

[54] ARTIFICIAL SPEECH DEVICE

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[52] U.S. Cl. 179/1 AL; 3/1.3

[51] Int. Cl.² A61F 1/20; G10L 1/10

[58] Field of Search 179/1 AL

[56] References Cited

UNITED STATES PATENTS

2,862,209	12/1958	Cooper	179/1
3,066,186	11/1962	Trammill	179/1
3,291,912	12/1966	Flanagan	179/1
3,766,318	10/1973	Webb	179/1

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[57]

ABSTRACT

Disclosed is a device which generates sound in selected waveforms and at selected frequencies via a transducer located in the mouth for conversion into intelligible speech by a person who has lost the use of the larynx or vocal cords. The device impulses the diaphragm of the transducer with pulses of generally rectangular waveform to provide the generated sound with a waveform comprising a series of damped sinusoids with harmonics. Such waveforms enable use of the device with practically any individual regardless of the resonant and other acoustical characteristics of the individual's mouth, and permits the transducer and an included tube for directing the sound to be freely placed in and disposed at a variety of different locations throughout the mouth. The frequency of the generated sound may be varied by varying the pulse repetition rate, while the amplitude of the sound can be varied by changing the pulse width.

2 Claims, 22 Drawing Figures

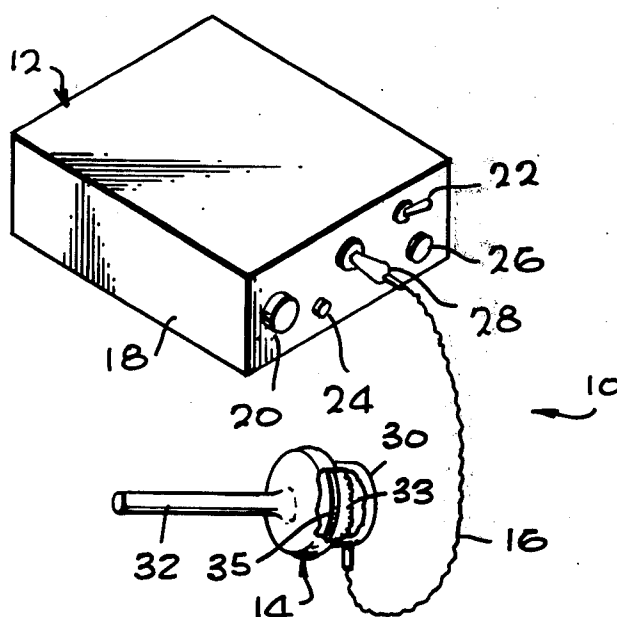


Fig. 1

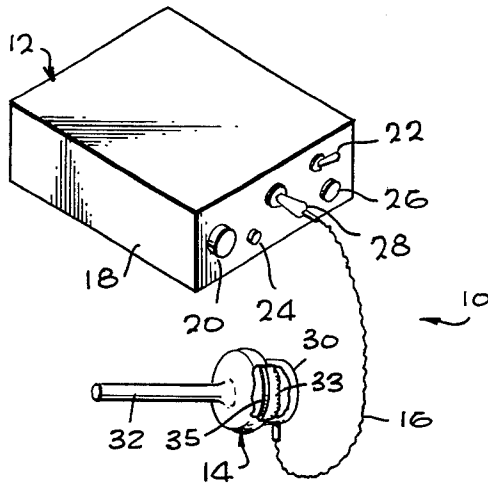


Fig. 2

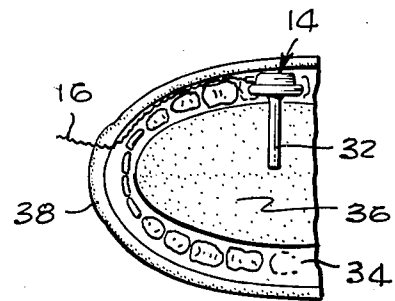


Fig. 3

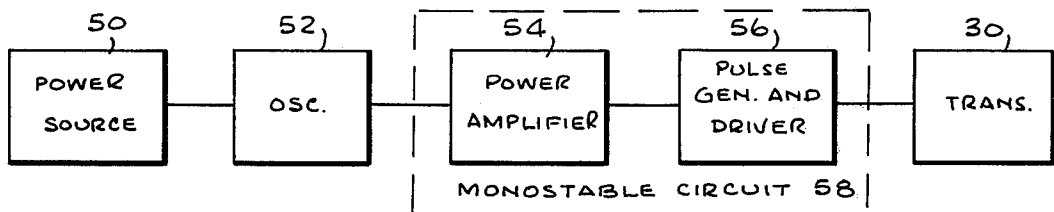


Fig. 4

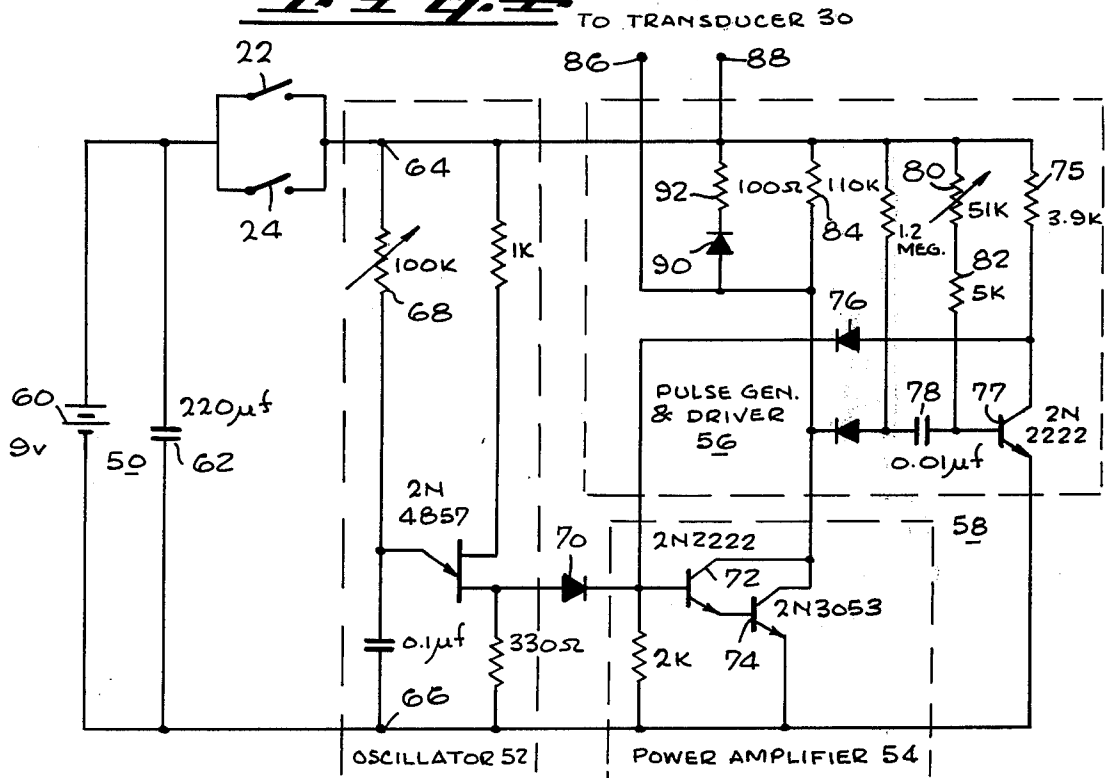


Fig. 5

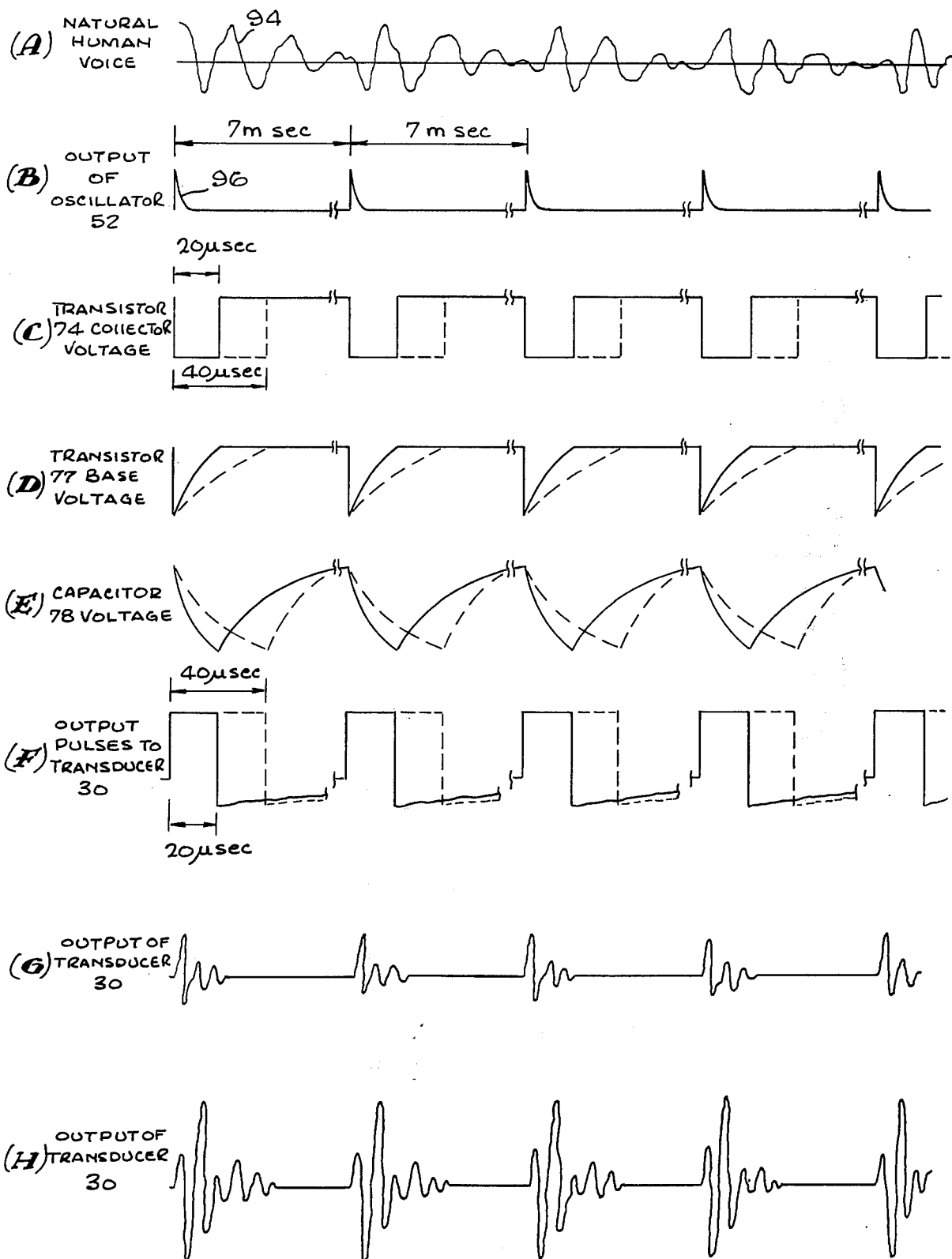


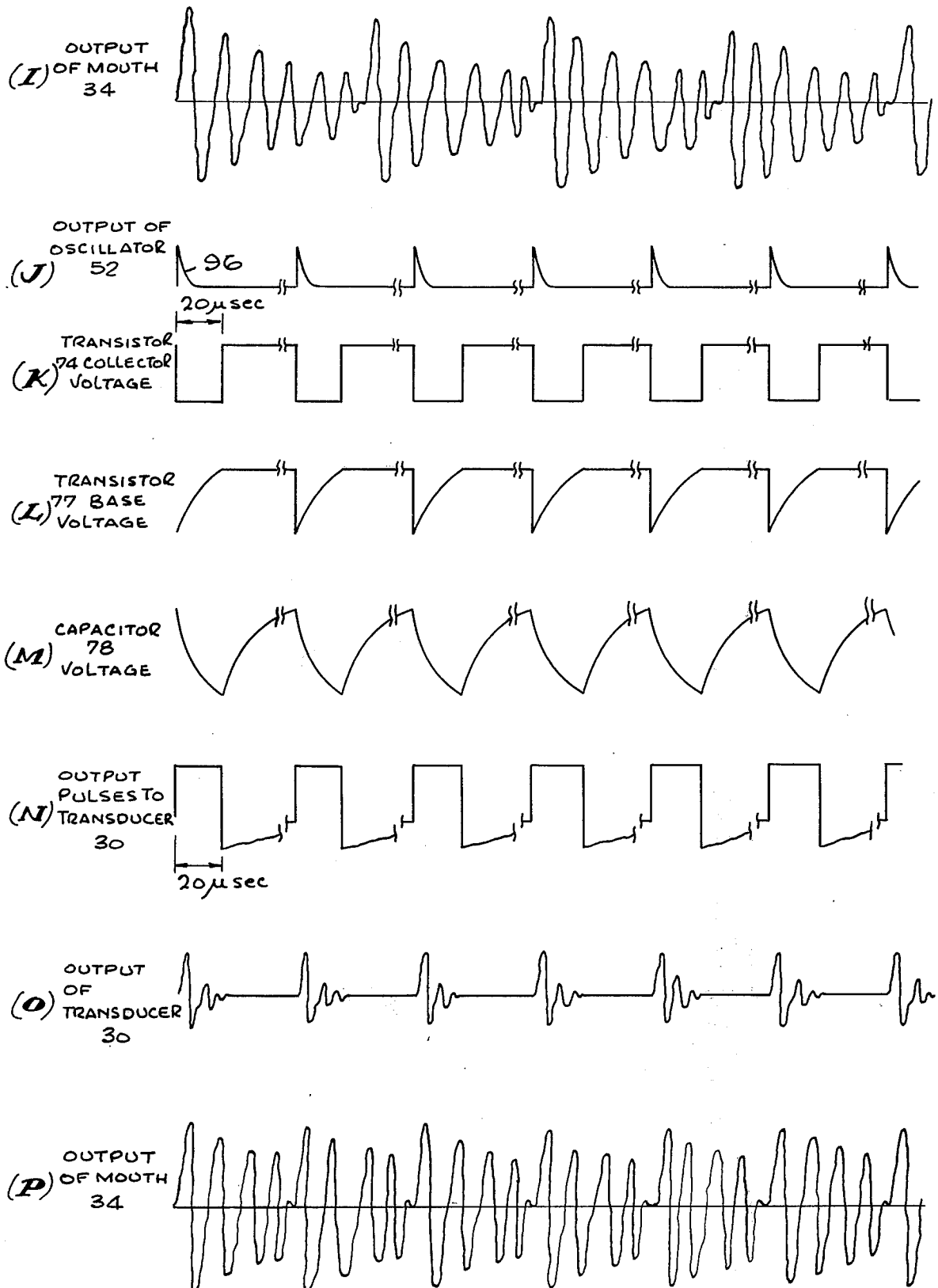
Fig. 5

FIG. 6A

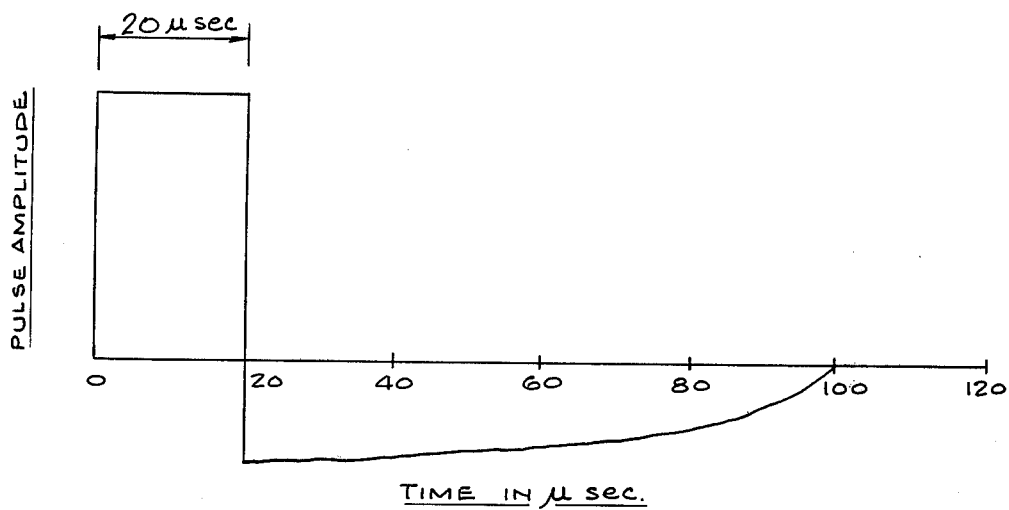
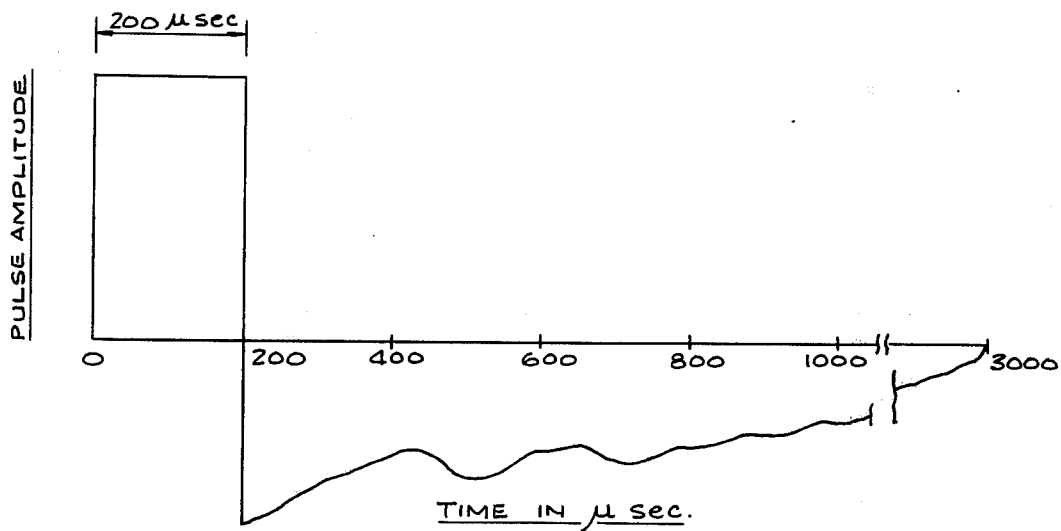


