Aug. 18, 1953 | S. HEYTOW ET AL | 2,649,006

MUSICAL INSTRUMENT

Filed Nov. 13, 1950 | 5 Sheets-Sheet 1

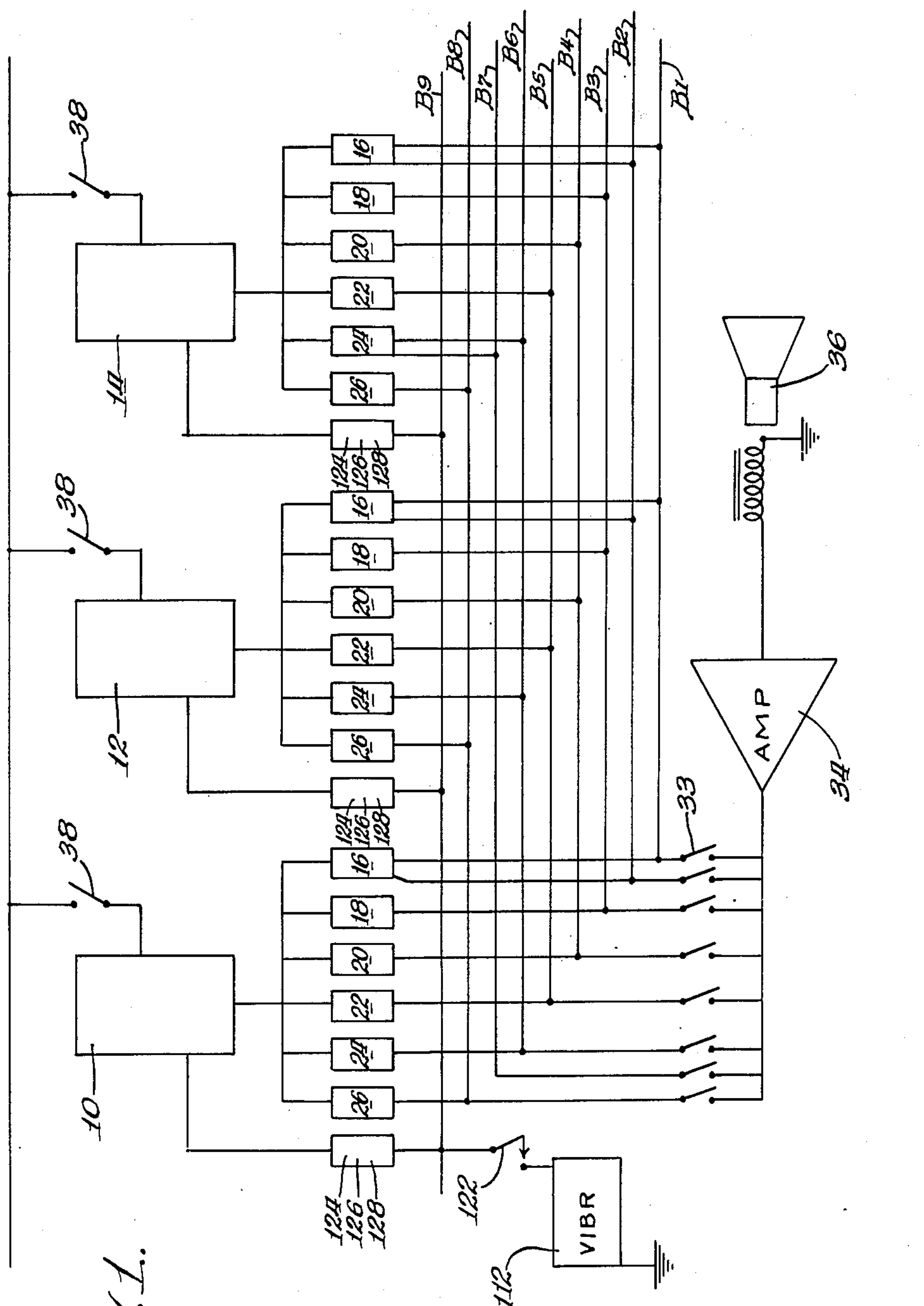

Fig. 1.

