

June 30, 1959

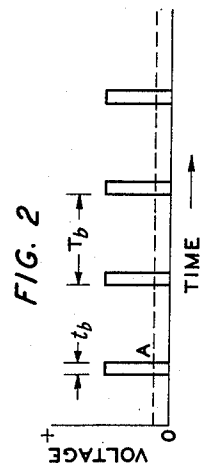
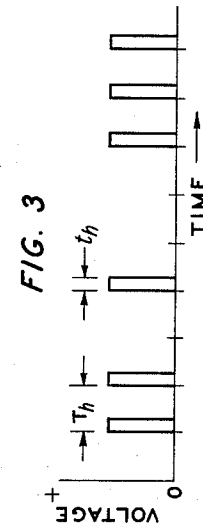
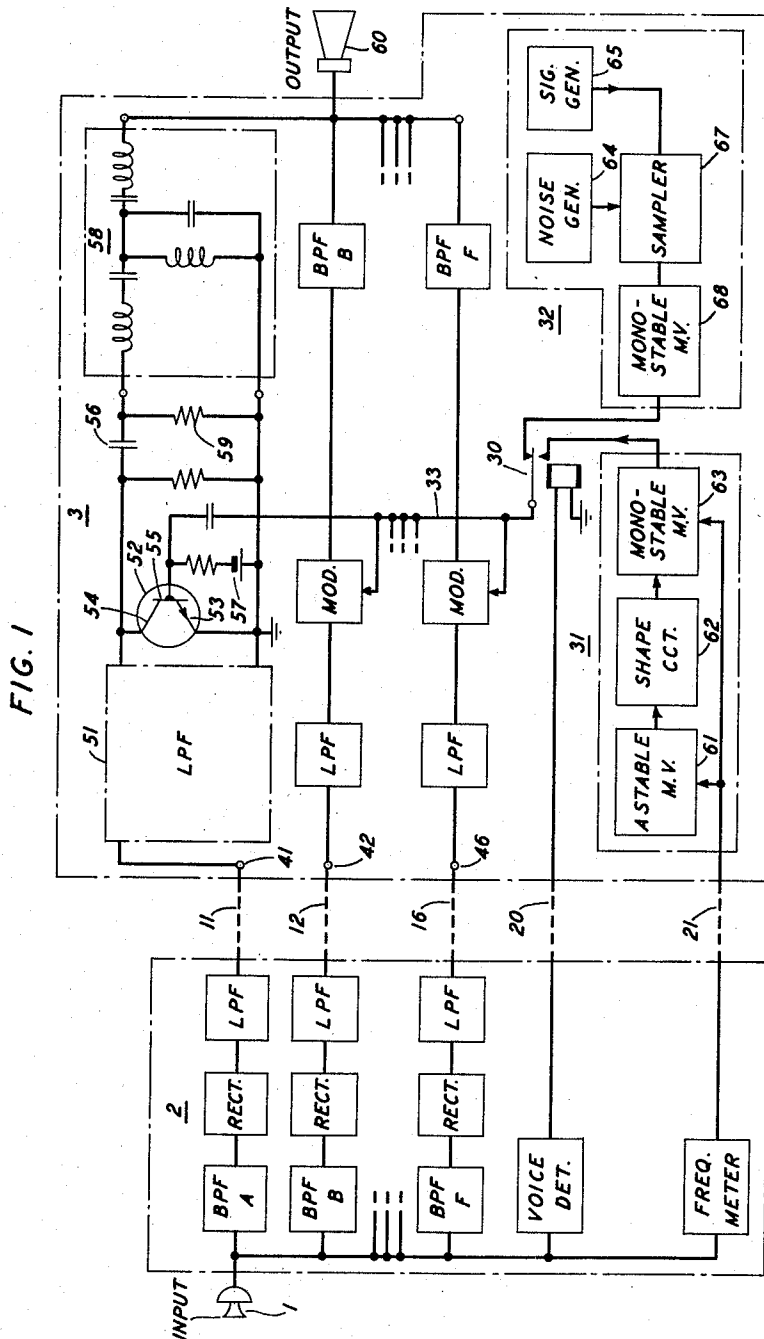
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VOCODER ABSORPTION MODULATION SYSTEM

