March 7, 1950 W. O. CRANE 2,500,063

ELECTRIC SIREN

Filed Nov. 26, 1945 2 Sheets-Sheet 1

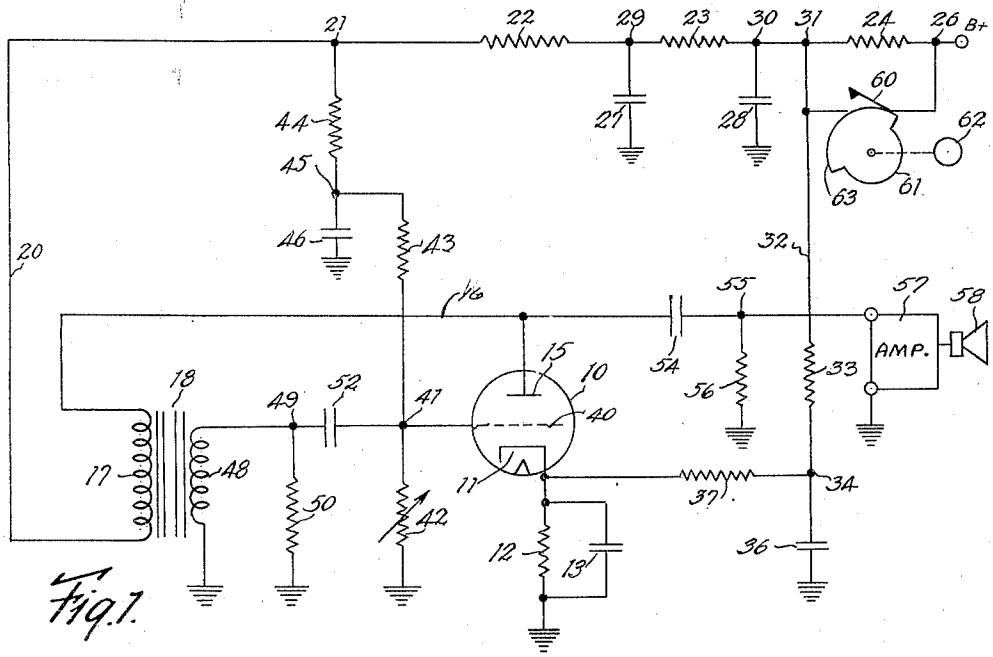

Fig. 1.

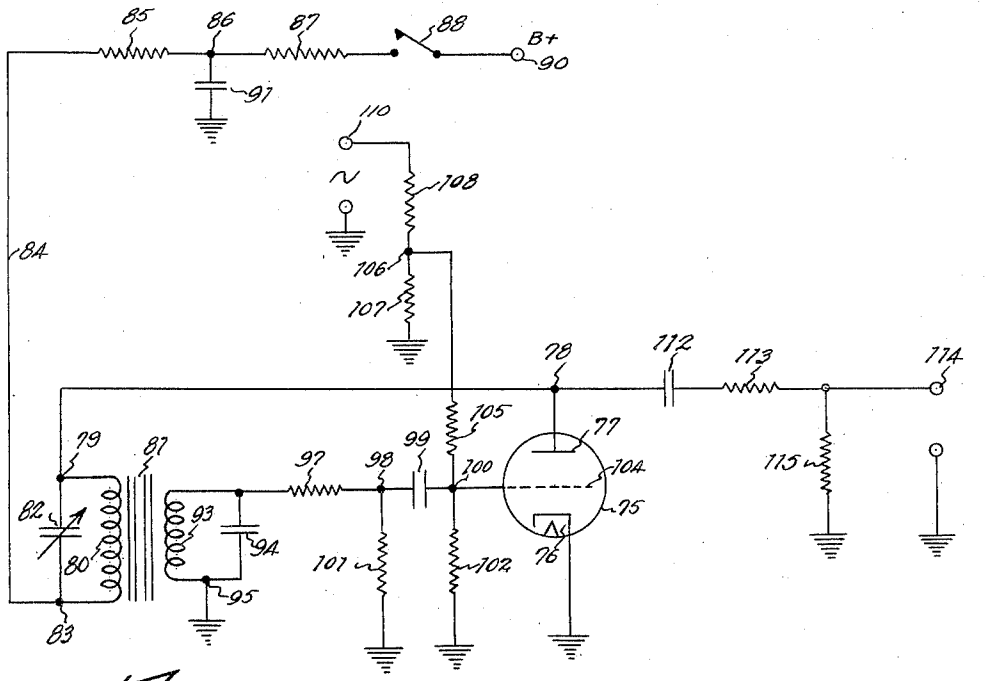

Fig. 3.

