March 31, 1970 W. E. ABEL 3,504,364

ELECTRONIC SIREN

Filed Nov. 7, 1966 3 Sheets-Sheet 1

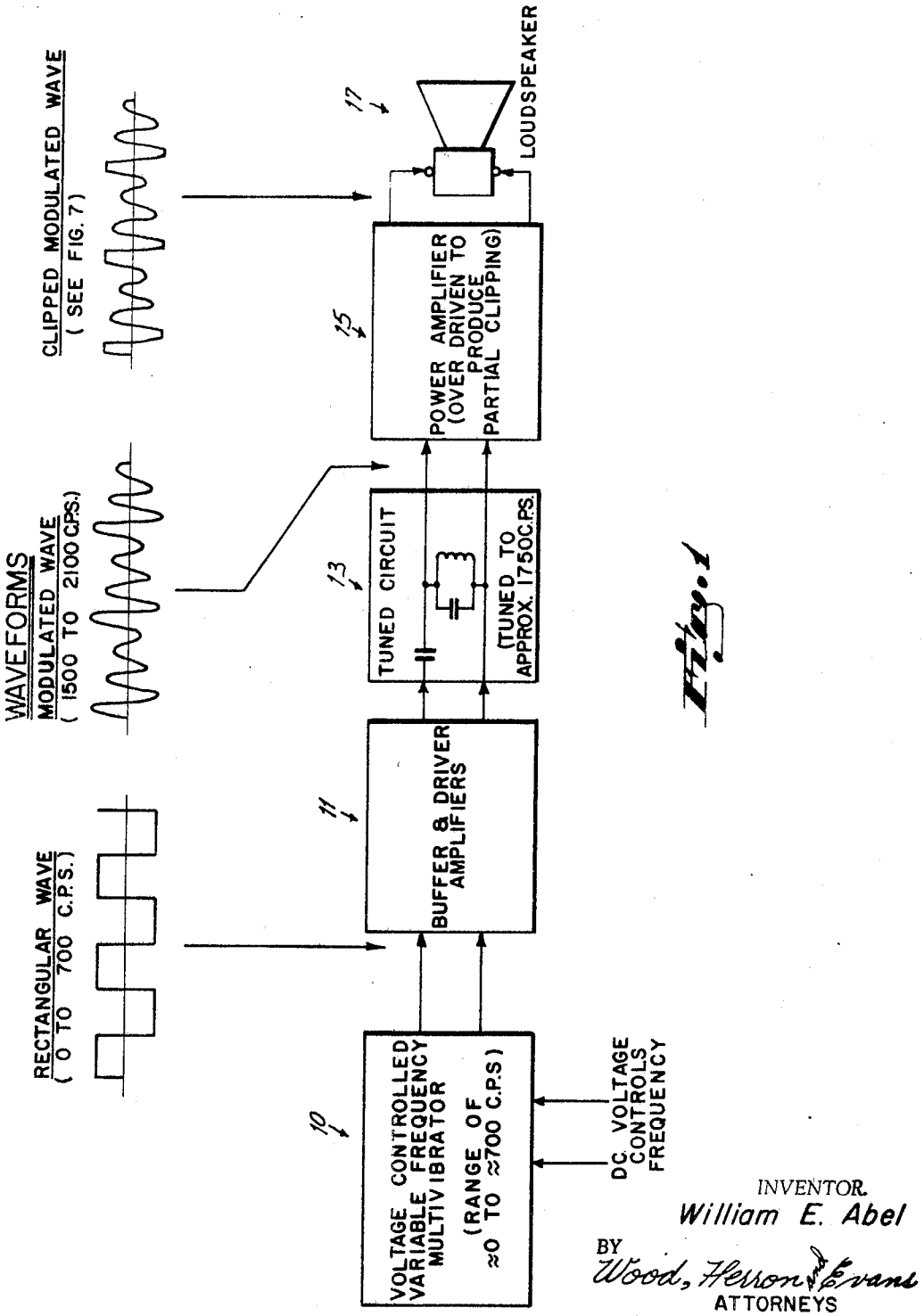


Fig. 1

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ELECTRONIC SIREN

Filed Nov. 7, 1966 3 Sheets-Sheet 2

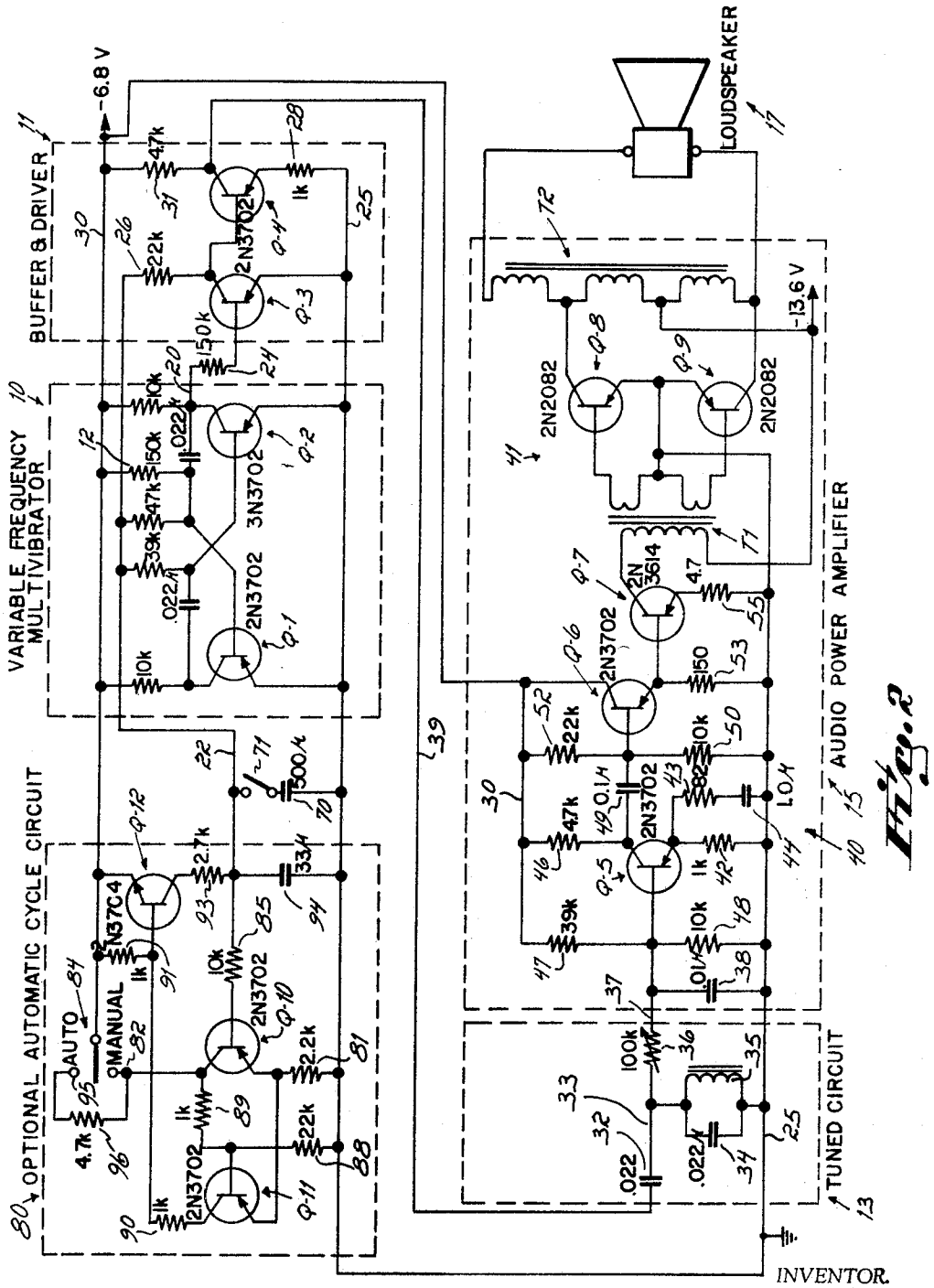


Fig. 2

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ELECTRONIC SIREN

Filed Nov. 7, 1966 3 Sheets-Sheet 3

PURE SINE WAVE

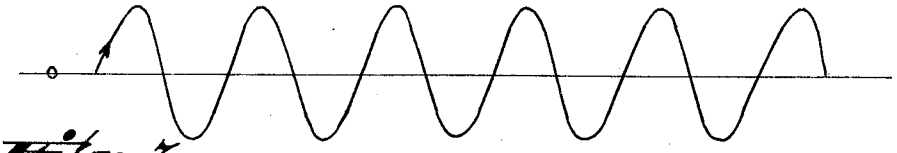


Fig. 3

SINE WAVE WITH HARMONIC DISTORTION



Fig. 4

SINE WAVE WITH INTERMODULATION DISTORTION

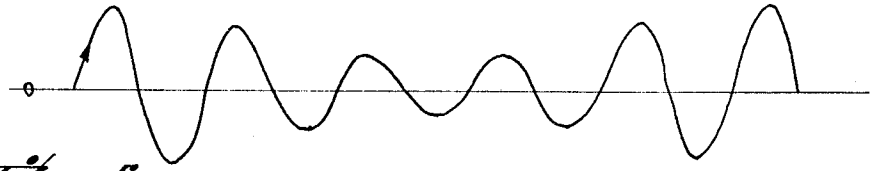


Fig. 5

RECTANGULAR WAVEFORM



Fig. 6

SIREN WAVEFORM

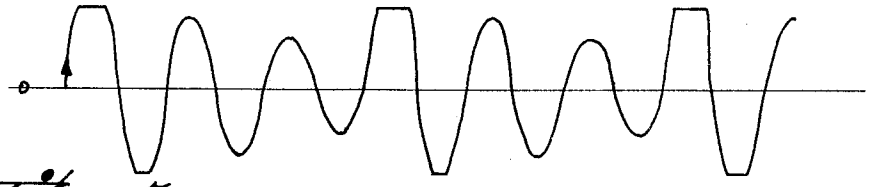


Fig. 7

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Patented Mar. 31, 1970

3,504,364

ELECTRONIC SIREN

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Int. Cl. G08b 3/00; G10k 7/00
U.S. Cl. 340—384 2 Claims

ABSTRACT OF THE DISCLOSURE

An electric siren for providing an audible acoustic output having a high apparent loudness relative to the electrical power input thereto, including a source of periodic complex waveforms having a fundamental frequency lying in the approximate range of 0–1300 cycles per second and having odd harmonics thereof, a shock excited induced oscillatory network having a resonant frequency higher than the frequency of the complex waveforms for effectively providing in response to said complex waveforms an audio-frequency electrical signal having a substantial degree of intermodulation distortion, an overdriven amplifier responsive to the output of the oscillatory network for harmonically distorting the audio-frequency electrical signal, and a speaker connected to the output of the amplifier for converting the audio-frequency electrical signal into an audible acoustic output.