Filed Oct. 7, 1955

3 Sheets-Sheet 1



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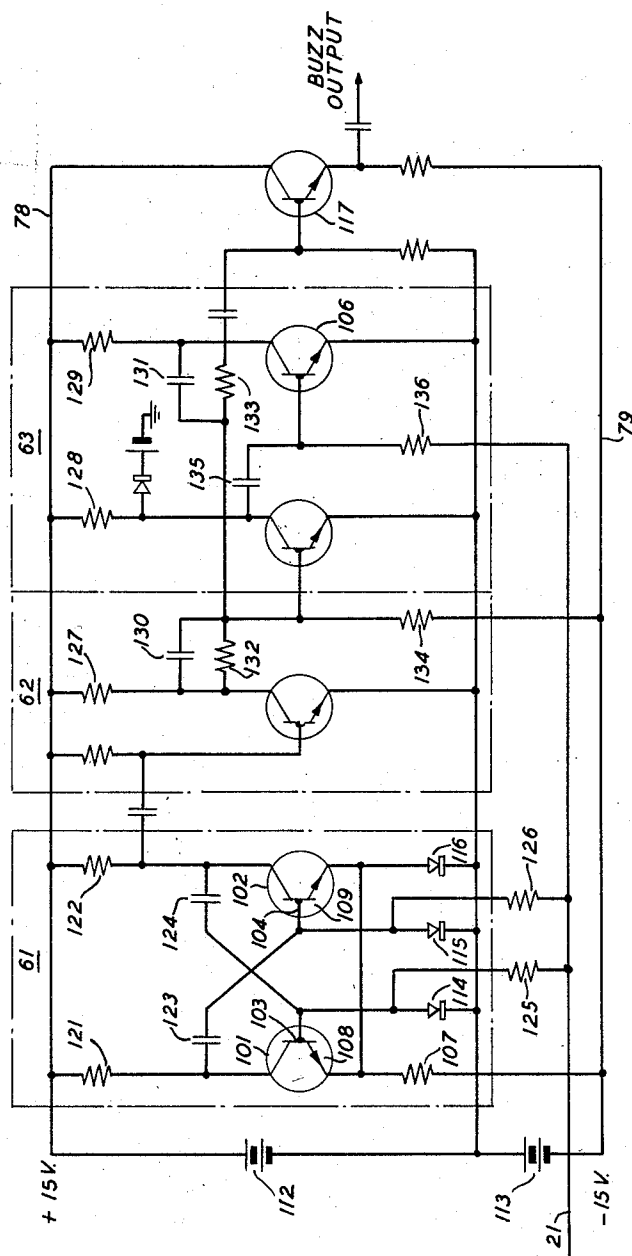
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VOCODER ABSORPTION MODULATION SYSTEM

Filed Oct. 7, 1955

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FIG. 4



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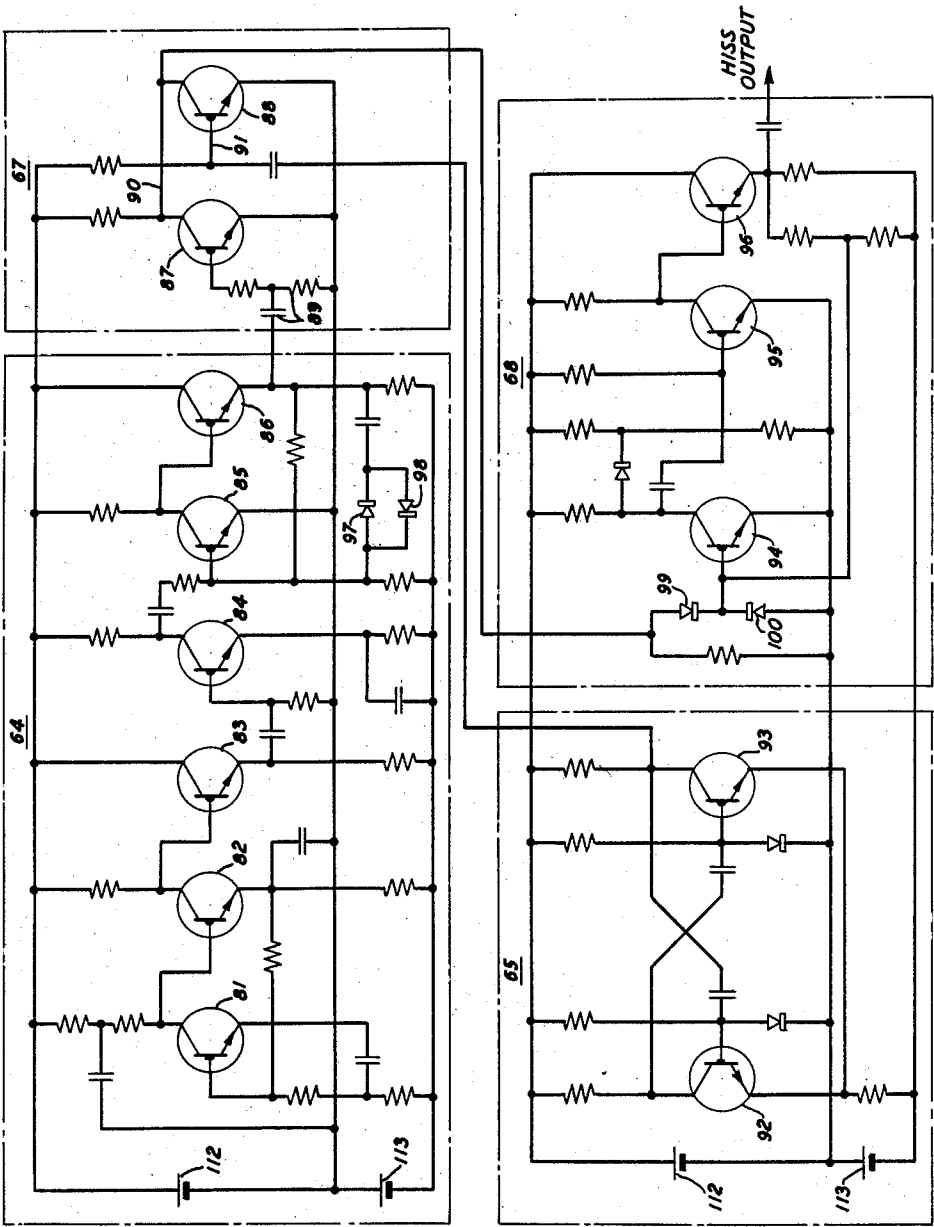
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VOCODER ABSORPTION MODULATION SYSTEM