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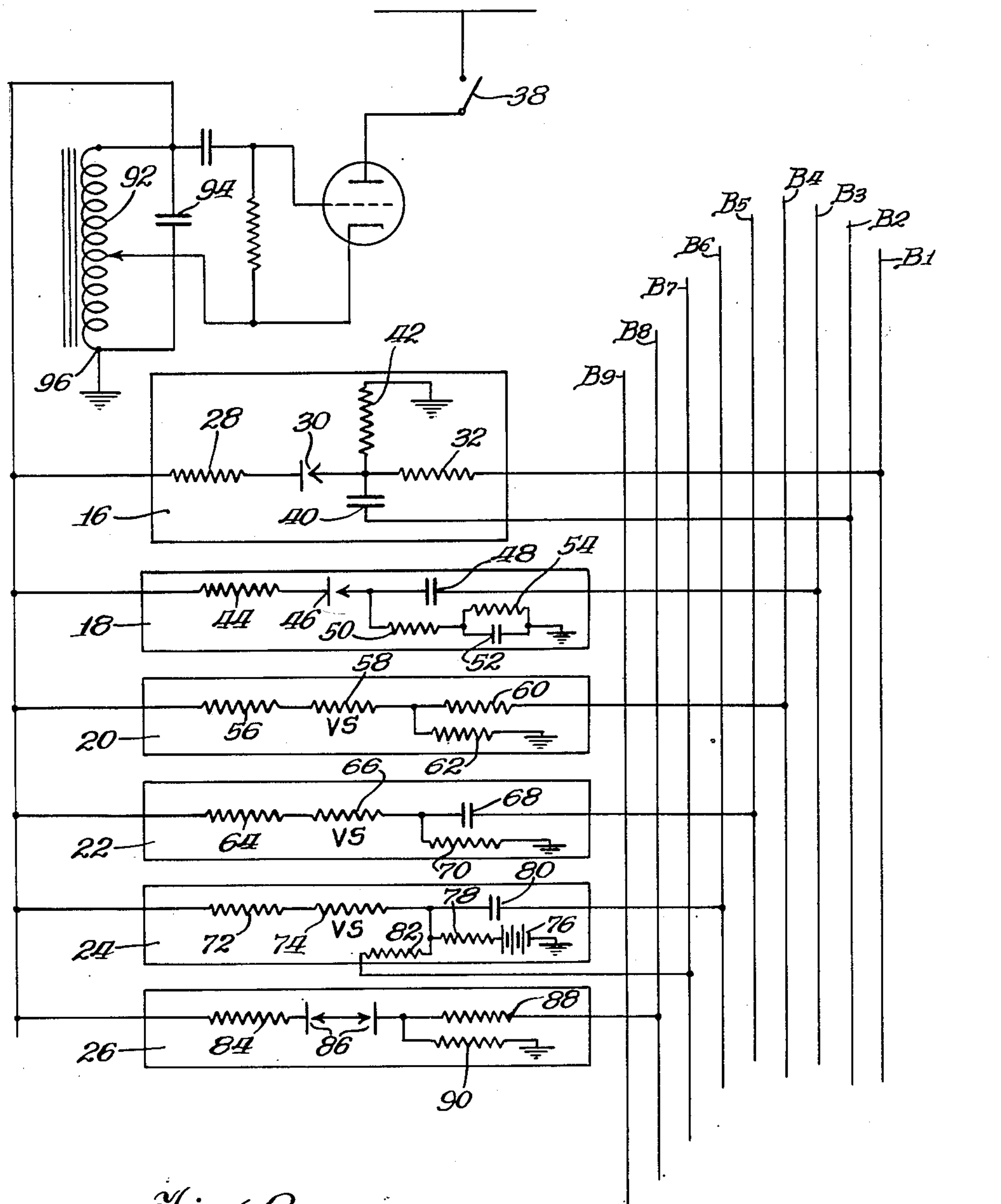

Fig. 2.