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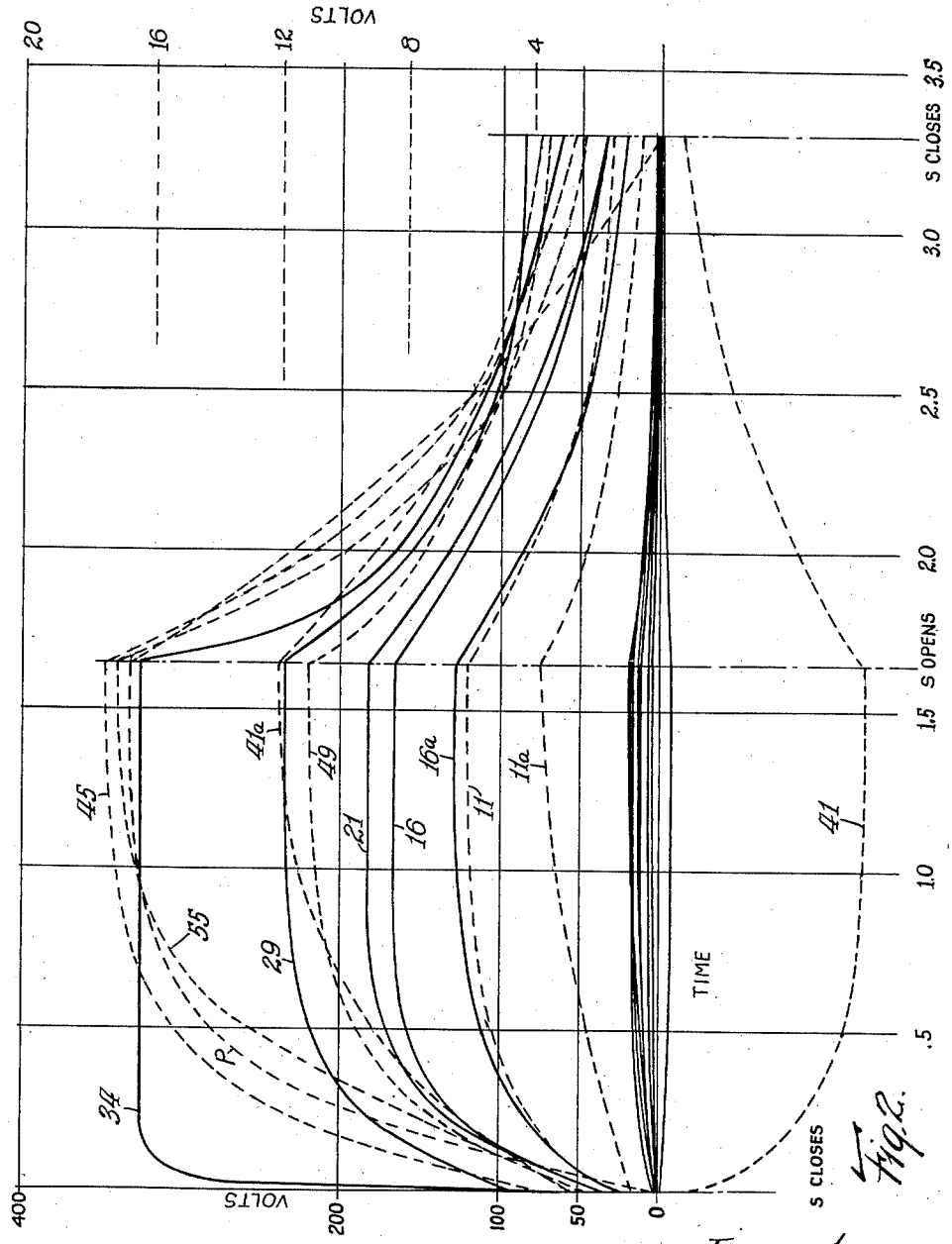

Fig. 2.