This invention relates to sirens and, more particularly, to electronic sirens.

Electronic sirens, as the term is used herein, relate to those sirens in which the audible signal is produced by first generating an audio frequency electrical signal, amplifying it, and thereafter feeding the suitably amplified signal to a loud speaker where it is connected to an audible siren output. These sirens are to be distinguished from, and contrasted with, other types of audible signaling devices well-known in the art; such as, air whistles, mechanical horns, bells, buzzers, and the like, in which the audible signal is not derived from an audio-frequency electrical signal, but rather is derived by some form of mechanical means.

In recent years, electronic sirens have come into widespread acceptance in many applications where mobile audible signal systems are desired, such as, in police cars, fire engines, and ambulances, as well as in applications where stationary audible signaling systems are desired as, for example, in burgular and fire alarm systems. The electronic sirens which have heretofore been proposed in accordance with various prior art schemes have generally employed a square wave generator for producing the audio frequency electrical signal.

This approach, however, has not been entirely satisfactory for a variety of reasons. For example, the prior art square wave electronic sirens have not been very efficient. By the term efficiency as used herein is meant the ratio of the apparent loudness to the electrical power input to the siren, the apparent loudness being the degree of loudness perceived by the human ear. In fact, the prior art square wave sirens, for a given electrical power input, have audible outputs with very low apparent loudness as interpreted by the human ear. Consequently, it has been necessary when audible signals having a high degree of apparent loudness are desired, to provide a siren which consumes an undesirably large amount of electrical power. Such increased power requirements unduly complicate and increase the cost of the siren.

In addition, the extra power required to operate the inefficient prior art square wave sirens provided an unnecessary drain on the electrical system used to provide the input power. This excessive drain is particularly undesirable in applications in which the sirens are mounted in vehicles since the vehicles necessarily have limited sources of electrical power, such as storage batteries, which are easily discharged by excessive power drain over extended periods.

It has been an objective of this invention, therefore, to provide an electronic siren which provides an audible signal having a high apparent loudness for a given electrical power input. This objective has been accomplished in accordance with the principles of this invention by utilizing a fundamentally different and unobvious concept in the structure and operation of sirens which is characterized by the generation of an audio-frequency electrical signal lying in the range of frequencies to which the human ear is relatively highly sensitive and having a substantial degree of intermodulation distortion. Listening tests conducted with a siren employing an audio frequency electrical signal having the characteristics described have demonstrated that the apparent loudness to the human ear of such a siren is from 3–6 decibels higher than that of a conventional square wave siren consuming the same input electrical power. This decibel increase represents a 200–400 percent increase in apparent power output over the conventional siren.

In practice, the increased efficiency of the siren of this invention has a very important effect. Specifically, it has been found that the limiting factor in the design of siren systems lies in the maximum electrical power than can safely be fed to speakers. Therefore, it is not possible, when increased apparent loudness is desired, to increase without limitation the electrical input to the speaker. If such an approach is taken, the safe limit of speaker input is soon exceeded and the speaker damaged. With the siren of this invention, the efficiency, as defined earlier, is greater and, therefore, a larger apparent loudness can be obtained from a given speaker than with conventional square wave sirens and be done without speaker damage.

It has been another objective of this invention to provide a simple and reliable audio-frequency signal generator for use with the siren of this invention which is capable of producing an electrical signal in the frequency range to which the human ear has the greatest sensitivity and which has a high degree of intermodulation distortion, as well as some harmonic distortion. In accordance with the principles of this invention, this objective is accomplished by providing a rectangular wave generator whose output lies in the frequency range of approximately 0–1300 c.p.s. and a tuned circuit resonant at a frequency in excess of the generator operating frequency and which is responsive to the rectangular wave. In operation, the frequency of the rectangular wave effectively modulates a sine wave produced by the oscillatory nature of the tuned circuit which is shock-excited by the rectangular waveform input thereto, producing an audio-frequency signal having a high degree of intermodulation distortion

and which lies within a band close to and including the resonant frequency of the tuned circuit. The circuit parameters are selected such that this band lies within a frequency range to which the human ear is particularly sensitive.

If desired, the output of the tuned circuit may be further distorted by feeding it to a clipping circuit. This introduces harmonic distortion which, like the intermodulation distortion introduced earlier, is a sound to which the human ear is particularly sensitive. Thus, clipping further increases the efficiency of the siren, that is, it further increases the apparent loudness of the audible siren output for a given electrical input. An additional advantage of clipping, unrelated to the enhanced apparent loudness feature, is that it improves the electrical efficiency of the power amplification stages used in the siren system, thereby decreasing heating of the amplifier circuitry.

