitor, an input line, an output line, means for maintaining said capacitor discharged so long as the voltage on said input line is substantially zero, means for maintaining said output line in fixed relation to the voltage of said capacitor, means including a solid state gate connecting said input line to said capacitor, mean normally maintaining said gate non-conductive while said voltage on said input line is substantially zero, and means responsive to the voltage on said input lead when said input lead exceeds a predetermined voltage for rendering said gate conductive.

10. The combination according to claim 1 wherein is provided adjustable resistance connected in series between said control means and said at least one oscillator, said at least one oscillator being arranged to operate at a frequency proportional to the voltage of said voltage source, and inversely proportional to the value of said adjustable resistance.

11. The combination according to claim 2, wherein is included a sample and hold circuit connected to said common bus line, said sample and hold circuit including means for producing and storing a voltage equal to V_n for application to said at least one oscillator for a time at least equal to the duration of a measure of music.

12. In an electronic chord organ, an array of keys, means for generating a control voltage in response to playing of a selected key of said array of keys for only part of a measure of music, said voltage having a value which is a function of the selected key, a two terminal sample and hold device having an input terminal connected to sample said voltage and an output voltage terminal, said sample and hold circuit having a hold time of at least one measure of said music for maintaining a musical chord at constant amplitude, a triad of voltage controlled means responsive to the voltage at said output terminal for calling forth said musical chord of notes and means responsive through said sample and hold circuit to said playing of a selected key for generating a rhythmic series of impulses for sounding the notes of said chord through gate means in a predetermined tempo and rhythm during said hold time.

13. In an electronic chord organ, means a triad of a voltage controlled for generating any selected one of a plurality of chords in response to playing of a selected

key of said organ for part of a measure, said first means including a sample and hold circuit means responsive to said selected key for maintaining each of the selected chords at constant amplitude for plural measures following release of said selected key, means responsive through said sample and hold circuit means to said selected key for rhythmically sounding the notes of said each of said selected chord through gate means in a predetermined tempo and rhythm during operation of said means for maintaining, said means for rhythmically sounding including means for generating a series of rhythmic percussive pulses in said tempo and rhythm.

14. An organ system comprising a triad of voltage controlled oscillators having each a control terminal, means for applying control voltages to all said terminals, means responsive to said voltages for rendering said oscillators operative to oscillate at the frequencies of a triad musical chord, said means for applying control voltages including voltage dropping variable tuning resistances connected between said means for applying control voltages and said control terminals of said oscillators, respectively, means for generating a rhythmic series of impulses in predetermined tempo, means responsive to said impulses for gating on the outputs of said triad of voltage controlled oscillators in rhythmic sequence, a series of keys of a keyboard, and means responsive through said means for applying control voltages to playing of any one of said keys for initiating operation of said means for generating said rhythmic series of impulses respectively, until one of said keys is again played, and said means for applying control voltage comprising means responsive to playing of the last mentioned one of said keys for re-initiating operation of said means for generating said rhythmic series of impulses.

15. In an organ system, a voltage controlled tone oscillator, a voltage sample and hold circuit comprising an amplifier having an input circuit and an output circuit, means for establishing a control voltage selectively in response to closure of a selected key switch of a plurality of key switches of said organ system, means including at least one diode for applying said control voltage less at least one diode voltage drop to said input circuit, means deriving a further voltage equal to said control voltage from said output circuit, and means for applying said further voltage to said voltage controlled oscillator in voltage controlling relation thereto, said voltage sample and hold circuit having a hold time of about at least 20 seconds.

16. The combination according to claim 15, wherein said sample and hold circuit includes a storage capacitor, and means for adjusting the voltage of said storage capacitor substantially instantaneously on closure of any of said key switches.

17. In an electronic organ, a keyboard having an array of keys, an array of two contact key-switches operated by said keys to close when said keys are actuated; a resistive voltage divider having a tap connected to each of said keyswitches, a diode connected conductively between each of said taps and one contact of each of said keyswitches, and a common bus connected to the others of said contacts, a source of voltage connected to one end of said divider, a reference point connected to the other end of said divider, and resistance connected between that one of said taps connected to the last one of said array of keyswitches and

said reference point, a voltage terminal connected at a point of said resistance, and a voltage responsive multivibrator oscillator connected jointly to said common bus and to said voltage terminal and arranged to oscillate at a frequency which is a function of the difference of the voltages of said common bus and of said terminal.