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UNITED STATES PATENT OFFICE

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ELECTRIC SIREN

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5 Claims. (Cl. 250—36)

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This invention relates to an electrical apparatus and particularly to a generator of sound currents which vary in frequency and amplitude in a manner corresponding to sound waves in a siren. In sirens, a variable pitch is generated with the apparent volume of the sound increasing with pitch. Sirens of this type are used for signalling purposes. In many places, it is desirable to provide a simple electric siren which will simulate ordinary sirens and which may be used in connection with loud speakers. Thus, ships and war vessels have loud speakers as part of public address systems. It is highly desirable to provide means for utilizing such loud speakers to provide siren tones in times of danger, as warning signals or the like.

In order to obtain a true siren effect, it is necessary that a substantial frequency variation of emitted sound be provided, that such variation occur at a relatively slow rate and that the intensity of sound appear to increase with increase in pitch. The frequency variation itself should be continuous from a minimum value to a maximum value and back again, A complete frequency variation cycle, hereinafter referred to as a siren cycle, is relatively slow and may have a duration of the order of from about one second to four seconds. The actual sound energy with increase in freuqency need not necessarily increase, although it is necessary that listeners think so. Thus, the same sound energy at a low frequency will not sound as loud and will not be as piercing as at a higher frequency. However, the sound energy with increase in frequency should not decrease to the point where the siren effect is lost. Preferably, the actual power output should increase with frequency.

While various means for obtaining different frequencies are known, a simple and effective generator of siren current waves has hitherto not been available. Inasmuch as sirens are used generally in times of danger, it is essential that the system as a whole be fool-proof, dependable and be simple. From the point of view of cost and service, it is desirable that a system of this character have a minimum of components and use standard parts as much as possible.

In accordance with the invention, there is provided a system which is simple, has relatively few components, substantially all of which are standard components in audio and radio frequency work. A system embodying the present invention is not critical, requires no critical adjustments, and may be easily adjusted to suit different requirements with regard to pitch, volume variation and performance in general.

In accordance with the invention, an audio frequency oscillator is provided, which oscillator utilizes the non-linear characteristics of vacuum tubes and also iron-core transformers. In addition thereto, circuits are provided in which relatively slow transient effects are utilized for controlling the oscillator. By utilizing transient phenomena, a slow variation of potential available in an oscillator may be provided. While either the transient effect and the non-linear reaction may be relied upon independently for generating sound waves as warning signals, it is preferred to combine the two in a siren.

The invention will now be described in connection with the drawings wherein exemplary embodiments are disclosed, it being understood that this is merely illustrative and may be modified within wide limits. In the drawings, Figure 1 is a circuit diagram of a siren system. Figure 2 shows some characteristic curves for the system of Figure 1. Figure 3 is a circuit diagram of a warning system wherein the frequency is fixed.

Referring to Figure 1, vacuum tube 10 has cathode 11 connected to ground through bias resistor 12. Bias resistor 12 may be shunted by by-pass condenser 13 to prevent cathode degeneration. Vacuum tube 10 has anode 15 connected to lead 16 going to primary 17 of transformer 18. Transformer 18 is of the iron-core type and preferably is so designed that the iron core readily saturates. The core is preferably of Mu-metal or other ferromagnetic metal having a sharp knee on the B—H curve. Primary 17 is connected through lead 20 to junction point 21. From junction point 21, a connection goes to resistors 22 to 24 inclusive, all in series, and thence to junction point 26 for connection to a source of B plus voltage. Grounded condensers 27 and 28 are connected to junction points 29 and 30 respectively between resistors 22 and 23 on the one hand and 23 and 24 on the other hand. From junction point 31 between resistors 23 and 24, lead 32 is connected to dropping resistor 33, thence to junction 34. Junction 34 has by-pass condenser 36 connected to ground, this condenser having substantial capacitance. Junction 34 is connected to cathode 11 through resistor 37.

Going back to vacuum tube 10, control grid 40 is connected to junction point 41. Junction point 41 is connected to ground through variable resistor 42 and is also connected by resistors 43 and 44 in series to junction 21. Junction 45, between resistors 43 and 44, is connected to grounded by-pass condenser 46, this condenser having substantial capacitance.