In a preferred embodiment of the invention, the rectangular wave generator is a variable frequency multivibrator, the tuned circuit which effectively introduces intermodulation distortion is an L-C tank, and the clipper which introduces harmonic distortion is an overdriven amplifier.

Other objectives and advantages of this invention will be more readily apparent from a detailed description of the invention taken in conjunction with the accompanying drawings in which:

FIGURE 1 depicts a block diagram circuit of an electronic siren constructed in accordance with the principles of this invention,

FIGURE 2 depicts a detailed circuit diagram of the electronic siren of FIGURE 1,

FIGURE 3 depicts an undistorted sine wave which effectively is operated upon and wave-shaped in accordance with the principles of this invention to produce an audio-frequency electric alarm signal,

FIGURE 4 shows the sine wave of FIGURE 3 having harmonic distortion.

FIGURE 5 shows the sine wave of FIGURE 3 having intermodulation distortion,

FIGURE 6 shows the rectangular wave form which is output from the multivibrator of the preferred embodiment of the invention, and

FIGURE 7 shows the clipped and modulated output waveform of a siren constructed in accordance with the principles of this invention having intermodulation distortion, as well as some harmonic distortion.

A preferred embodiment of the invention, as shown more particularly in FIGURE 1, includes as its principal component a free running or astable multivibrator **10**. The multivibrator provides a rectangular wave (see FIGURE 6), which is a periodic complex signal abundant in odd harmonics, having a frequency which preferably lies between approximately 0 c.p.s. and 700 c.p.s. The multivibrator output frequency is also preferably variable in response to a D.C. voltage control signal. Buffer and driver amplifiers **11** are also included to provide isolation, amplification, and wave shaping of the rectangular wave output of the multivibrator **10**. Following this, the rectangular waves are fed to a tuned circuit **13**. The tuned circuit **13** functions to derive from the rectangular wave signal input thereto, due to its shock excitation induced oscillatory nature, those frequencies lying in the range of 1500 c.p.s. to 2100 c.p.s. to which the human ear is highly sensitive, providing at its output terminals a 1500–2100 c.p.s. sine wave which has been effectively modulated by a signal at the frequency of the multivibrator to thereby introduce intermodulation distortion. Also included in the preferred embodiment is an overdriven audio power amplifier **15**. The overdriven amplifier is responsive to the modulated wave output from the tuned circuit **13** and, in addition to amplifying the tuned circuit output, is also effective to provide partial clipping to thereby introduce harmonic distortion. The output of the power amplifier **15** is effectively, that is, the equivalent of, a 1500–2100 c.p.s. sine wave which has been modulated by the low frequency of the multivibrator introducing intermodulation distortion and clipped by the overdriven amplifier introducing harmonic distortion. This clipped and modulated output of the amplifier **15** (see FIGURE 7) is then fed to a suitable loud speaker **17** which converts the audio frequency electrical signal to an audible siren output having a high apparent loudness relative to the electrical power input to the speaker.

By varying the level of the D.C. control voltage input to the multivibrator **10**, the frequency of the rectangular wave can be varied from approximately 0 to 700 cycles per second. Varying the output frequency of the multivibrator is effective to vary the apparent pitch or frequency of the audible siren output as perceived by the human ear. Applicant has discovered that audible siren signals produced in accordance with this invention appear to the human ear to have the same pitch or frequency as the lower modulating frequency which is output from the multivibrator. The human ear, it is believed, "demodulates" the higher frequency 1500 c.p.s.–2100 c.p.s. "carrier" which has been modulated by the lower frequency multivibrator modulating signal. Thus, by varying the multivibrator output frequency it is possible to alter the pitch of the audible siren output as perceived by the human ear.

As shown more particularly in FIGURE 2, the multivibrator **10** includes a pair of cross-coupled transistors Q1 and Q2 which are connected in a two-stage RC coupled amplifier circuit configuration with the output coupled back to the input to effectively provide a feedback oscillator. Since the structural and operational details of the multivibrator **10** are completely conventional and form no part of this invention, it will not be described in detail. It is sufficient to note only that the transistors Q1 and Q2 are supplied by a grounded line **25** and a regulated voltage negative line **30**, and alternately conduct, providing an output on a multivibrator output line **20**, the frequency of which can be varied between 0–700 c.p.s. by varying the D.C. bias level produced on a line **22**. It shall be further noted that the conventional multivibrator **10** has been modified to include therein a resistor **12** connected between the base of transistor Q1 and the negative line **30**. This resistor permits the multivibrator **10** to be stopped, that is, to cease oscillating, upon the application of a suitably low control voltage on bias line **22**.

In operation, increasing the bias, that is, driving the D.C. control voltage on the bias line **22** more negative, is effective to raise the frequency of the multivibrator oscillation. Similarly, decreasing the bias, that is, driving the D.C. control voltage on line **22** more positive, is effective to decrease the oscillator output frequency. If the bias level on line **22** is driven sufficiently positive, the multivibrator **10** ceases to oscillate. This result is produced by the resistor **12** which provides a current flow into the base of transistor Q1 of a magniture sufficient to cause transistor Q1 to remain conductive at some arbitrary low bias level present on line **22**, which bias level corresponds to the multivibrator "shut-off" bias.