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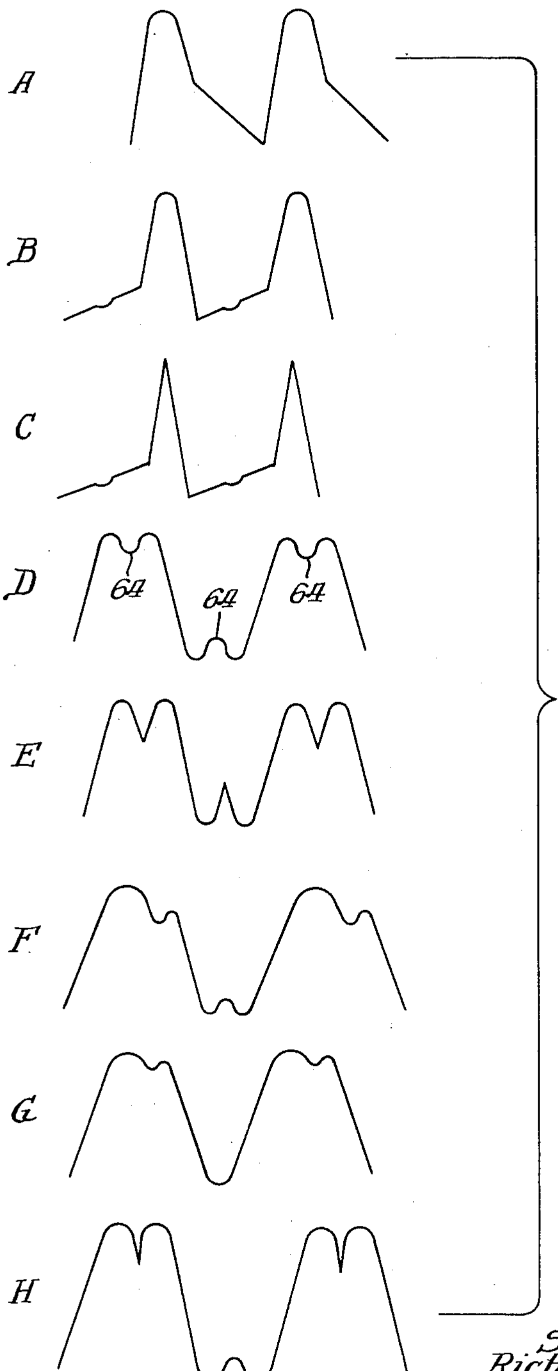

Fig. 3.

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Fig. 4.

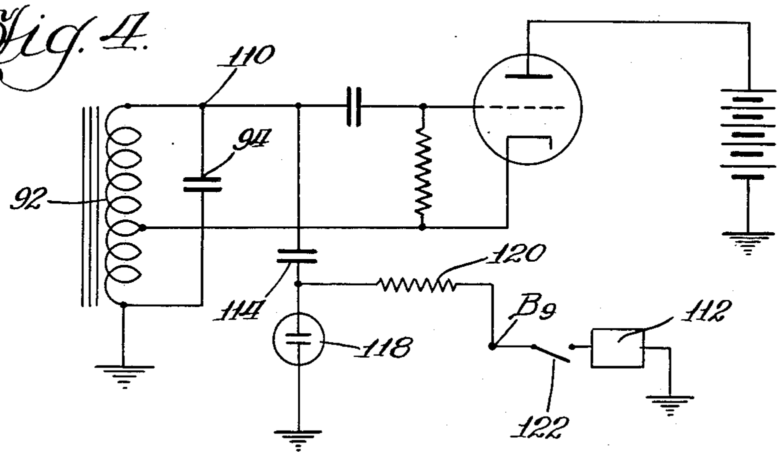
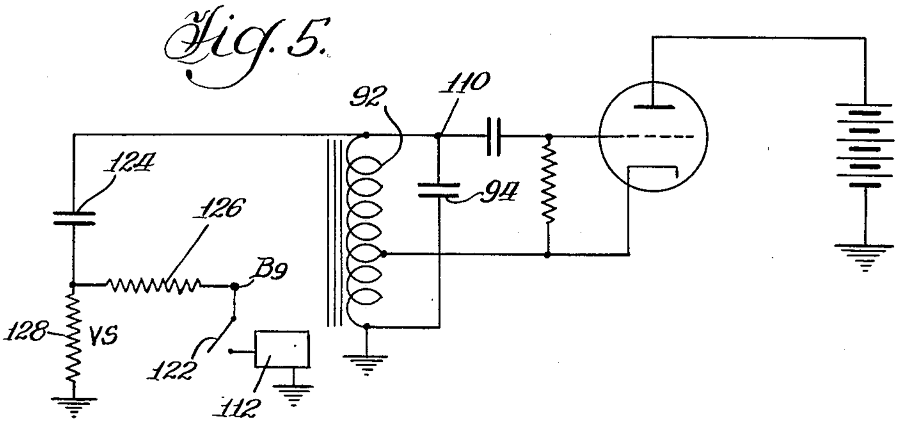


Fig. 5.