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FIG. 5



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VOCODER ABSORPTION MODULATION SYSTEM 5

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Application October 7, 1955, Serial No. 539,234 10

8 Claims. (Cl. 179—15.55)

This invention relates to the artificial production of speech or similar complex waves. The invention also relates to the transmission of speech signals over a narrow frequency channel from a given point where the input speech is analyzed to a distant point where the speech sounds are reconstructed.

A vocoder system representative of the many devices for such transmission and reconstruction of speech is disclosed, for example, in H. W. Dudley Patent 2,151,091, March 21, 1939. In such a system the input speech wave is analyzed to determine its fundamental frequency, if there be one, and to determine its power pattern over the frequency spectrum of interest. This analysis is translated into electrical signals which then may be transmitted over a narrow frequency channel to control artificial production of speech at a distant station.

The first of these analysis signals indicates whether or no a fundamental frequency exists in the input wave. The second signal indicates what that fundamental frequency is. The functions of these two signals may obviously be performed by one signal and the Dudley teachings so comprehend. For clarity of discussion, however, the two functions are herein considered as performed by separate signals. The third signal consists in a multiplicity of separate subsignals, known as "spectrum control signals," respectively indicating the power level of the input wave within one of the frequency subbands which together constitute the full frequency spectrum of the input wave.

Throughout the prior art these signals are employed at the receiving station in the same general fashion. Two alternative sources of speech frequency energy are there provided, a "buzz source" and a "hiss source." In the event that wave analysis indicates the existence of a fundamental frequency, the first electrical signal selects the buzz source to provide energy for the artificial production of speech.

This buzz source normally consists in some form of relaxation oscillator which produces an output rich in harmonics of its fundamental frequency. Such an output is representative of sounds produced by the vocal cords, "voiced sounds."

Alternative to the buzz source, this first electrical signal may select as an energy source at the receiving location, the hiss source. This source is characterized by an even distribution of output power over the frequency band of interest. It is thus representative of speech sounds such as the sibilants, "unvoiced sounds." This source normally consists in a familiar noise generator, for example, a gas tube.

The second of the electrical signals produced by the analysis equipment is employed to control the frequency of oscillation of the buzz source. Thus this second signal determines the fundamental frequency of the waves to be artificially produced.

Whichever one of the energy sources may be selected, its energy is applied to a plurality of frequency-selective

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channels in parallel. To each of these channels an appropriate one of the spectrum control signals is also applied to produce an amplitude modulation product with the locally supplied energy. Thus, frequency subbands coextensive with those represented by the respective spectrum control signals are selected from the broad energy spectrum generated by the buzz or hiss source and this subband of energy is modulated in accordance with that appropriate control signal. The modulated outputs of all these frequency-selective channels are then combined to produce artificially a wave corresponding to the original input wave.

Now from the foregoing discussion it appears that there are two separate parts together comprising the complete system. First, the analysis equipment which generates the three types of control signals; and second, the synthesis equipment which utilizes these control signals to produce artificially a wave. The present invention is directed towards improvement of the second part of the system, the synthesis equipment, but the nature of this improvement becomes more clear with reference to an integrated system. Recognizing then that the control signals may be arbitrarily selected to produce artificially any form of complex wave, the invention is, nonetheless, discussed in the context of an entire voice analysis, transmission, and synthesis system.

From the foregoing discussion it appears also that common to the synthesis systems are three elements of structure: a buzz source, a hiss source, and a device to form a modulation product of locally supplied energy and an externally-derived spectrum control signal.