FIG. 6B



ARTIFICIAL SPEECH DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to devices for generating sound for conversion into speech by persons otherwise unable to speak intelligibly due to the loss of the use of the larynx or vocal cords, and more particularly to devices of this type which introduce the generated sound directly into the mouth of the user.

2. History of the Prior Art

An increasing number of persons have lost the ability to speak intelligibly or to speak at all due to impairment of the larynx or to the vocal cords contained therein. During normal speech, the vocal cords vibrate in response to the expulsion of air from the lungs to create sound which is converted by the mouth into intelligible speech. Where use of the vocal cords is lost such as by reason of surgical removal of the larynx, the person loses his ability to speak. With considerable training and practice, the person so handicapped can sometimes develop a technique in which air is expelled from the stomach in such fashion as to create a sound for conversion by the mouth to speech. Such technique, however, has serious limitations making the use of artificial speech devices generally preferable.

There are a variety of artificial speech devices designed to solve the speech problem noted above. Most of these devices generate sound which is introduced into the mouth to replace the sound normally provided by the vocal cords. U.S. Pat. No. 3,291,912 of Flanagan is an example of one such device in which the sound is generated outside the mouth and is thereafter transmitted through the throat and into the mouth. The Flanagan arrangement transmits the sound through the throat by exciting a diaphragm adjacent the throat wall with a train of pulses. A basic timing device is used to determine the basic frequency of the generated sound, and a plurality of pulses are then generated during each period so defined and applied to excite the diaphragm. U.S. Pat. Nos. 2,862,209 of Cooper and 3,084,221 of Cooper et al illustrate arrangements in which the sound is introduced directly into the mouth. The Cooper patent discloses a denture which acts as a horn to direct sound from a transducer to the back of the mouth. The Cooper et al patent shows a bite block which may be selectively compressed between the teeth to control the introduction of sound into the mouth. Still other devices are shown by U.S. Pat. Nos. 2,093,453 of Kellotat and 3,508,000 of Snyder. The Kellotat patent discloses a denture which responds to exhaled air to produce sound within the mouth. The Snyder patent discloses an arrangement which generates an electromagnetic signal inside the mouth for conversion into sound outside of the mouth.

While arrangements which provide the generated sound outside of the mouth have the advantage that no device is required to be placed within the mouth, such arrangements have proven to be generally unsatisfactory in most instances, principally because of the difficulty of producing sound within the mouth of sufficient amplitude to be readily intelligible. Moreover the generated sound is typically of such a nature that it does not resonate with or otherwise compliment the acoustical characteristics of the user's mouth, resulting in further reduction in the intelligibility of the speech.

Arrangements which locate the transducer within the mouth or otherwise function to introduce the generated sound directly into the mouth have proven to be generally superior, principally because the loss in volume is minimized in such situations. However, such arrangements leave much to be desired from other standpoints. For instance, most such arrangements use a signal of sinusoidal or similar waveform to excite the transducer. The resulting acoustical energy typically has a waveform which is itself sinusoidal and of singular frequency and amplitude. The singular frequency of the sound waveform typically requires that the transducer assembly be placed at a fixed, critical location within the mouth in an attempt to match resonant characteristics of the mouth to the generated sound. The dentures and similar devices used to hold the transducer assembly at a fixed location within the mouth as so required, result in arrangements which are very uncomfortable and cumbersome for the user. Moreover even in the relatively uncommon situation where the singular frequency of the generated sound is closely matched to the resonant characteristics of the mouth, the resulting speech leaves something to be desired in terms of intelligibility, among other reasons because the generally constant amplitude characteristic of the generated sound is unlike that of normal speech.