18. In an organ system having a plurality of key switches respectively allocated to notes of the musical scale, a plurality of resistances all connected in a series chain, a source of voltage connected to one end of said chain, a ground point connected to the other end of said chain, a common bus, the junctions of said plurality of resistances being at voltages V_n , a plurality of diodes connected in conductive relation between junctions of said resistances and said common bus, means for deriving a voltage V_s responsive to the current flowing in said chain, a sample and hold circuit, said sample and hold circuit including an amplifier having an input terminal and an output terminal, means connecting said input terminal to said common bus, three multivibrator oscillators responsive jointly to V_s and V_n , means including variable resistances respectively connecting said output terminal in common to said three multivibrator oscillators, said variable resistances including a resistance in series commonly with all said oscillators for concurrently tuning all said oscillators, said variable resistances including resistances respectively connected individually in series with each of said oscillators for individually tuning said oscillators, means for deriving tone signals from said oscillators, and means for acoustically transducing said tone signals.

19. The combination according to claim 18, wherein the sample and hold sustain time of said sustain circuit extends over plural measures of music played on said organ.

20. The combination according to claim 18, wherein one of said voltage controlled oscillators is a root voltage controlled oscillator, another of said oscillators is a third voltage controlled oscillator, and still another of said oscillators is a fifth voltage controlled oscillator, and wherein is provided switch means for at will modifying the frequency of said third voltage controlled oscillator between major third and minor third frequencies by introducing a further resistance between said bus and said third voltage controlled oscillator.

21. The combination according to claim 18, wherein said sample and hold circuit connected between said common bus and said oscillators includes means for compensating for diode voltage drops in said plurality of diodes such that the voltage at the output of said sample and hold circuit equals V_n .

22. The combination according to claim 18, wherein said sample and hold circuit includes a further diode connected in series with said common bus, a first amplifier connected in cascade with said further diode, said first amplifier including transistors arranged to provide at the output of said first amplifier the voltage

V_n minus one diode voltage drop, a further amplifier, a normally off FET switch connecting said first amplifier in cascade with said further amplifier, said second amplifier being arranged to add one diode voltage drop to its input voltage, means for tuning said FET switch on in response to closure of any of said key switches, said sample and hold circuit having a configuration arranged to provide said voltage V_n at its output, said further amplifier including a hold capacitor connected across the input of said further amplifier.

23. The combination according to claim 18, wherein the frequencies of said oscillators are independent of the voltage of said source of voltage connected to said one end of said chain.

24. An organ system, including a series resistance chain, composed of plurality resistances, a source of supply voltage connected to one end of said chain, a common bus, means for deriving from one point of said chain a voltage V_s , means for connecting junctions of said plural resistances to said common bus, each of said last means including a diode and a key switch connected between each of said junctions and said common bus, said diodes being poled conductively of said supply voltage, said resistances of said series resistance chain connected between said one point of said chain and said source of supply voltage having values such that a series of voltages V_n is provided at said junctions such that $V_n - V_s$ vary with the frequencies of notes of the equally tempered musical scale, a sample and hold circuit connected in cascade with said common bus, said sample and hold circuit being arranged and adapted to so compensate for any voltage drop through said diodes as to provide an output voltage equal to V_n , a multivibrator oscillator responsive to the difference of said last named voltage V_n and V_s to generate tone signals of said frequencies of the equally tempered musical scale.

25. The combination according to claim 24, wherein said oscillator is responsive to a current flow into said oscillator in response to and proportional to the voltage $V_n - V_s$ and is independent of variations of voltage of said source of supply voltage and of the temperature of said diodes.

26. In an organ system, a voltage controlled tone oscillator, a voltage sample and hold circuit having an input and an output, means including key switches for generating a control voltage for said voltage controlled tone oscillator, plural diodes conductively connected between said means for generating a voltage and said input circuit, whereby plural diode voltage drops occur between said means for generating a voltage and said input circuit, said sample and hold circuit including means for adding diode voltage rises corresponding to said diode voltage drops between said input circuit and said output circuit, and means connecting said output circuit to said oscillator in control relation.

* * * * *