Consider first the modulator. Prior vocoder teachings show the employment of various devices known in the modulator art. In the vocoder field, however, these modulators have been subject to the objection that extraneous energy may "leak" to the output circuits as a form of noise. This failing has been attributed to several causes. The individual elements of the modulation circuit may vary in electrical characteristics over a period of time or instantaneous variations in the same characteristics may result in spurious signals. The former difficulty has led to further problems in the maintenance of circuit elements to reduce unwanted variations. The second difficulty has led in some cases to more complex circuitry or to employment of more expensive elements to preclude unnecessary spurious responses.

This invention stems from the recognition that if a modulating device have effectively infinite values of conductance on the one hand and of impedance on the other, it may well serve to provide a completely noise-free modulator by reducing the proportionate effect of minor characteristic changes. In a preferred embodiment, the invention employs just such a device, and a simple one, in the form of a transistor switch described in P. A. Reiling application, Serial No. 410,924, filed February 17, 1954. In the adaptation of a switch such as that shown by Reiling to the vocoder art, the invention achieves an important object in providing a relatively noise-free modulator for a voice synthesizer, which modulator, through its simplicity, reduces markedly any requirements for maintenance.

This modulator switch, in order to function in the desired manner, requires a source of pulses to control the modulation process. Accordingly the buzz and hiss sources of the invention are adapted to this particular employment and, as they must be adapted to employment in the particular environment of driving this modulator, so are they also adapted by the invention to their larger environment of a vocoder system.

Looking first to the buzz source, it is well known that harmonics of the fundamental frequency of a sound con-

tribute greatly to the quality of that sound, be it naturally or artificially produced. In the prior art various forms of relaxation oscillator, frequency controlled by an appropriate signal, have been employed as a buzz source inasmuch as the output of the relaxation oscillator is well known to be rich in the harmonics of its fundamental frequency. The invention then relates this teaching of the prior art to its modulator requirement for a pulsed control signal and adopts from the prior art such a relaxation oscillator.

It is well known that a square wave comprising a sequence of pulses of durations t_b , recurring at equal intervals T_b , may be represented by a Fourier series of cosine terms in which the coefficient of the n th term may be written

$$A_n = \frac{2}{n\pi} \sin \frac{n\pi t_b}{T_b}$$

See, for example, F. E. Terman, "Radio Engineer's Handbook" (McGraw-Hill, 1943), page 22, and Rayleigh, "Theory of Sound" (Dover, 1945), vol. 1, page 25.

In physical terms this means that if the consecutive harmonics appearing throughout a frequency range of interest are to be of substantially equal amplitudes, the ratio of pulse duration, t_b , to pulse period, T_b , must be small, for example, 0.01. Further it is necessary that the ratio

$$\frac{t_b}{T_b}$$

must remain constant. And, if these conditions be fulfilled, then the energy level of a square wave is maintained independent of frequency and an increase in duration of pulses is accompanied by a corresponding decrease in the occurrence rate of these pulses.

Recognizing these teachings the invention adapts them to the peculiar problems of the voice synthesizer. It provides as a buzz source a square wave energy source in which the pulse duration is small in comparison to the period of recurrence of that square wave. In addition, it provides for a constant ratio between the pulse duration and the pulse period. In so doing the invention establishes substantially uniform amplitudes among the fundamental and harmonics of the square wave throughout a frequency range of interest. At the same time it precludes any casual variation of the energy level of that square wave with a variation in its frequency.

In achieving these limited purposes the invention in a larger sense provides a buzz source as a control for the modulator which will insure noise-free operation of that modulator, a uniform harmonic content in the modulated signal it controls, and, at the same time, freedom of the modulation output from the effects of a spurious amplitude modulation. All of these objectives the invention achieves with a buzz source which employs square wave generators simultaneously controlled with respect to frequency and pulse duration by an external signal.

Finally, the hiss source. In the context of artificial speech synthesis familiar noise sources such as gas-filled tubes have been open to the criticism that a lack of complete uniformity in their frequency spectrum has resulted in the introduction of extraneous noise into the system output. Further, the random amplitude output of such devices makes their use impractical for the purpose of the invention. To actuate the modulator of the invention from a full On to a full Off condition requires signals of a certain minimum amplitude. Thus, from two viewpoints, known hiss sources appear to be inadequate to cooperate effectively with this modulator.

This leads to a further object of the invention, namely, to provide a source of pulsed energy distributed uniformly over a given frequency spectrum. This object is achieved by employment, in a preferred embodiment of the invention, of a periodic pulse train generator in combination

with a device for eliminating random ones of pulses appearing in the generated train.

In attaining the above-discussed objects, the improved modulator, the suitable buzz source and the appropriate hiss source, the invention provides three cooperative structures which combine to achieve a principal object. Together they provide a modulating system simple and relatively free of requirements for maintenance, yet similarly free of undesired noise and capable of increased fidelity in the artificial production of speech.