Accordingly, it would be desirable to provide an artificial speech device for generating sound which is easily converted into highly intelligible speech by virtually any user, regardless of acoustical characteristics of the user's mouth or of the particular location within the mouth at which the sound is introduced. Such an arrangement in which a sound capable of resonating at any of many different frequencies is produced would not only produce more intelligible speech but would enable the transducer assembly to be loosely placed in and readily moved about the inside of the user's mouth, thereby freeing the user from annoying dentures and similar arrangements.

BRIEF DESCRIPTION OF THE INVENTION

Artificial speech devices in accordance with the invention generate pulses which impulse the diaphragm of the transducer to produce an acoustical waveform which is essentially a damped sinusoid and which therefore closely approximates the waveforms of normal speech. The damped sinusoids include numerous harmonics, enabling them to resonate in virtually any mouth independent of the acoustical characteristics of the mouth. The transducer arrangement can be placed in practically any location within the mouth, so long as the sound produced thereby is directed over the tongue and into the speech forming area of the mouth. Accordingly, the transducer assembly consisting of the transducer and a hollow tube connected thereto for directing the sound to the back of the mouth may be naturally positioned so as to be held loosely within the mouth.

The basic frequency of operation is determined by an oscillator which generates a succession of generally equally spaced timing signals to define the periods. A monostable circuit responds to the occurrence of each timing signal to change state for a selected period of time and provide a driving pulse of generally rectangular waveform to the transducer. The generated pulse impulses the transducer diaphragm, then terminates for the remainder of the period, leaving the transducer dia-

phragm free to vibrate in response to the impulsing thereof. The amplitude of the generated sound and thus of the resulting speech can be controlled by varying the width of the pulses. The pitch or frequency of the sound can be varied by varying the rate of occurrence of the timing pulses.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of a preferred embodiment of the invention, as illustrated in the accompanying drawings, in which:

FIG. 1 is a perspective view of an artificial speech device according to the invention;

FIG. 2 is a plan view of the inside of the mouth of a user showing a typical positioning of the sound unit of the artificial speech device therein;

FIG. 3 is a basic block diagram of the electrical portion of the artificial speech device of FIG. 1;

FIG. 4 is a schematic diagram of the arrangement of FIG. 3;

FIGS. 5A through 5P are waveforms useful in explaining the operation of the artificial speech device in FIG. 1; and

FIGS. 6A and 6B are waveforms which are also useful in explaining the operation of the artificial speech device of FIG. 1.

DETAILED DESCRIPTION

A preferred form of artificial speech device 10 in accordance with the invention is illustrated in FIG. 1. The device 10 includes a control unit 12 carried in a convenient location such as the user's shirt pocket and a sound unit 14 which can be placed in the user's mouth as shown in FIG. 2. The sound unit 14 is coupled to the control unit 12 by a cord 16 comprising a pair of wires.

The control unit 12 comprises a generally rectangular housing 18 which contains the power source in the form of a longlife battery, the electronics for generating signals applied to the sound unit 14 via the cord 16, and various controls for the device 10. The controls appear on the front panel of the housing 18 and include a volume control 20 for adjusting the volume of sound produced by the sound unit 14, a toggle switch 22 for turning the device on to generate the sound at the sound unit 14, a pushbutton 24 which may be used in lieu of the toggle switch 22 and which produces sound at the sound unit 14 when depressed, and a pitch control 26 which varies the pitch of the sound produced by the sound unit 14 by varying the base frequency thereof. A plug and jack arrangement 28 couples the cord 16 to the inside of the housing 18.

The sound unit 14 includes an electro-acoustic transducer 30 and a sound tube 32. The transducer 30 responds to electrical signals generated by the control unit 12 and carried by the cord 16, to generate acoustical energy which is then carried by the sound tube 32. A coil 33 within the transducer 30 responds to the electrical signals delivered by the cord 16 to cause movement of a diaphragm 35 and thereby generate acoustical energy. The transducer 30 may comprise an electro-acoustic transducer of the type commonly used in hearing aids. Alternatively, the transducer 30 may comprise other types of transducers such as a piezoelectric transducer or a magnetostrictive transducer. The sound tube 32 which comprises a piece of hollow

plastic tubing rests on top of the tongue as shown in FIG. 2 and serves to direct the sound to the speech forming area of the user's mouth.

In operation the control unit 12 is placed in a convenient location on the user's person such as a front shirt pocket or an inside coat pocket and the sound unit 14 is placed within the user's mouth 34 in a convenient and comfortable location and so that the sound tube 32 is disposed over or on top of the tongue 36. The cord 16 extends between the lips 38 of the mouth opening and to the control unit 12. The sound generated by the transducer 30 is passed by the sound tube 32 over the top of the tongue 36 and toward the region of the throat. As is known in the art such sound is converted into speech by manipulation of the mouth, tongue, throat and lips much in the same way as normal speech is produced. The only difference is that the sound which is converted into speech is provided by the sound unit 14 rather than by the vocal cords in the present instance.