Transformer 18 has secondary 48 with one terminal grounded, and the other terminal connected to junction 49. Junction 49 has resistor

50 connected between it and ground, this resistor providing a load for the transformer secondary. Between junctions 49 and 41, condenser 52 is provided, this condenser having suitable capacitance for determining the resonance characteristics of the grid circuit. This also functions as a blocking condenser.

Lead 16 is connected to condenser 54, the other terminal of this condenser being connected to junction 55. Resistor 56 is connected between junction 55 and ground. Junction 55 forms an output terminal for connection to amplifier 57 with the output of the amplifier going to speaker 58. Speaker 58 is preferably a loud speaker having sufficient power handling ability to provide proper siren effects.

Shunted across resistor 24 is switch 60 which may be opened and closed by any suitable means. A switch opening and closing cycle will determine a siren cycle so that the opening and closing of switch 60 may be carried on at a relatively slow rate. Thus, for automatic operation, switch 60 may be opened and closed by cam 61 driven from motor 62. Cam 61 has rise 63 extending for 180 degrees so that, for one revolution of cam 61, switch 60 is closed half of the time and open half the time. Cam 61 may make about fifteen revolutions per minute so that switch 60 will be closed for two seconds and open for two seconds. It is not necessary that a siren cycle be divided into equal parts. It is understood, however, that the time of switch operation may be varied and other means for shorting out resistance 24 may be provided. Thus, resistance 24 may be the plate to cathode resistance of an electron discharge tube. Switch 60 may be replaced by bias control means on a control grid. When the grid potential of an electron discharge tube is positive or about equal to that of the cathode, the plate to cathode resistance will be low and may be considered negligible for all ordinary purposes. This would correspond to a closed switch condition. With the grid bias made negative to the cathode but above cut off, the anode to cathode resistance may be adjusted to any desired high value.

Resistance 24 is preferably large in comparison to resistors 22 and 23. Condensers 27 and 28 are also large and of the order of filter condensers in the power supply of an average radio receiver. Resistors 43 and 44 are preferably high enough so that, together with resistance 42, the bias of control grid 40 may be adjusted to a point above cut off. Transformer 18 has a step down ratio of the order of ten to one, it being understood that the secondary voltage is about one-tenth of the primary.

In a typical system, the various elements have the following values:

Resistor 12, 1,500 ohms
Resistors 22 and 23, 25,000 ohms each
Resistor 24, 430,000 ohms
Resistor 33, 20,000 ohms
Resistor 37, 350,000 ohms
Resistor 42, up to 20,000 ohms
Resistor 43, 36,000 ohms
Resistor 44, 300,000 ohms
Resistor 50, 430,000 ohms
Resistor 56, 12,000 ohms
Condensers 27 and 28, 4 m. f. each
Condensers 36 and 46, 1 m. f. each
Condenser 52, .5 m. f.
Vacuum tube 10, 6SN7 (both sections in parallel)

Transformer 18 has a laminated core of Mumetal. Primary 17 has an inductance of 7.5 henries at 1000 cycles per second with a primary to secondary ratio of ten to one. The transformer is so designed that the inductance change shall be at least 80% when measured under the conditions of zero D. C. in the primary and 3 milli-amperes in the primary and computed by dividing the difference between the two inductance values by the inductance at 1.85 milliamperes. The connections of the primary and secondary are so chosen that, when a voltage is applied across primary 17, the potential between the primary terminal connected to line 16 and the secondary terminal connected to ground should be the sum of the primary and secondary voltages. The primary has 3610 turns of number 40 wire, while the secondary has 361 turns of number 36 wire. The core is a shell type with F laminations. The stack is $\frac{7}{32}$'' high and measures $1\frac{3}{16}$'' x 1⅛''. The window is ¾'' x ¼''.

To energize the above system, a voltage of 300 was applied between terminal 26 and ground.

Referring now to Figure 2, some characteristic curves in connection with the typical system of Figure 1 is given. The curves in full lines are drawn to a voltage scale shown at the left, while the curves in dotted lines are drawn to the scale shown at the right. The horizontal axis shows time in seconds with switch 60 closed at zero time and opened at around 1.67 seconds after zero time. The numbers on the curves show the voltage with respect to ground of the points in the circuit bearing the corresponding numbers.