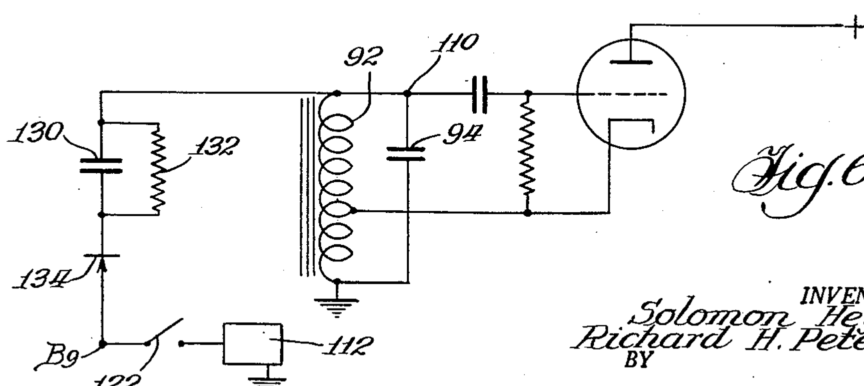


Fig. 6.

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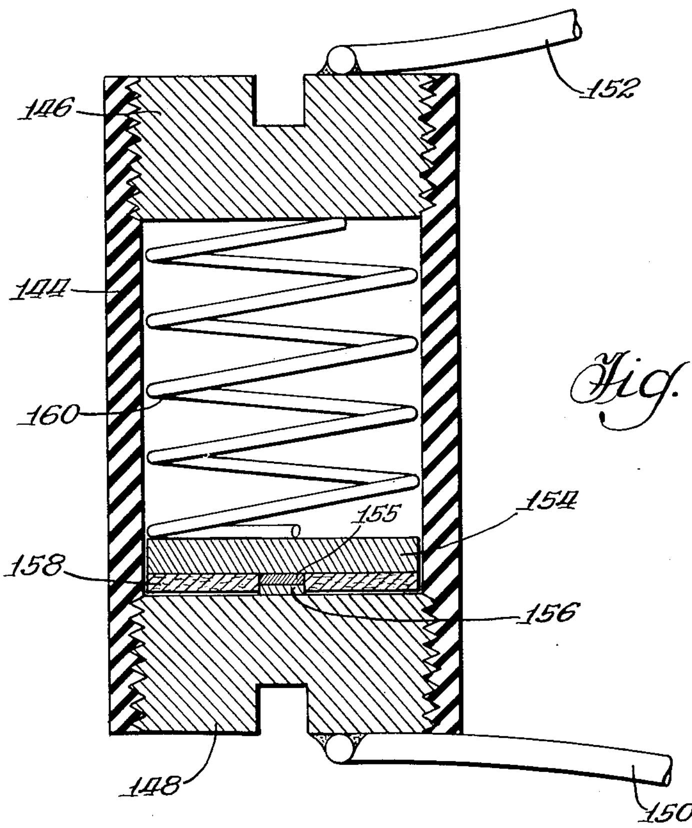

Fig. 8.

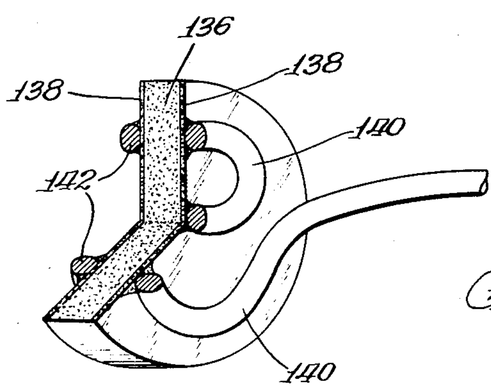

Fig. 7.

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UNITED STATES PATENT OFFICE

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MUSICAL INSTRUMENT

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Application November 13, 1950, Serial No. 195,222

11 Claims. (Cl. 84—1.20)

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Our invention relates to electronic musical instruments and includes among its objects and advantages improved means for generating oscillations of the specialized wave shapes effective for generating a variety of tones of different timbre or musical quality.

Many attempts have been made to generate electrical oscillations having wave forms that are effective imitations of the tonal qualities of the human voice and known musical instruments, but even the most elaborate and expensive equipment still leaves much to be desired along that line, in the opinion of persons of advanced aesthetic standards. At the same time, many of the less expensive electronic musical instruments produce results that are much worse, sometimes even repulsive to the highly cultivated ear.

One of the systems that has achieved some measure of success generates a basic wave of saw-tooth form and attempts to develop the various desired wave forms out of it by means of combinations of filters. By this means a rough approximation to many tone qualities can be obtained, but with the limitation that filters can only remove harmonic components originally present, and therefore a frequency absent from the original impulse, or present in insufficient amount only, cannot be supplied by such means. U. S. Patent 2,233,948, issued March 4, 1941, on an invention of Winston E. Kock, indicates the general type of tone-forming equipment referred to.

The oscillator employed according to the invention also lends itself readily to the addition of an electronic vibrato effect in a very simple and dependable form.