In accordance with a feature of the invention to be described in detail hereafter, the artificial speech device 10 produces acoustical energy which is readily converted into intelligible speech regardless of the particular acoustical and resonant characteristics of the mouth. This is done by producing a sound waveform having a variety of harmonic components, one or more of which are at the appropriate frequency so as to resonate and favorably interact with the particular characteristics of virtually any mouth. In accordance with a further feature of the invention, the sound waveform produced by the artificial speech device 10 is very similar to that of normal speech so as to make the resulting speech more intelligible. A still further feature of the invention results from the fact that the sound produced by the artificial speech device 10 need not be critically adjusted to the particular oral characteristics of the user. For this reason the sound unit 14 may be placed in virtually any convenient and comfortable position within the mouth 34, so long as the sound tube 32 is positioned to direct sound in such a fashion that it reaches the back of the mouth. This provides for a "natural positioning" type of use in which the sound unit 14 can be allowed to float or move freely throughout the mouth so as to be used in a location most convenient and effective for the individual. In addition to eliminating dentures or other inconvenient or uncomfortable arrangements required by those prior art systems in which the location and direction of the sound is critical, the natural positioning arrangement of the sound unit made possible by the present invention makes the device much more pleasant to use in terms of comfort within the mouth and reduction of nervousness and anxiety which frequently occur when the user becomes conscious that he must retain the sound unit continually within the mouth during prolonged conversational periods and must maintain the sound unit in a specific position or location if satisfactory results are to be obtained. The physical configuration of the sound unit 14 aids in the comfort and ease of use. Because the transducer 30 has a substantially larger diameter than the tube 32, the transducer 30 tends to stay outside the teeth and tends to prevent the entire sound unit from falling or slipping into the central area of the mouth.

FIG. 3 comprises a basic block diagram of the electronic portion of the artificial speech device 10. As shown in FIG. 3 the device 10 includes a power source

50 feeding an oscillator 52. The oscillator 52 which is made variable in frequency so as to be able to vary the pitch of the generated sound produces a series of generally equally spaced timing signals or pulses which define the base or nominal operating frequency of the device 10. This frequency can be selected so as to complement the voice and other characteristics of the user. For example, a base frequency on the order of 200 hertz may typically be chosen in the case of a male user.

The timing pulses produced by the oscillator 52 are applied to a power amplifier 54 which together with a portion of a pulse generator and driver 56 comprises a monostable circuit 58. The power amplifier 54 responds to each timing pulse from the oscillator 52 to saturate a transistor and thereby switch the monostable circuit 58 into its unstable state. With the monostable circuit 58 in the unstable state, the driver portion of the pulse generator and driver 56 provides a pulse of generally rectangular waveform to the transducer 30. Generation of the pulse is continued so long as the monostable circuit 58 remains in the unstable state as determined by the time constant of an RC circuit within the pulse generator and driver 56. The RC circuit maintains the monostable circuit 58 within the first state for a selected period of time, then switches the monostable circuit into its stable state by turning off the transistor within the power amplifier 54 and at the same time biasing a transistor within the pulse generator and driver 56 into conduction. This terminates the pulse of rectangular waveform provided to the transducer 30, and no further signal is provided to the transducer during the remainder of the period defined by the timing pulse from the oscillator 52. Upon the occurrence of the next timing pulse from the oscillator 52 so as to define the beginning of a new period, the process is repeated with the monostable circuit 58 again changing state to provide a pulse of generally rectangular waveform to the transducer 30. The time constant defined by the RC circuit within the pulse generator and driver 56 is made variable so as to vary the widths of the rectangular pulses and thereby the amplitude of the sound produced by the transducer 30.

Each of the rectangular drive pulses impulses the diaphragm of the transducer 30 by driving the diaphragm in a selected direction and by a selected amount and thereafter allowing the diaphragm to undergo free vibratory motion in response to the impulsing thereof. The resulting acoustical energy generated by the transducer 30 comprises a succession of damped sinusoidal waveforms with harmonics.