Thus, curve 34 shows the comparatively sharp rise in voltage upon closure of switch 60. Curve 29 shows the rise in voltage at point 29, this being with respect to ground as previously indicated. Curve 21 shows the voltage rise at point 21. This shows the additional filtering action of the various condensers. Curve 16 shows the voltage at the anode of vacuum tube 10. All the preceeding curves show direct current voltages.

Curve 16*a* shows the envelope of alternating potential at anode 15. It is understood that the actual potential oscillates around the zero potential line with the frequency of oscillations varying between the limits previously given.

The remaining curves and solid lines crowded near the zero axis are merely shown to the same scale as the preceeding curves for purposes of ready comparison. These curves have been reproduced to a larger scale and are shown in dotted lines. Thus, curve 45 shows the direct current potential at point 45. Curve 55*a* shows the envelope of the alternating potential at the point bearing the corresponding number. Curve 41*a* shows the envelope of the alternating current potential at point 41 which, in effect, is control grid 40. Curve 49*a* gives the alternating potential envelope at the high side of transformer secondary 48. Curve 11 shows the direct current potential at the cathode of vacuum tube 10, while curve 11*a* shows the envelope of the corresponding alternating potential. Curve 41 shows the direct current potential at the grid input. Curve P shows the power output in decibels at terminal 55. The scale at the right is used for this curve, although it is understood that the scale does not refer to volts but is merely an abstract number.

At the opening of the switch, the decay of the various curves is clearly indicated. It is clear from the curves that the rise in absolute value at the time of the closure of the switch of the various voltages is somewhat faster than

the decay of these same voltages at the opening of the switch. It will be noted from curves 45 and 41 that the relative bias potential of the control grid with respect to the cathode drops in an algebraic sense. Thus, just prior to switch closure, the control grid is biased to about two volts negative to the cathode. Just prior to the opening of the switch, the grid potential is about 12 volts negative with respect to the cathode.

In general, this change in grid bias is due to the increase in amplitude of oscillations at the secondary of transformer 18. It is clear that, on a positive swing of control grid 40, a comparatively low resistance discharge path through the vacuum tube to ground will be provided for condenser 52. On the other hand, on the negative swing of control grid 40, the time constant of the discharge path of condenser 52 will be increased. Thus, after closure of the switch, the oscillations generated by vacuum tube 10 in conjunction with transformer 18 will be similar to that of a blocking oscillator and gradually charge condenser 52 so that grid 40 becomes increasingly negative.

It is clear, however, from the shape of the various curves that, unlike a blocking oscillator, the system will continue oscillating indefinitely with the switch either open or closed. With the switch closed, the amplitude of oscillations builds up, thus increasing the power output of the system. The increased current flow through the primary of transformer 18 will decrease the inductance of the transformer and thus tend to raise the natural frequency of oscillations. The closure of switch 60 results in higher potentials being impressed on vacuum tube 10. As a result, the amplifying factor of the vacuum tube is changed, and the amplitude of oscillations is increased.

Upon opening of switch 60, a reverse action ensues, and conditions return to those existing just prior to the time when the switch was closed. Due to the decreased potential and the discharge of the various condensers, transformer 18 tends to reduce the natural frequency of the system. At the same time, the amplitude of oscillations in vacuum tube 10 decreases. As will be apparent from curve P, the decrease in power at the output of the system is slower than the rise in power when the switch is first closed. Thus, the volume of sound of the siren increases with increase in pitch, the increase being faster than the decrease.

While the values of the various components may be varied over wide limits, it will be observed that the siren provides two substantially different conditions in an oscillator. Under one condition, when the pitch and volume are at a minimum, the applied voltage at the system is comparatively low, resulting in maximum inductance at the feedback transformer and minimum voltage amplitude. When power and frequency are a maximum, the applied voltage to the system is a maximum with inductance at the feedback transformer reduced to a minimum and the amplitude of oscillations at a maximum. In general, while the various components may be adjusted to various values, it is preferred to have the time constants of the cathode, grid and anode circuits all about the same value and substantially less than the period of a complete siren cycle. As shown here, the time constant of the various cathode, anode and grid circuits are of the order of about one-tenth of the period of a siren cycle. This may be varied to

be somewhat larger or smaller, depending upon desired operating conditions.