In the accompanying drawings:

Figure 1 is an assembled block diagram of a portion of a musical instrument according to the invention;

Figure 2 is a diagram of the oscillator for one note, and six different wave-shaping units for modifying the oscillator wave shape, capable of delivering eight different wave shapes corresponding to eight different qualities of musical sound;

Figure 3 is a diagram illustrating the types of wave shape obtainable from equipment according to Figure 2;

Figure 4 is a wiring diagram of an oscillator provided with means for producing a vibrato;

Figure 5 is a wiring diagram of the same oscillator with a different vibrato means;

Figure 6 is a wiring diagram of the same oscillator with a third vibrato means;

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Figure 7 is a perspective, partly in section, of a voltage-sensitive resistor; and

Figure 8 is a section of a selenium rectifier.

In the embodiment of the invention selected for illustration, and referring first to Figure 1, there are indicated three tone-generating units 10, 12 and 14. Each of these units may be a conventional Hartley oscillator, which is a type well known to those skilled in the art. Each oscillator delivers a wave of dependably constant frequency and substantially sine curve shape. A complete organ bank would call for 61 or 73 or 85 such oscillators, one for the pitch corresponding to each note to be produced.

The output from each of the oscillators 10, 12 and 14 is connected to each of six wave-shaping units 16, 18, 20, 22, 24 and 26. As the arrangement requires all six shaping units in connection with each oscillator, it will be apparent that a complete organ bank involves a large number of wave-shaping units, and accordingly the cost of the individual wave-shaping unit becomes a rather critical consideration. More specifically, whether or not it is necessary to use a vacuum tube in each wave-shaping unit becomes a decisive factor, so far as cost is concerned.

It is well known in the art that an acoustical wave of sine curve shape produces a very dull tuning-fork effect on the ear and is of very little musical interest.

Figure 2 indicates the details of the wave-shaping units 16, 18, 20, 22, 24 and 26. The wave-shaping unit 16 receives the sine curve wave from the oscillator and passes it in succession through protective resistor 28, selenium rectifying plate 30 and resistor 32 to the collecting bus B_1.

Since the selenium rectifying plate passes current freely in one direction and has a relatively high resistance to the passage of current in the opposite direction, the oscillation impressed on bus bar B_1 will have substantially the wave form of Figure 3A. When the bank switch 33 (see Fig. 1) connects bus B_1 through the amplifier 34 to the loud speaker 36, the notes delivered to the loud speaker will have this wave shape, which corresponds to the violin diapason note of a pipe organ. Thus, by closing the bank switch 33 and manipulating the individual note contacts 38, which are actuated by the individual keys of the keyboard, any selected plurality of notes of violin diapason timbre are delivered simultaneously to the loud speaker as the artist plays.

For convenience in discussing the functioning of the parts involved, rectifying means, considered in connection with the specific functions described in this invention, may conveniently be referred to as of two sorts, substantial and absolute. The well-known selenium rectifying plate has a very low resistance in one direction, but in the other direction it still conducts current, with a resistance that may be from 50 to 5,000 times as great as in the low-resistance direction. However, a diode or triode vacuum tube can be made to conduct current easily in one direction and not at all in the opposite direction. Such a rectifier is an absolute rectifier, and the characteristics with respect to which it differs from a substantial rectifier are advantageous in some combinations and disadvantageous in others.

The circuit to bus B_2 differs from that to bus B_1 only in taking the oscillation coming through the rectifier plate 30 through a capacitor 40 instead of through resistor 32. This has the effect of emphasizing the higher harmonics a little at the expense of the lower ones, and the effect on the ear is that of an ordinary violin. A typical wave shape as recorded by an oscillograph for this shape is shown in Figure 3B. In both instances the circuit is connected to ground between plate 30 and the next element, through a load resistor 42.

An effective reed tone is produced by wave-shaping unit 18. In this unit the wave is passed through resistor 44, rectifying plate 46 and capacitor 48 in series. The portion of the circuit between plate 46 and capacitor 48 is not grounded as in unit 16, but through resistor 50 and a self-biasing network consisting of the capacitor 52 and a resistor 54, connected in parallel between resistor 50 and ground. Such a combination holds the adjacent portions of rectifier 46 and capacitor 48 at ground potential when no energy is flowing, but an oscillating voltage builds up D. C. potential for these parts, so that the rectifier plate does not conduct except during the short period of time when the instantaneous voltage from the oscillator is greater than the D. C. bias. The result is a wave shape as illustrated in Figure 3C. This wave produces a very good reed-like tone and is indicated as collected on the bus bar B3. It is particularly lifelike because, for a fraction of a second at the beginning of each note, the timbre is changing as the bias is built up.