The combined buffer and driver amplifier **11** includes a first transistor Q3 and a second transistor Q4. Transistor Q3 has a base coupled to the multivibrator output line **20** via a coupling resistor **24**, which base constitutes the input to the buffer transistor Q3. The transistor Q3 further includes an emitter which is directly connected to the grounded line **25**, and a collector which is connected to line **22** via a load resistor **26**, the load resistor **26** at its other end being connected to line **22** for reasons to be described. The collector of transistor Q3 constitutes the output of the transistor. The transistor Q4 includes a base which is connected to the collector of transistor Q3, which base constitutes the input to the transistor Q4. The transistor Q4 further includes an emitter which is connected

to the grounded line **25** via a biasing resistor **28**, and a collector which is connected to the negative line **30** via a load resistor **31**.

In operation, the rectangular wave output from the multivibrator **10** present on line **20** is fed via the coupling resistor **24** to the base of transistor Q3 where it is amplified. The amplified output which is present at the collector of transistor Q3 is then input to the base of transistor Q4 where it is further amplified. The resistor **26**, because it is connected to the bias line **22**, function to increase and decrease the current available at the collector of transistor Q3 which is actually input to the base of transistor Q4, as the bias level on line **22** increases and decreases, respectively. The practical effect of this is to vary the output of transistor Q4, at low multivibrator frequencies only, in a manner such that the output decreases and increases with decreasing and increasing multivibrator frequency, respectively. Thus, a siren output is obtained which, in the low multivibrator frequency range, rises and falls in loudness with increasing and decreasing frequency in a manner similar to mechanical sirens.

The amplified rectangular wave present at the collector of transistor Q4 is coupled via a line **39** to the tuned circuit **13**. The tuned circuit **13** includes a coupling capacitor **32** connected between lines **39** and a line **33** which is the effective tuned circuit output, a capacitor **34** and an inductor **35** connected in parallel between the line **33** and the grounded line **25**, and a resitsor **36** connected between the line **33** and the amplifier input line **37**. The resistor **36** isolates the tuned circuit **13** from the audio amplifier **15**.

In operation, the tuned circuit **13** is adjusted to be resonant at approximately 1750 c.p.s., which corresponds to the approximate geometical mean of the frequency range to which the adult human ear is most sensitive, and when so adjusted produces across output lines **31** and **25**, a 1500 c.p.s.–2100 c.p.s. sine wave having intermodulation distortion. The particular value of the resonant frequency, which may vary as desired, is selected to correspond to the geometric mean of the siren output frequency range desired, which is in all cases above the modulating frequency provided by the multivibrator. For example, it is known that young children have an audio frequency range of maximum sensitivity that is upwardly displaced in frequency relative to that for adults. Specifically, children have the greatest sensitivity to sounds in the approximate range of 2000–4000 c.p.s. Thus, the tuned circuit resonant frequency desired is approximately 2800 c.p.s. corresponding to the geometric mean of the 2000–4000 c.p.s. frequency sensitivity range. Under these conditions, that is, designing a siren for children, the modulating frequency of the multivibrator is preferably in the range of 0–1300 c.p.s.

The resistor **36**, which is preferably variable, is used to regulate the signal level output from the tuned circuit **13**. This level in turn determines the degree to which the audio power amplifier **15** is overdriven and, hence, the degree of clipping present and the resultant harmonic distortion.

The audio power amplifier **15** includes a conventional three-stage audio-frequency transistor amplifier configuration generally indicated by the numeral **40**, and a conventional transistorized push-pull output amplifier configuration generally indicated by the numeral **41**. The three-stage audio-frequency amplifier **40**, in which the last stage functions as a driver for the push-pull output amplifier **41**, includes a first transistor Q5 having a base which constitutes the input **37** to the amplifier **15** and which is resistively coupled to the tuned circuit output line **33**, and an emitter which is coupled to the grounded line **25** via a D.C. biasing resistor **42** which is in parallel with an A.C. biasing resistor **43** and a capacitor **44**. A capacitor **38** connected between the amplifier input line **37** and the grounded line **25** is provided to block signals above the audio-frequency range. The transistor Q5 further includes a collector which is connected via a load resistor **46** to the negative line **30**. A voltage divider including resistors **47** and **48** connected between the grounded line **25** and the negative line **30** is connected at its mid-point to the base of transistor Q5 for biasing the transistor. The output of first transistor amplifier stage Q5 taken at the collector thereof is R-C coupled to the base of the second transistor amplifier stage Q6 via a coupling capacitor **49** which is connected between the collector of transistor Q5 and the base of transistor Q6. A voltage divider including a resistor **50** and a resistor **52** is connected between the grounded line **25** and the negative line **30** and has its mid-point connected to the base of transistor Q6 to thereby provide biasing for this transistor. Transistor Q6 also includes a collector connected directly to the negative line **30**, and an emitter connected via load resistor **53** to the grounded line **25**. The emitter of transistor Q6, which constitutes the output of the second transistor amplifier stage, is directly coupled to the base of the third amplifying stage or driving transistor Q7, which base constitutes the input to transistor Q7. Transistor Q7, in addition, includes an emitter which is connected to the grounded line **25** via a biasing resistor **55**, and a collector at which the output of the third amplifying stage, or driver, is obtained.