Best results in approximating a siren tone have been obtained by so designing the system that the output energy, as indicated by curve P, has as much of a linear rise and drop as possible. As will be noted from the curves, the decay is more linear than the rise. Also, it is preferred to have the variation of power with respect to time greater on the rise than on the fall. However, the variation of power and pitch should be slow enough to be audibly sensible. In other words, the slope of the rise on curve P is substantially greater than the slope of the fall of this curve after the switch is opened. A linear rate of the logarithm of power variation appears to be desirable. Thus, a db. curve should have a generally linear rise and fall. The purpose of this is to simulate a motor-driven siren. On the speed-up of the siren, the motor increases its speed faster than on the reverse portion of the cycle where the mechanical system would tend to coast.

It it understood that the saturating effects present in transformer 18 and the disposition of the secondary in the grid input circuit, together with transient effects, will tend to prevent the generation by vacuum tube 10 of any pure sine wave. In other words, the system does not generate oscillations having a sinusoidal wave shape at the resonant frequency. It has been found that the entire system when operating is rich in harmonics as is true in over-excited oscillators. This is particularly true of the clipping action in the grid circuit on positive and negative swings. In particular, condenser 54 and resistance 56 may be considered as comprising a filter section for emphasizing a harmonic. In the example given, the values are such that a third harmonic is particularly emphasized.

As a rule, only odd harmonics are present in the output circuit. This is believed to be due to grid clipping on both positive and negative swings. When the grid goes positive, the low grid to cathode resistance effectively shorts resistance 42. The entire circuit involving the secondary of transformer 18 has the frequency determining constants changed sharply. During the part of the cycle when the grid is positive, transformer 18 is believed to saturate. This is particularly true when switch 60 is closed, impressing a high voltage on both the transformer primary and vacuum tube. The saturation of transformer 18 occurs over a larger part of a cycle under these high voltage conditions. Thus, the transformer and oscillator both introduce distortion during a part of each cycle of oscillation.

In the system given above, the frequency when switch 60 is closed is around 1200 cycles per second and, when the switch is opened, the frequency drops to around 600 cycles per second. By variation of resistance 42, the range of frequency between the maximum and minimum may be controlled. The value of condenser 52 has an effect on the resonant frequency.

It is evident that switch 60 may be retained in either open or closed position and the entire system be energized or deenergized for use as the generator of a simple constant frequency warning signal. However, where a single output frequency is desired to simulate a motor-driven horn rather than siren, the circuit may be simplified somewhat as shown in Figure 3.

Referring now to Figure 3, vacuum tube 75 has cathode 76 grounded, while anode 77 is connected to lead 78. Lead 78 is connected to terminal 79 of primary 80 of iron core transformer 81. Primary 80 has condenser 82 shunted across. Terminal 83 of primary 80 is connected by lead 84 to resistance 85. Resistance 85 is connected through junction 86 to resistance 87 and thence, through switch 88, to B plus terminal 90. Grounded condenser 91 is connected to junction 86.

Transformer 81 has secondary 93 shunted by condenser 94, one terminal of the secondary being grounded at 95, while terminal 96 is connected through resistance 97 to junction 98. Junction 98 is connected through condenser 99 to junction 100. Grounded resistors 101 and 102 are connected to junction 98 and 100 respectively. Vacuum tube 75 has control grid 104 connected to junction 100, this junction also being connected through resistance 105 to junction 106. Junction 106 has resistors 107 and 108 connected on each side thereof and thus forms a potential dividing network. Resistance 107 is grounded, while resistance 108 is connected to terminal 110. Terminal 110 anad ground are adapted to be supplied by a 60 cycle source of alternating current.

Lead 78 is connected by condenser 112 and resistance 113 to output terminal 114. Resistance 115 is connected between ground and the output terminal.

Transformer 81 may have a step-down ratio substantially the same as that of Figure 1. Since the system operates at a fixed frequency, any transformer having the inductance for determining a desired frequency may be used.