The wave-shaping unit 20 is for producing a tone of stopped diapason or stopped flute timbre. The incoming sine wave passes through resistor 56 and then through a voltage-sensitive resistor 58. For clarity in the drawings, each voltage-sensitive resistor is further characterized by the letters "VS" close beside it. Such a resistor has the characteristic that its resistance decreases with a characteristic rate of decrease as the impressed voltage increases. This is not a thermal phenomenon, with a time lag to change its temperature, but occurs instantaneously and contemporaneously as a function of the voltage. The voltage levels at which the decrease occurs and the amount and abruptness of decrease can be controlled by the design of the resistor. More particularly, the resistor is of granular silicon carbide with a ceramic binder, fired at high temperature. The ratio of carbide to binder and the grain size and dimensions of the plate control the high and low resistance values and the abruptness of the variation. After passing through the resistor, the circuit is the same as for bus bar B_1, through the final decoupling resistor 60 with the grounded load resistor 62 connected to the circuit between parts 58 and 60. For best results we select a voltage-sensitive resistor that reduces its resistance during about the middle of the impressed sine curve voltage and delivers extra current momentarily, so that the issuing wave, as illustrated in Figure 3D, has a central bump 64 in the middle of each excursion. In successful installations we employ voltage-sensitive resistors 58 that have a resistance of the order of magnitude of one or two megohms at about 4.5 volts, but at about 9 volts its resistance may drop to about 200,000 ohms or so. Harmonic analysis of this wave form yields the odd-order harmonics in relatively large proportions, with the even harmonics substantially absent, and the effect on the ear is rather precisely that of the stopped diapason timbre of an ordinary pipe organ, which is indicated in Figure 2 as collected on bus bar B_4.

The unit 22 employs a voltage-sensitive resistor, with a different silicon carbide plate. By substituting a plate of lower resistance and more abrupt resistance drop, we have discovered that a clarinet-type tone results. The difference is also shown by the oscillograph, which gives a curve according to 3E. In unit 22, the incoming sine wave passes through the resistor 64, voltage-sensitive resistor 66 and capacitor 68 to emphasize the higher harmonics, with the grounded load resistor 70 connected to the circuit between 66 and 68. This tone is collected on bus B_5.

In unit 24 the incoming sine wave passes through the resistor 72 and voltage-sensitive resistor 74. The voltage-sensitive resistor 74 is given constant D. C. bias, available in advance of the instant the circuit begins to function, as by means of a biasing battery 76 inserted between ground and the load resistor 78. If the resulting oscillation is delivered through a resistor 82, indicated as connected to bus B_7, the wave form is according to Figure 3G, and the effect on the ear is that of the melodia, or open flute tone of a pipe organ. Alternatively, if the wave is delivered to bus B_6 through capacitor 80, the lower harmonics are relatively reduced, and the higher harmonics increased, to give the wave form of Figure 3F and the effect of the open diapason stop on a pipe organ.

A woodwind tone of very pleasing character is produced in unit 26. The oscillograph wave form is indicated in Figure 3H. The incoming sine wave passes through resistor 84, and a double set 86 of selenium rectifiers connected in series and in opposition, and thereafter through resistor 88 to the bus bar B_8, with the circuit between 86 and 88 grounded through load resistor 90.

It will be obvious that various combinations of the above circuits can be simultaneously delivered to the loud speaker by the person playing the instrument, by simply connecting several of the different busses to the amplifier all at the same time. Also, other combinations of the variable resistor and selenium plate may be arranged to give additional wave forms.

In this connection, it is emphasized that, while the oscillograph shapes of Figure 3 are those actually obtained, and while they have been included herein to make the disclosure as complete as possible, waves of identical aesthetic characteristics may appear on an oscillograph with shapes that are highly different to casual inspection. This is because the human ear has no perception of phase differences between the harmonic components of the wave. Thus two waves that produce a substantially identical impression on the cultivated ear may look entirely different on the oscillograph, but if the oscillograph wave is resolved into a Fourier series, and the amplitudes of all its harmonic overtones are computed, independent of phase, it will be found that the two wave shapes contain approximately the same overtone ingredients, thus establishing that the difference in the recorded shape is due to phase of differences only. For instance, the bumps 64 of Figure 3D presumably are the other side up at the receiving end of the voltage-sensitive resistance 58, but by the time the oscillation has gone on through the rest of the circuit and through the circuits of the oscillograph itself, the phase has usually shifted enough to give the curve indicated.