The power amplifier **41**, which is responsive to the output of the three-stage audio-frequency transistor amplifier **40**, includes transistors Q8 and Q9 having their bases transformer-coupled to the collector of the transistor Q7 via an input transformer T–1 which has its primary winding connected between the collector of transistor Q7 and a source of negative potential. The emitters of transistors Q8 and Q9 are connected in common to the grounded mid-point of the coupling and input transformer secondary winding. The collectors of transistors Q8 and Q9 are connected across the primary winding of an output transformer T–2 used to couple the output of the push-pull power amplifying stage to the loud speaker **17**.

The three-stage audio-frequency transistor amplifier **40** and the push-pull power amplifier **41** in combination function to amplify the output from the tuned circuit **13**, raising it to a level sufficient to drive the loud speaker **17**. The operation of multistage transistor amplifiers and transistor push-pull amplifiers is well-known in the art, and consequently, a detailed description is not necessary. Such a detailed description may be found in any standard electronics text book as, for example, Electronic Fundamentals and Applications, third edition, John D. Ryder, Prentice Hall, February 1965, particularly, chapter 9, entitled "Linear Small Signal Amplifiers," and chapter 11, entitled "Class A and B Amplifiers With Large Signals." The loud speaker **17**, when used in conjunction with a circuit of the type disclosed herein, may be of any of the commercially available types having approximately 10 ohms input impedance, to thereby provide impedance matching.

To permit the pitch of the siren to be automatically and continuously raised and lowered, an automatic cycle circuit generally indicated by the numeral **80** may be utilized, if desired. The circuit **80** includes a first transistor Q10 having an emitter connected to the grounded line **25** via a biasing resistor **81**, a collector connected directly to one contact **82** of a single pole, double throw switch generally indicated by the numeral **84**. The contact **82** of the switch **84** is connected via a resistor **96** to the other switch contact **95**. The transistor Q10 additionally includes a base coupled via a resistor **85** to the line **22**. The automatic cycling circuit **80** has a second transistor Q11 having an emitter connected to the emitter of transistor Q10, and a base connected to the grounded line **25** via a biasing resistor **88** and to the collector of transistor Q10 via a coupling resistor **89**. Transistor Q11 further includes a collector coupled to the base of a third transistor Q12 via a load resistor **90**. The base of transistor Q12 is also connected to the negative line **30** via a resistor **91**. Transistor Q12 additionally includes an emitter connected

directly to the negative line 30 and a collector connected to the line 22 via a charging resistor 93. A capacitor 94 forming a portion of the automatic cycling circuit 80 is connected between the grounded line 25 and the line 22. A second capacitor 70 connected between lines 22 and 25 via a switch 71 is provided to permit alteration of the net capacitance between lines 22 and 25.

The preferred embodiment of this invention has two principal modes of operation, namely, an automatic mode and a manual mode. In the automatic mode the siren produces an output which has a continuously increasing and decreasing apparent pitch. The frequency of the cycle increase and decrease in apparent pitch is equal to the multivibrator output frequency. The automatic mode is produced by placing the movable contact of switch 84 in the upper position. The manual mode of operation is produced by placing the movable contact of switch 84 in the lower position. The siren output in this mode is characterized by a rise in apparent pitch when the switch is initially closed, followed by a fall in apparent pitch if the switch 84 is opened shortly thereafter. If the switch 84 is maintained closed for a period exceeding the charge time of the capacitor 94, before re-opening, the rise and fall in apparent pitch will be separated by a period of continuous apparent pitch.

MANUAL MODE

In operation, when the switch 84 of automatic cycle circuit 80 is in its lower position coupling the switch contact 82 with the negative line 30 the transistor Q11 is biased into conduction. The current flow in the emitter-conductor path of transistor Q11 through the resistor 81 drives the potential of the emitter of transistor Q10 to a more negative value biasing transistor Q10 into cutoff. In addition, the conduction of transistor Q11 is also effective to bias transistor Q12 into conduction. More specifically, the increased current flow through the emitter-collector path of transistor Q11 draws sufficient current through the base of transistor Q12 to bias transistor Q12 into conduction.

The initiation of conduction of transistor Q12 causes the capacitor 94 to initiate charging, raising the bias level present on line 22. The charging of capacitor 94 continues, continuing to raise the bias level on line 22, until the capacitor 94 is fully charged. The time required for the capacitor 94 to fully charge depends on the RC time constant of the circuit which is a function of the capacitance of capacitor 94 and, principally, the resistance of the resistor 93. The maximum level of charge achieved by the capacitor 94 is a function of the steady state voltage of the tap point (line 22) of a voltage divider consisting of the resistor 93 and the resistive paths from line 22 to ground line 25.