In practice, load resistors 85 and 87 need not have a very high value and may be of the order of between 5000 and 10,000 ohms each. Condenser 91 preferably has substantial capacitance of the order of about .5 m. f. Condenser 82 may be variable and, in practice, may be any one of a number of fixed condensers controlled by a suitable switch. Condenser 82 has a comparatively small capacitance of the order of .01 m. f. Condenser 94 on the other hand has a higher capacitance of the order of .1 m. f. Resistance 97 is not very large as a rule, being somewhat over 5000 ohms. Condenser 99 may have a capacitance of the order of 0.5, while resistance 101 and 102 may each be about one-half megohm. Resistance 105 is quite high of the order of about one megohm, while resistance 107 and 108 may be smaller such as about 300,000 ohms each. The actual ratio of values of 107 and 108 will be determined by the operating bias on control grid 104.

Vacuum tube 75 may be type 6SN7. Condenser 112 is fairly small such as .05 m. f., while resistance 113 may be of the order of 50,000 or 75,000 ohms. Resistor 115 may be of the order of 10,000 or 12,000 ohms.

With a B supply of about 300 volts and a 60 cycle signal of about one volt on the tube grid, a system having the values previously given will oscillate between about 400 and 500 cycles per second. The 60 cycle signal or any other suitable signal merely provides noise background. The output filter consisting of condenser 112 and resistances 113 and 115, in this particular instance, tends to pass the seventh harmonic. An amplifier and speaker may be provided for utilizing the output voltages.

The output from terminal 14 may be fed into an amplifier having any desired selective frequency characteristics and, thereafter, fed to a suitable speaker.

The system shown in Figure 3 in general operates as an over-excited oscillator in much the same manner as the system of Figure 1 with switch 60 in one position. In both systems, the grid of the oscillator goes positive. The grid also goes negative below cut-off in both systems. In general, it is preferred to so design the circuits of Figures 1 and 3 that positive grid clipping is greater than negative grid clipping. In Figure 3, the transformer primary circuit is resonant to a definite frequency, while the secondary circuit has its constants altered by virtue of the grid going positive and shunting out resistor 102. In both systems, a form of frequency modulation during part of each cycle of the fundamental occurs. It is clear that, by controlling the various distortion characteristics, any desired harmonic, usually odd, may be particularly emphasized.

In general, however, the acoustic output from a speaker may be used to determine the system constants exactly. The harmonic analysis of distorted outputs is difficult to perform. Where a siren tone is desired, the exact effects may be duplicated by controlling the various RC circuits and listening to the speaker output. In general, however, the curves in Figure 2 will be a guide.

Thus, the invention provides an over-excited oscillator including a saturable transformer. RC circuits are provided to vary the degree of over-excitation. In the siren, the RC circuits for the tube electrodes all have substantially similar time constants under operating conditions. Thus, one circuit is bound to affect another circuit because of coupling.

It is understood that only during the positive portion of a cycle (on the control grid) will the transformer saturate if it saturates at all. When switch 60 is open, the current through the primary drops so that the transformer core works well below the knee of the B—H curve as far as the direct current component is concerned. After the switch has been closed, the direct current component may be sufficient to saturate the core. Of course, the alternating currents superimposed on the direct current component may cause the transformer core to go above or below the direct current operating point. Thus, the oscillator is always over-excited to provide harmonics. The fundamental is altered by moving the operating point of the transformer core, this being the point on the B—H curve due to the D. C. component. In practice, the effective inductance of the transformer need not necessarily vary. As a result of grid clipping, amplitude modulation of the output occurs. This, together with frequency variation with change in potential, results in warbling.

The multi-section filter to the primary tends to linearize the voltage rise or decay with change in condition of the switch. By careful control of the relationship between time constants in the anode, control grid and cathode circuits, different operating characteristics may be obtained. Thus, the instantaneous operating point of vacuum tube 10 may be varied due to difference in voltage variation between the potentials on the various tube electrodes. The over-all characteristics of the oscillator may be varied by controlling the relation between time constants in the various tube electrode circuits. In practice, the differences between time constants will be small compared to a siren cycle. The reason is that

the instantaneous operating characteristics of the system cannot change too fast or the ear will not detect the change in over-all output characteristics.