The various objects and features of novelty which characterize the invention will appear more fully from the following detailed description of an illustrative embodiment when read in conjunction with the attached drawings in which:

Fig. 1 is a schematic circuit diagram of a representative speech analyzer and synthesizer in accordance with the invention;

Figs. 2 and 3 are pictorial representations of the electrical pulses derived from the invention's buzz source and hiss source respectively; and

Figs. 4 and 5 are detailed circuit diagrams of that buzz source and that hiss source.

Referring first to Fig. 1, the wave input applied to a microphone 1 is analyzed with respect to a number of frequency subbands, for example six, of which three are shown, by the analysis equipment 2. This analysis function is discussed in the Dudley Patent 2,151,091. Spectrum control signals are thus derived and applied to transmission lines 11, 12 . . . 16. Another control signal is derived in accordance with the prior art and applied to a line 20 for selective operation of a relay-actuated switch 30. This control signal applied to the line 20 thus selects either buzz source 31 or hiss source 32 for connection to another line 33. A pitch control signal is similarly applied to the line 21 for transmission to the synthesis apparatus 3 wherein the invention is employed. The spectrum control signals applied to lines 11, 12 . . . 16, are thence respectively applied to terminals 41, 42 . . . 46. The circuitry connected to the right of terminal 41 parallels in detail each of the other five similar channels save only that each is responsive to a different frequency subband of the complete frequency range contained in the complex wave to be artificially produced.

Now a low pass filter 51 eliminates extraneous signals from the spectrum control signal applied to the transmission line 11 by the analysis equipment 2. Thus, a slowly varying potential serves to charge the capacitor 56. A transistor 52 has its emitter 53 and collector 54 connected in series with the capacitor 56 across the input terminals of band pass filter 58. In this preferred embodiment the transistor 52 takes the form of an N-P-N junction transistor. However, as pointed out in the aforementioned Reiling application, this transistor may, as well, take the form of a P-N-P junction transistor. Advantageously such a transistor may be chosen in accordance with the teachings of J. J. Ebers and J. L. Moll, Proceedings of the I.R.E., December 1954, p. 1761. There it is shown that a normal transistor in a nonconducting state may permit a minimum collector current drain if the biases on the emitter and collector electrodes be in the reverse direction. Biasing potential applied by the battery 57 to the transistor base serves to maintain the transistor 52 in such a nonconducting state. As a result a substantially infinite impedance appears in the conducting path through the emitter 53 and collector 54 to ground.

But when a pulse of sufficient magnitude is applied to line 33 by either buzz source 31 or hiss source 32, through the switch 30, the effect of the biasing battery 57 is overcome and an effective short circuit is developed in this conducting path of the emitter and collector electrodes 53 and 54. Hence, with each such pulse, the condenser 56 is partially discharged through a resistor 59 and a negative pulse is applied to the band pass filter 58.

The magnitude of this negative pulse is of course dependent on that of the charge stored on the condenser 56, and so depends also on the magnitude of the spectrum control signal passing the filter 51. Thus the train of such pulses which results from application, over the conductor 33 to the transistor 52, of a train of pulses from the buzz source 31 or the hiss source 32, is in fact an intermodulation product between the buzz or hiss source pulse train and the spectrum control signal.

If the signal applied to the line 33 by either of the sources 31 or 32 be a repetitive one, and in accordance with the invention as discussed earlier, this signal is repetitive, it is apparent that frequency components in accordance with the preselected design of the band pass filter 58 are continuously delivered to a load 60, in this embodiment a loudspeaker. Hence, it develops that the spectrum control signal appearing on the line 11 of itself provides the power required for the operation of the transistor 52 and supplies, too, the power delivered to the load 60. In this fashion, then, the invention provides a modulator consisting essentially of a single transistor. Experiment has shown this modulator not only more durable in terms of maintenance-free operation but more effective than known modulators in achieving a high signal to noise ratio.

The pulse signals required to actuate these modulating transistor switches, e.g., the transistor 52, are derived from one of two alternative sources. An appropriate selection signal is applied to the line 20 by the analysis equipment 2. This signal serves to actuate the relay operated switch 30 which, in turn, applies the output of a buzz source 31 or a hiss source 32 to the line 33 and thence to the bases of each of the modulating switches, as represented by the transistor 52, in parallel.

Consider first the buzz source 31. As has been done in the prior art, the invention provides an astable multivibrator 61, the frequency of which is controlled, in accordance with the fundamental pitch of the sound to be produced, by a signal applied at the analyzer to the line 21.