The Hartley oscillators 10, 12 and 14 may be conventional. In Figure 2 we have indicated the basic frequency circuit, made up of an inductance 92 and a capacitor 94 connected in a closed loop and grounded at 96.

Referring now to the means for producing a vibrato, conventional means is indicated at 112 in Figure 1 for varying the potential of bus bar B_9 with respect to ground at a frequency of six or seven vibrations per second.

Referring now to Figure 4, it will be obvious that the frequency characteristics of the circuit containing the inductor 92 and capacitor 94 may be varied by changing the constants of the circuit with respect to either the capacitance or the inductance, and most conveniently by changing the capacitance. In Figure 4 we have indicated a capacitor 114 connected to point 110 and through a neon tube 118, to ground. Between capacitor 114 and tube 118 the circuit is connected through resistor 120 with bus bar B_9. Thus, with bus bar B_9 unbiased, the frequency of the oscillation may be tuned to the pitch desired. But if the operator connects bus B_9 to the variable potential source 112, as by means of panel switch 122, bus bar B_9 assumes a voltage which fluctuates at the desired low frequency. This renders the capacitor 114 effective whenever the potential rises to the point where tube 118 becomes conductive and hence a low resistance. It is possible with equipment as in Figure 4 to develop an effective vibrato.

In Figure 5 we have illustrated a capacitor 124 corresponding to capacitor 114 and connected to bus bar B_9 through a resistor 126. But the ground connection is through a voltage-sensitive resistor 128. This arrangement gives a very pleasing and smooth vibrato.

A different arrangement is indicated in Figure 6. The potential of the bus B_9, of course, oscillates with respect to ground, and the point 110 is connected to bus B_9 through a capacitor 130 shunted by resistor 132, and with this loop in series with a selenium rectifier 134 arranged in the direction to permit current to flow when the bus has a positive potential. This arrangement produces a smooth, pleasant vibrato. Furthermore, the selenium rectifier can be replaced with one of copper oxide or with a voltage-sensitive resistance of fairly high value. A diode or triode connected to function as a rectifier will also work, but of course it is much more expensive from both the standpoint of initial cost and cost of operation.

One form of voltage-sensitive resistor with which good results have been secured, is illustrated in Figure 7. It comprises a disk 136 of granular silicon carbide mixed with ceramic binder and fired at high temperature, with metal conducting plates 138 affixed to both sides. We have illustrated the plates 138 plated on the silicon carbide disk and soldered to wire connectors 140 and 142. The voltage-sensitive resistor is non-polar, i. e., its resistance characteristics are identical regardless of the direction of the applied voltage. The variable resistance is also single-valued and non-linear. It is single-valued in the sense that, at any applied voltage, there is only one corresponding resistance, regardless of whether the previous voltage was higher or lower. It is non-linear in the sense that the change in resistance divided by the corresponding change in voltage is not a constant.

Referring now to Figure 8, one form of rectifier with which satisfactory results have been obtained is a simple tube 144 of insulating fiber threaded at both ends to receive a metal top plug 146 and bottom plug 148. For convenience in assembly, both plugs may be slotted to receive a screwdriver. External leads 150 and 152 are convenient for connecting the device into a circuit. Inside the tube 144 we provide a thin metallic plate 154 having a small central boss or tit abutting the plug 148. The annular space around the boss is filled in with an insulating washer 158.

The boss consists of a layer 155 of selenium and a layer 156 of Wood's metal. A light compression coil spring 160 bears at its upper end against the plug 146 and at its lower end against the plate 154. This keeps the boss 156 in effective contact with the plug 148 and establishes an electrical connection through the device. A convenient size for such a device is about a quarter of an inch in diameter and three-fourths of an inch long. In such small sizes it is convenient to form the plate 154 by stamping it out of a large plate, one side of which has previously been coated with selenium and then with Wood's metal. Then the disk is placed in a small lathe and turned down to final shape This leaves a contact area ample for the extremely small currents involved, and at the same time reduces the condenser action at the contact surface to a very minor fraction of what it would be if the contact surface were the entire area of the plate 154.

Such a device has a low conductivity when the terminal 150 is negative and relatively high conductivity when that terminal is positive. In the wiring diagrams the arrow points in the direction of low resistance conductivity.