What is claimed is:

1. An audio frequency oscillator comprising a transformer having primary and secondary windings, a vacuum tube having cathode, grid and anode electrodes, a connection between said anode and one terminal of said primary, load resistors connected to the other terminal of said primary, at least one condenser of substantial capacitance connected between ground and said load resistors, the free terminal of said load resistors constituting terminals for connection to a source of direct current at high potential, connections disposing said secondary between said cathode and grid so that continuous oscillations may be generated, a voltage divider network connected between a load resistor and ground, said voltage divider network having an intermediate point thereon connected to said control grid and means for slowly switching a load resistor in and out of circuit, said load resistors and condensers together having a time constant about one tenth that of a switching cycle.

2. An audio frequency generator of siren tones comprising a vacuum tube having cathode, grid and anode, a transformer having primary and secondary windings with a step-down ratio, said secondary winding being connected across said grid and cathode, a connection from one terminal of said primary to said anode, a resistance condenser filter connected to the other terminal of said primary, said resistance condenser filter having terminals for connection to a source of direct current at high potential, means for impressing two substantially different voltages on said filter successively at regular intervals to provide a siren cycle, said filter having a time constant about one tenth that of a siren cycle so that the potential impressed upon said primary varies, said transformer windings being poled regeneratively as to maintain the vacuum tube continuously in oscillation, and an output circuit connected at the anode of said vacuum tube.

3. An audio frequency oscillator for a siren comprising a vacuum tube having cathode, control grid and anode, a grounded resistor connected to said cathode, a first condenser across said grounded resistor, a resistance and condenser in series between said cathode and ground, an iron core transformer having a saturable core under normal operating conditions, said transformer having a secondary providing a step-down ratio a third condenser connected between the control grid of said vacuum tube and one terminal of said secondary, the other terminal of said secondary being grounded, grounded resistors connected on opposite sides of said third condenser, a connection from one terminal of the primary of said transformer to said anode, a connection from the other terminal of said primary to a plurality of resistors in series and thence to a B plus terminal, said B plus terminal being adapted to be supplied with direct current at high voltage, the resistor adjacent the B plus terminal having a high value so that when it is shorted out the voltage at the anode of said vacuum tube may vary through a substantial range, means for cutting in and cutting out said last-named resistor adjacent the B plus terminal, grounded condensers connected between the junctions of said remaining resistors in series to provide a multi-section filter, a resistor connected between said other terminal of said primary and said control grid, a condenser shunting part of said last-named resistor, a resistance connected between the terminal remote from the B plus terminal of said shorting resistance and the connection between the resistance and condenser in series between cathode and ground, a condenser and resistance connected between the anode and ground, said oscillator having output terminals across said last-named resistor.

4. An audio frequency generator of waves for a siren system comprising a vacuum tube having cathode, control grid and anode, a biasing resistance connected between ground and cathode, a first condenser shunting said biasing resistance, a resistance and condenser in series between said cathode and ground, an iron core transformer having primary and secondary windings and having a step-down ratio, said secondary winding being connected between ground and one terminal of a second condenser, a connection between the control grid and other terminal of the second condenser, grounded resistors connected on opposite sides of said second condenser, a resistance connected to one terminal of said transformer primary and to a grounded condenser, a connection between said control grid and the high side of said last-named condenser, a multi-section resistance and condenser filter connected to said one terminal of said transformer primary, a dropping resistor connected between said multi-section filter and a B plus terminal, said B plus terminal being adapted to be connected to a source of direct current at high potential, a connection between said multi-section filter input and the junction of said resistance and condenser in series between cathode and ground, a connection between the other terminal of said primary and said anode, a condenser and resistance connected in series between said anode and ground, and an output circuit connected across said last-named resistance.

5. An audio frequency oscillator comprising a three-electrode vacuum tube having cathode, grid and anode electrodes, an iron core type of transformer having primary and secondary windings, connections disposing said primary in the anode circuit and said secondary in the grid circuit, said windings being regeneratively poled to maintain continuous oscillations, resistance-condenser circuits in the cathode, grid and anode circuits, said circuits having generally similar time constants of the order of between .1 and .4 second and means for impressing two different potentials on said system at successive intervals, said system oscillating at audio frequencies to produce a siren effect with a siren period of the order of about two seconds.

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