Referring briefly, however, to Fig. 2 it is seen that a train of pulses produced by such a multivibrator may have serious defects when employed as a buzz source in a speech synthesis system. If the period, T_b , between pulses be decreased without variation of the duration, t_b , of those pulses, the effect is to raise the time average value, A , of the train and vice versa. Consequently a frequency variation in a buzz source producing a train of pulses, such as illustrated in Fig. 2, results in variation of the energy level of that train. But if the period, T_b , of the pulses be varied directly with the duration, t_b , of those pulses, then no change in the average value of the pulse train is effected by a variation in their frequency.

Return now to Fig. 1. The output of the astable multivibrator 61 passes to the shaping circuit 62 wherein the wave form of that output is altered to provide a suitable trigger for a monostable multivibrator 63. Thus the frequency of the pulse train produced by the multivibrator 63 is determined by that of the multivibrator 61. But the signal applied to the line 21 to determine the frequency of the multivibrator 61 is similarly applied to the multivibrator 63 to determine the duration of output pulses of that multivibrator. Thus, diagrammatically are shown in Fig. 1, means for maintaining the energy output of the buzz source 31 at a level which is independent of frequency.

A more detailed understanding of this buzz source circuitry is gained by consideration of Fig. 4. In this figure the astable multivibrator 61 comprises a pair of transistors 101 and 102 intercoupled by capacitors 123 and 124 between their respective collectors and their bases 103 and 104. Control voltages applied through the line 21 and the resistors 125 and 126 to these bases 103 and 104, regulate the frequency of oscillation.

An interesting feature of this circuitry lies in the re-

sistor 107 connected in common to the emitters 108 and 109 of the transistors 101 and 102. This resistor 107 precludes the "lock-up" phenomenon observed in such circuits which are base stabilized, as by diodes 114, 115 and 116. If one of these transistors, 101 or 102, is conducting at saturation current, it does not amplify signals coupled to its base 103 or 104. Should both transistor 101 and 102 be in this heavy conduction state, the "lock-up" condition, no oscillation takes place. The magnitude of resistor 107 is chosen, however, to lie within a range such that appropriate bias potentials are applied to the respective emitters 103 and 104 under normal operating conditions but that disabling bias potentials are applied by current flow in an amount corresponding to the lock-up condition.

The output of the multivibrator 61 passes through the shaping circuit 62 where it is differentiated and clipped to appear as a trigger for the monostable multivibrator 63. The signal applied to the line 21 appears on the base of the transistor 106 through resistor 136 of the monostable multivibrator 63 to control the duration of its On time. The output of that multivibrator 63 then is applied for amplification to the transistor 117. The output of that transistor 117 constitutes a buzz output in which the duration of pulses is related directly to their period by the common action on the two multivibrators 61 and 63 of control voltages appearing on the line 21.

A representative set of values for the components of the multivibrators 61 and 63 to vary the buzz output frequency from 70 to 300 cycles per second, with a concurrent pulse duration change from 143 microseconds to 33.3 microseconds, by a change of the control voltage on the line 21 from +2 to +16 volts, is as follows:

Capacitors 123 and 124	-----microfarad	35
Resistors 121, 122, 127, 128	-----kilohms	15
Capacitors 130, 131	-----micro-microfarads	200
Capacitor 135	-----do	.0068
Resistors 125, 126	-----kilohms	27
Resistors 129, 133	-----do	22
Resistor 132	-----do	51
Resistor 134	-----do	150

Alternative to the buzz source 31 (Fig. 1), the hiss source 32 supplies energy to actuate the transistor switches exemplified by the transistor 52. Such switches, it has been seen, require actuating pulses of amplitudes exceeding a preassigned value in order to effect the change from infinite to zero impedance contemplated by the invention. And to function as a proper hiss source it is requisite that this element develop a uniform energy level output throughout a frequency range of interest.

Rigorous mathematical analysis shows that such a uniform output is contained in a train of pulses such as shown in Fig. 3. Here is illustrated a train of periodic pulses of a period, T_h , and of a duration, t_h , from which periodic train random pulses have been omitted.

A similar uniform energy level may be obtained, and the scope of the invention so comprehends, by random variation of the duration, t_h , of the pulses or by similar random variations of the period, T_h , of the pulse train. But in the preferred embodiment shown in Fig. 1, a noise generator 64 delivers random pulses to a sampler 67. Concurrently, a signal generator 65, which may advantageously take the form of an astable multivibrator, delivers a uniform train of pulses to this same sampler 67. The sampler 67 is so arranged that it provides an output to trigger the multivibrator 68 only when the noise generator 64 has no pulsed output of suitable polarity and amplitude. Thus random pulses from the noise generator 64 serve to eliminate from the sampler output random ones of the pulses from the signal generator 65 and, in corresponding fashion, so control the hiss output of multivibrator 68.

The detailed functioning of such a hiss source can best be seen with reference to Fig. 5. Transistors 81 and 82

amplify random self-originated noise, which amplified signal is applied to a buffer stage, transistor 83. This stage prevents overloading of the transistor 82 and provides a differentiated output to an amplifying transistor 84. In the circuitry of that transistor 84 the signal is again differentiated and applied to limiting transistors 85 and 86.