While the capacitor 94 is charging, the bias on line 22 is increasing from approximately zero volts to the maximum bias level determined as indicated previously. This continuously increasing bias on line 22 raises the frequency of the multivibrator output on line 20. The increasing frequency rectangular waves from the multivibrator 10 on line 20 are input to the buffer and driver 11 via the coupling resistor 24. In the buffer and driver 11 amplification of the rectangular waves occur, the amount of amplification, at low multivibrator frequencies, increasing as the existing bias level on line 22 constituting the supply voltage for transistor Q3 is increased. This variation of the amplification provided by the buffer and driver 11 at low multivibrator frequencies causes the audible siren output to have an apparent loudness which decreases and increases as the frequency of the multivibrator decreases and increases, respectively. Thus, an audible siren output is produced which more closely approximates the audible output of a mechanical siren.

The output of the buffer and driver 11 is input to the tuned circuit 13 where intermodulation distortion is introduced in the manner described previously. The output of the tuned circuit 13 in turn is input to the audio-frequency power amplifier 15 and, following suitable amplification, is input to a loud speaker 17 for producing the audible siren output.

When the capacitor 94 has fully charged, the bias level on line 22 is constant, causing the frequency of the multivibrator 10 to stabilize at its maximum frequency level. With the frequency of the multivibrator 10 stabilized, the output of the loud speaker 17 is of constant pitch. This condition of constant pitch when the capacitor 94 is fully charged is to be contrasted with the increasing pitch of the audible siren output which is present when the capacitor 94 is in the process of charging.

When the movable contact of switch 84 is disconnected from the switch contact 82 and transferred to the position shown in FIGURE 2, the transistor Q11 is switched to a non-conducting state. This in turn drives transistor Q12 to a non-conducting state. The transistor Q10 remains non-conductive with the switch 84 in the position shown in FIGURE 2 because of the absence of a supply voltage. With the transistor Q12 switched to the non-conducting state, the capacitor 94 is discharged through the resistance paths existing between lines 22 and 25. As the capacitor 94 is discharging the level on line 22 is decreasing, in turn continuously reducing the frequency of the multivibrator 10. The continuously reducing frequency of the multivibrator 10 when the multivibrator is operating at a low frequency, is accompanied by continuously reducing amplification in the buffer and driver 11 as a consequence of the decreased bias on line 22 which is no longer sufficiently large to cause transistor Q4 to saturate. This reduced amplification, it is emphasized, is only present at low multivibrator frequencies when the bias on line 22 is too low to saturate transistor Q4. The combined effect of the continuously decreasing multivibrator frequency and buffer and driver amplification level present at low multivibrator frequencies is reflected at the loud speaker 17 as an audible output having both decreasing pitch and decreasing loudness.

To provide variation in the time required for the bias on line 22 to reach any given level, the capacitor 70 may be connected in shunt with the capacitor 94 by closing the switch 71. This has the practical effect of lengthening the period of time required for the siren output to reach its maximum pitch, as well as lengthening the period of time required for the siren to change from a maximum pitch to a minimum pitch.

AUTOMATIC MODE

If the movable contact of switch 84 is transferred from the position shown in FIGURE 2 to its upper position thereby coupling the line 30 with switch contact 95, the transistor Q11 is biased into conduction, in turn driving transistor Q12 into conduction, and maintaining transistor Q10 in non-conduction. With the transistor Q12 conducting, the capacitor 94 begins charging and continues charging until the voltage across the capacitor 94 is equal to the sum of the voltage across resistor 81 and the forward bias voltage drop of the emitter junction of transistor Q10. When the voltage across the capacitor 94 reaches this sum, the transistor Q10 is biased into conduction, biasing transistor Q11 into cut-off, which in turn drives transistor Q12 into cut-off.

With transistor Q12 non-conducting the capacitor 94 discharges through the resistive paths existing between line 22 and ground line 25. These resistive paths include the resistor 85, the resistor 81, and the resistors in the multivibrator circuit and buffer circuit which are connected to the line 22. The capacitor 94 continues discharging until the voltage across it is equal to the sum of the voltage across resistor 81 and the forward bias junction voltage between emitter and the base of transistor Q10. It is important to note that the voltage drop across the resistor 81 when the transistor Q10 is non-conducting is different than when the transistor Q10 is

conducting due to the existance of different values of load resistance for the transistors Q10 and Q11 under the two conditions of conduction. When the capacitor **94** has discharged to the point that the voltage across it is equal to the sum of the voltages across the resistor **81** and the emitter-base junction of transistor Q10, the transistor Q10 is switched off, driving transistor Q11 into conduction which in turn drives transistor Q12 into conduction.

The charging and discharging cycle for the capacitor **94** repeats itself indefinitely until the switch **84** is transferred to the position shown in FIGURE 2.

While the capacitor **94** is charging and discharging, the bias level on line **22** is correspondingly increasing and decreasing causing the multivibrator frequency to increase and decrease, respectively. The continuous increasing and decreasing of the multivibrator frequency is reflected at the loud speaker **17** output as an audible siren output of continuously increasing and decreasing pitch. This continuously increasing and decreasing pitch output from the loud speaker **17** is of approximately uniform and constant loudness. This condition of substantially constant siren output loudness is produced not withstanding varying supply voltage input to the resistor **26** of the buffer and driver **11** on line **22** since the voltage on line **22** does not drop below the value necessary to supply sufficient current to the transistor Q4 for maintaining it in saturation during the entire charging and discharging cycle.