Values that have been satisfactory in practical operation are as follows:

Resistor 28	0.025 meg.
Resistor 32	0.1 meg.
Capacitor 40	0.0025 mf.
Resistor 42	0.2 meg.
Resistor 44	0.025 meg.
Capacitor 48	0.0025 mf.
Resistor 50	0.03 meg.
Capacitor 52	0.01 mf.
Resistor 54	0.03 meg.
Resistor 56	0.025 meg.
Voltage-sensitive resistor 58	2.0 meg. to about 0.2 meg.
Resistor 60	0.25 meg.
Resistor 62	0.033 meg.
Resistor 64	0.025 meg.
Voltage-sensitive resistor 66	0.1 meg. to about .01 meg.
Capacitor 68	0.0005 mf.

Resistor 70	0.025 meg.
Resistor 72	0.025 meg.
Voltage-sensitive resistor 74	about 2.0 meg. to about 0.2 meg.
Resistor 78	0.033 meg.
Capacitor 80	0.0005 meg.
Resistor 82	0.25 meg.
Resistor 84	0.025 meg.
Resistor 88	0.025 meg.
Resistor 90	0.1 meg.
Capacitor 94	0.75 mf. for 440-cycle tone
Capacitor 114	0.02 mf.
Neon tube 118	General Electric type NE 2
Resistor 120	0.25 meg.
Capacitor 124	0.02 mf.
Resistor 126	0.25 meg.
Voltage-sensitive resistor 128	about 2.0 meg. to about 0.02 meg.
Capacitor 130	0.02 mf.
Resistor 132	0.15 meg.

Complete electronic organs according to the invention are in successful operation. In addition to the low cost due to the absence of tubes in the wave-shaping units, equipment according to the invention is remarkably durable in service and requires a minimum of adjustment, even after prolonged use.

Others may readily adapt the invention for various conditions of service by employing one or more of the novel features disclosed or equivalents thereof. As at present advised with respect to the apparent scope of our invention, we desire to claim the following subject matter.

We claim:

1. In an electronic musical instrument of the type embodying means for amplifying an electrical oscillation and generating a sound wave of corresponding wave shape; electronic equipment for generating an oscillation of predetermined wave form corresponding to predetermined tonal characteristics in the resulting sound wave, comprising, in combination: generating means comprising an oscillator for generating an electrical oscillation of substantially smooth shape and of the same frequency as the fundamental frequency of the desired sound wave; distorting means including no discharge device and comprising a surface contact rectifier connected to receive the output of said generating means, whereby the wave form of the oscillation is distorted to increase its complexity; a loud speaker; and connections for energizing said loud speaker according to the distorted oscillation.

2. Equipment according to claim 1, in combination with biasing means operatively connected to said distorting means.

3. Equipment according to claim 2, in which said biasing means is normally inoperative and is rendered operative by the input signal.

4. Equipment according to claim 1, in which said distorting means comprises two surface contact rectifiers connected to receive the output of said oscillator in opposite polarity.

5. Equipment according to claim 1, in which a set, or plurality, of different distorting means are all connected in parallel to receive the output of said oscillator; said different distorting means producing different distorted wave shapes, all of the same fundamental frequency; in combination with a plurality of similar oscillators and sets of distorting means, of various frequencies; a plurality of bus bars; each bus bar connected to receive the output of similar distorting means associated with all of said oscillators; and player-controlled connections for connecting any selected combination of bus bars to said loud speaker.

6. Equipment according to claim 1, in which said oscillators are normally inoperative, in combination with player-controlled key means for delivering plate voltage to render them operative.

7. In an electronic musical instrument of the type embodying means for amplifying an electrical oscillation and generating a sound wave of corresponding wave shape; electronic equipment for generating an oscillation of predetermined wave form corresponding to predetermined tonal characteristics in the resulting sound wave, comprising, in combination: generating means comprising an oscillator for generating an electrical oscillation of substantially smooth shape and of the same frequency as the fundamental frequency of the desired sound wave; distorting means including no discharge device and comprising a non-linear voltage-sensitive resistance connected to receive the output of said generating means, whereby the wave form of the oscillation is distorted to increase its complexity; a loud speaker; and connections for energizing said loud speaker according to the distorted oscillation.

8. Equipment according to claim 7, in which said generating means comprises a Hartley oscillator, and delivers an oscillation having the shape of a substantially perfect sine curve.

9. Equipment according to claim 7, in which said non-linear resistance is bi-directional and has a resistance that decreases with increased voltage to a fraction of its resistance at low voltage.

10. Equipment according to claim 7 in combination with biasing means operatively connected to said distorting means.

11. Equipment according to claim 7, in which said oscillators are normally inoperative, in combination with player-controlled key means for delivering plate voltage to render them operative.

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