The negative feedback from the latter to the former varies with the voltage output of the transistor 86. This variation is accomplished by the action of varistor diodes 97 and 98, advantageously of the type set forth in W. Schockley Patent 2,714,702, granted August 2, 1955, which diodes appear in the feedback path from transistor 86 to transistor 85. The resistance of these diodes in a forward direction has a high value below a given threshold voltage applied to them. Conversely this resistance becomes negligible at voltages in excess of that threshold. Accordingly a high level output from transistor 86 is applied almost in its entirety as negative feedback to the input of transistor 85. Hence the output of transistor 86 is limited in value. This limited output is then applied through a differentiator 89 to the base of the transistor 87 where it appears, by the action of the differentiator 89, as a sharp pulse.

In sampler 67, a transistor 87 is normally in a nonconducting state for lack of a biasing potential. Accordingly the potential of a conductor 90, common to the collector electrodes of the two transistors 87 and 88, is normally controlled by current flowing in the transistor 88. Hence, if a pulse be applied to the base 91 of the transistor 88 of magnitude and polarity to render that latter transistor nonconducting, a positive pulse appears on the conductor 90 and is transmitted to monostable multivibrator 68 where it serves to trigger the transistor 94. This transistor is normally held in a quiescent state by virtue of stabilizing diodes 99 and 100.

If, however, coincident with the arrival of the pulse which renders the transistor 88 nonconducting, a pulse should arrive to drive the transistor 87 into conduction then the potential of the conductor 90 is not affected by the behavior of the transistor 88 and no pulse is delivered to trigger the multivibrator 68.

Now an astable multivibrator 65 provides a train of negative pulses to the base 91 of the transistor 88. Without the first transistor 87, the second transistor 88 serves as a conduit to transmit the pulses of the astable multivibrator 65 to the monostable multivibrator 68. But, with the first transistor 87, the second transistor 88 operates as a coincidence gate. Thus, from the train of pulses appearing on conductor 90, as a result of the influence of the multivibrator 65, positive pulses appearing at the differentiator 89 eliminate such of those pulses as may be coincident in time with those differentiated pulses.

From this discussion of Fig. 5 it is seen that the output of a monostable multivibrator 68, conventional in form and comprising the transistors 94 and 95, is delivered by way of amplifying transistor 96 to the switch 30 of Fig. 1 as a uniform train of pulses from which train random pulses are eliminated by the action of random noise energy arriving at the differentiator 89.

And in consideration of the import of the structures detailed in Figs. 4 and 5, in connection with the operation of Fig. 1, it similarly appears that the invention shows one embodiment of each of three elements adapted to cooperate in a vocoder voice synthesis system toward providing an improved local energy source for the artificial production of speech. While one specific embodiment of the invention has been selected for detailed description, the invention is not, of course, limited in its application to the embodiment described. This embodiment should be taken as illustrative of the invention and not as restrictive thereof.

What is claimed is:

1. Apparatus for the production of artificial speech 75

sounds comprising a plurality of channels, each responsive to one of a like plurality of frequency subbands of a complex wave, each of said channels comprising a frequency-selective element having an input circuit and an output circuit connected thereto, each of said input circuits comprising an electrical storage element connected in series with said frequency-selective element, a like plurality of sources of spectrum control signals of various magnitudes, means for applying said spectrum control signals to said input circuits respectively, whereby energy of said spectrum control signals is stored in said elements, a like plurality of switches each having a pair of conduction terminals and a control terminal, each of said conduction terminal pairs being connected to one of said input circuits, a load connected in common to all of said output circuits, means for generating a sequence of periodic pulses, means for varying the durations of said pulses in proportion to the period of said sequence, and means for applying said periodic pulse sequence simultaneously to the control terminals of all of said switches, thereby to cause energy of said spectrum control signals, as modulated by various frequency components of said pulse sequence, to flow through said several input circuits and said several frequency-selective elements respectively and to said common load, in amounts which are in substantial proportion to the magnitudes of said control signals throughout a range of such magnitudes which extends substantially to zero magnitude.