As in the manual mode of operation, it is also possible in the automatic mode of operation to close the switch **71** placing capacitor **70** in shunt with capacitor **94** to thereby increase the time required for a complete charging and discharging cycle. This extends the time required for varying the pitch of the loud speaker **17** output between its maximum level when the siren is cycling in the automatic mode and its minimum level when the siren is cycling in the automatic mode.

It has been found that the preferred embodiment of the invention having circuit components of the type and values indicated in FIGURE 2 of the drawing provides an electrical power output of 75 watts RMS and 120 watts peak into a 10 ohm load with a nominal D.C. input of 13.6 volts. It has also been found that with a nominal D.C. input of 13.6 volts the siren of the preferred embodiment draws a current of approximately 500 milliamps when in the standby condition and 8 amps when generating an audible siren output. It has further been found that the siren provides an audio power output of 60 watts RMS when operating at a frequency of 1000 c.p.s. with an D.C. input voltage of 13.6 volts. It is to be understood that the types and values of the components shown in FIGURE 2 of the drawing, as well as the above operating specifications, are disclosed merely for the purpose of illustrating the structure and operation of a preferred embodiment of the invention and are not to be construed as limiting the scope of the invention.

The waveform of FIGURE 7 may be produced by first generating the undistorted sine wave of FIGURE 3, thereafter clipping it for obtaining the harmonically distorted waveform of FIGURE 4 and finally modulating the clipped wave with a low frequency signal to thereby introduce intermodulation distortion and approximate the waveform of FIGURE 7. Of course, the distorted wave of FIGURE 7 may also be produced by first modulating the undistorted sine wave of FIGURE 3 with a lower frequency signal to obtain intermolulation distortions as shown in FIGURE 5, and finally, if desired, clipping the distorted wave of FIGURE 5 to introduce harmonic distortion.

It is further contemplated that other types of amplifiers can be used for raising the distorted audio-frequency signal to a level sufficient to drive the loud speaker.

It is also to be understood that the audio-frequency signal lying in a range to which the human ear is highly sensitive and having a high degree of intermodulation distortion can be produced in a manner different from that described in conjunction with FIGURES 2 and 3. For example, a first signal generator may be provided for generating a first signal lying in the range of frequencies to which the human ear is highly sensitive. The first signal can then be amplitude modulated, using a suitable amplitude modulation device, with a second audio-frequency signal lower than said first signal, the second signal being generated by a second signal generator. The resultant signal produced by the amplitude modulation process is the desired speaker input signal and lies in the range of frequencies to which the human ear is highly sensitive and contains a high degree of intermodulation distortion.

It is further to be understood that the term modulation as used herein necessarily refers to amplitude modulation inasmuch as intermodulation distortion, which characterizes the audio-frequency signal of this invention used to drive the loud speaker, is an amplitude modulation phenomenon.

It is also to be understood that the "frequency range to which the human ear is highly sensitive," as the phrase is used herein, includes the general range of approximately 400–4000 c.p.s. when considering the hearing abilities of both children and adults alone. The upper limit of this range of relatively high sensitivity typically drops off to about 2000 c.p.s. yielding a range of approximately 400–2000 c.p.s., when considering the hearing abilities of adults alone.

I claim:

1. An electronic siren comprising:

(a) a signal generator for providing an audio-frequency electrical signal having a substantial degree of intermodulation distortion, said generator including:

(1) a source of periodic complex waveforms having a fundamental frequency selectively variable within the approximate range of 0–1300 c.p.s. and having odd harmonics thereof, said source of waveforms having an input responsive to a variable voltage input thereto for varying said fundamental frequency, and

(2) a shock excited induced oscillatory network connected to said source of periodic complex waveforms, said network having a resonant frequency higher than said frequency of said complex waveforms for effectively providing said audio frequency electrical signal having a substantial degree of intermodulation distortion,

(b) a control circuit for said signal generator comprising:

(1) a source of potential,

(2) a capacitor,

(3) circuit means connecting said capacitor to said input of said source of periodic complex waves for applying the voltage across said capacitor to said input, and

(4) a switch connected in circuit with said capacitor and said potential source for enabling said capacitor to charge to a specific voltage level when said switch is activated and remain charged at said specific voltage level so long as said switch remains activated, in turn enabling said capacitor to apply to said input a control voltage which increases in magnitude to said specific level in response to said switch activation and remains at said level so long as said switch remains activated, thereby causing the fundamental frequency of said waveform source to increase to a predetermined frequency in response to switch activation and remain at said predetermined frequency so long as said switch remains activated, and

(c) a speaker connected to said generator for con-

verting said audio frequency electrical signal to an audible acoustic output.

2. The electronic siren of claim 1 wherein said signal generator further includes an amplifier interconnected between said oscillatory network and said periodic waveform source, said amplifier having an amplification characteristic which increases with increasing fundamental frequency of said waveform source, enabling the apparent loudness of said audible signal to increase to a specified level when said switch is activated and remain thereat so long as said switch is activated.

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