2. Apparatus for the production of artificial speech sounds comprising a plurality of channels, each responsive to one of a like plurality of frequency subbands of a complex wave, each of said channels comprising a frequency-selective element having an input circuit and an output circuit connected thereto, each of said input circuits comprising an electrical storage element connected in series with said frequency-selective element, a like plurality of sources of spectrum control signals of various magnitudes, means for applying said spectrum control signals to said input circuits respectively, whereby energy of said spectrum control signals is stored in said elements, a like plurality of switches each having a pair of conduction terminals and a control terminal, each of said conduction terminal pairs being connected to one of said input circuits, a load connected in common to all of said output circuits, means responsive in frequency to an external control signal for generating a sequence of trigger pulses, means responsive to each of said trigger pulses for generating one of a second sequence of pulses, the durations of the pulses of said second sequence being substantially inversely proportional to the magnitude of an external control signal, a source of a pitch signal, means for applying said pitch signal simultaneously to said trigger pulse generating means and to said second sequence generating means, whereby the durations of the several pulses of said sequence are in proportion to the period of said sequence, and means for applying the pulses of said sequence simultaneously to the control terminals of all of said switches, thereby to cause energy of said spectrum control signals, as modulated by various frequency components of said pulse sequence, to flow through said several input circuits and said several frequency selective elements respectively and to said common load, in amounts which are in substantial proportion to the magnitudes of said control signals throughout a range of such magnitudes which extends substantially to zero magnitude.

3. A system for the artificial synthesis of a complex wave having a plurality of frequency subbands which comprises a source of a like plurality of spectrum control signals, each of said signals having a value representative of the momentary energy content of said wave within a different one of said frequency subbands, a like plurality of channels, each of said channels comprising an output element for passing a frequency subband corresponding to a different one of said spectrum control signals respectively, an input element and a storage element connected

in tandem with said output element, an impedance element connected in series with said storage element and in parallel with said output element, and signal-controlled means for discharging said storage element through said impedance element, and a load impedance connected in common to all of said output elements, means for applying each of said spectrum control signals to a corresponding one of said input elements, and means for applying a control signal in common to each of said discharging means.

4. In apparatus for the artificial synthesis of a complex wave having an energy content distributed throughout a plurality of frequency subbands, a synthesis channel for one of said frequency subband components of said complex wave which comprises a source of a spectrum control signal having an amplitude representative of the energy content of said complex wave frequency subband, an element for storing electrical energy of said signal, filter means for blocking electrical energy removed in frequency from said subband, said filter means comprising two input terminals and two output terminals, a signal controlled switch having two conduction terminals and a control terminal, said conduction terminals being connected in series with said input terminals and said storage element, an impedance element connected between said input terminals, a load impedance connected between said output terminals, means for applying said spectrum control signal between said conduction terminals whereby energy of said signal is stored in said storage element, and means for applying a control signal to said control terminal whereby said storage element is discharged through said impedance element and said conduction terminals thereby to derive a signal in said load impedance.

5. In artificial speech synthesis apparatus, in combination with a source of a pitch signal, means for generating a complex periodic wave of energy content substantially independent of frequency, for use in the production of artificial voiced sounds, which comprises means for generating a train of trigger pulses, means responsive to the successive pulses of said train for generating a sequence of substantially flat-topped pulses of like amplitudes and of controllable durations, one for each trigger pulse, means for applying said pitch signal to said trigger pulse generating means in a sense to increase the trigger pulse rate with increase of said signal, and means for simultaneously applying said pitch signal to said sequence-generating means in a sense to reduce said durations with increase of said signal.

6. In combination with apparatus as defined in claim

5, a plurality of sources of spectrum control signals that are individually representative of the energies of individual subbands that together embrace the frequency band of a voice signal to be synthesized, a like plurality of signal storage elements, means for storing the amplitudes of the several control signals on the several storage elements, respectively, a sound reproducer connected to all of said storage elements in common, a switch connected to each storage element for partially discharging it into said reproducer in response to an initiating pulse, and means for applying said flat-topped pulses in succession as initiating pulses to all of said switches together, thereby partially to discharge all of said storage elements in like succession into said reproducer.

7. In artificial speech synthesis apparatus, means for generating a complex aperiodic wave for use in the production of artificial unvoiced sounds which comprises means for generating a regular sequence of pulses of like amplitudes and like durations, a noise source, a sampling gate having a conduction input terminal, a control terminal and an output terminal, said gate being constructed to pass to its output terminal a signal applied to its input terminal when and only when a signal is also applied to its control terminal, means for applying the pulses of said sequence to said conduction input terminal, means for applying the noise of said noise source to said control terminal, and means for utilizing the signal appearing at said output point, said signal thus consisting of a completely irregular train of like pulses.

8. In combination with apparatus as defined in claim 7, a plurality of sources of spectrum control signals that are individually representative of the energies of individual subbands that together embrace the frequency band of a voice signal to be synthesized, a like plurality of signal storage elements, means for storing the amplitudes of the several control signals on the several storage elements, respectively, a sound reproducer connected to all of said storage elements in common, a switch connected to each storage element for partially discharging it into said reproducer in response to an initiating pulse, and means for applying said uniform amplitude pulses in succession as initiating pulses to all of said switches together, thereby partially to discharge all of said storage elements in like succession into said reproducer.

References Cited in the file of this patent

UNITED STATES PATENTS

2,151,091 Dudley ----- Mar. 21, 1939