A preferred arrangement of the artificial speech device 10 of FIG. 3 is schematically illustrated in FIG. 4. The power source 50 comprises a conventional 9 volt battery 60 coupled in parallel with a capacitor 62 across the input terminals 64 and 66 of the oscillator 52. Closure of either the toggle switch 22 or the push-button 24 couples the power source 50 to energize the oscillator 52 and feed the power amplifier 54. The oscillator 52 which is of conventional form responds by generating a plurality of timing signals or pulses at a frequency determined by a variable resistor 68 within the oscillator circuit. The timing pulses are applied via a diode 70 to the base of a transistor 72 coupled to control the conduction of a transistor 74.

The transistors 72 and 74 may be biased into conduction by the action of a resistor 75 and a diode 76 when

a transistor 77 is not conducting to switch the monostable circuit 58 into its unstable state. The monostable circuit is normally in its stable state in which the transistors 72 and 74 are not conducting and the transistor 77 is biased into conduction by a capacitor 78, a variable resistor 80, and a fixed resistor 82. A resistor 84 coupled in circuit with the transistors 72 and 74 is also coupled to a terminal 86 directly and to a terminal 88 through a flyback circuit comprising the serial combination of a diode 90 and a resistor 92. The terminals 86 and 88 are coupled via the wires of the cord 16 to the transducer 30.

The manner in which the circuit of FIG. 4 functions to produce sound in accordance with the invention can best be understood by referring to the waveforms of FIGS. 5 and 6. FIG. 5A depicts the waveform of the natural voice when the sound "ah" is made. This waveform, which is an accurate representation of the waveform actually appearing on an oscilloscope in response to the electrical measurement of such sound, is divided into a succession of periods which in this instance are approximately 7 milliseconds in length denoting a base frequency of the voice of approximately 143 hertz. The waveform 94 of FIG. 5A comprises a succession of damped sinusoids with each sinusoid occurring within a different period. The waveform components are not perfect sinusoids in that they include harmonic components in a variety of different frequencies.

The waveforms of FIGS. 5B through 5I illustrate the manner in which the circuit of FIG. 4 is used in conjunction with the user's mouth to produce sounds very similar to those of the natural human voice. The variable resistor 68 within the oscillator 52 is varied to adjust the base frequency to approximately 143 hertz. This means that every 7 milliseconds the oscillator 52 generates a new timing signal or pulse 96 to define the beginning of a new period as shown in FIG. 5B. Each pulse 96 is applied via the diode 70 to momentarily bias the transistors 72 and 74 into conduction. Conduction of the transistor 74 causes current to flow through the resistor 84, causing a reduction in the collector voltage of the transistor 74 as shown in FIG. 5C. This is accompanied by generation of an output pulse to the transducer 30 as shown in FIG. 5F. At the moment that the transistor 74 is biased into conduction as a result of a pulse 96 from the oscillator 52, the transistor 77 is biased into nonconduction as shown by FIG. 5D which is a representation of the base voltage thereof. At the same time, the charge level of the capacitor 78 begins to change as shown in FIG. 5E.

With the transistor 77 being biased into nonconduction, current at the collector thereof flows through the diode 76 to the base of the transistor 72 to hold the transistors 72 and 74 in a conductive state and thereby temporarily hold the monostable circuit 58 in the unstable state. Discharge of the capacitor 78 as shown in FIG. 5E is controlled by the resistor 82 and the variable resistor 80. When the level of charge on the capacitor 78 reaches a certain value, the transistor 77 is biased into conduction which diverts the current from the diode 76 and thereby biases the transistors 72 and 74 into nonconduction, to return the monostable circuit 58 to the stable state. As seen in FIG. 5F, termination of conduction by the transistor 74 terminates the flow of current through the resistor 84 and thereby the output pulse to the transducer 30.

The flyback circuit comprising the diode 90 and the resistor 92 permits relatively rapid change of the current flowing through the coil 33 of the transducer 30. When the pulse to the transducer 30 is terminated, the voltage thereof decreases through zero to a negative value due to the inductive effect of the coil 33 and the force returning the diaphragm to the initial position. As shown in FIG. 5F, the voltage gradually decreases back to zero from its negative value as the inductive effect of the transducer coil 33 is overcome. The minor variations in the voltage waveform in this region are caused by movements of the transducer diaphragm 35 in response to the behavior of the sound waves within the sound tube 32. Such behavior of the transducer diaphragm 35 and the resulting signal aberrations are directly related to the advantageous use of the transducer to generate desired acoustical waveforms in accordance with the invention.

In the present example, the variable resistor 80 in the arrangement of FIG. 4 has been set to deliver output pulses which are of about 20 microseconds duration. Such pulses are of relatively short duration and result in an acoustical waveform of relatively small amplitude as shown in FIG. 5G. The amplitude of the acoustical waveform is increased by widening the rectangular pulses applied to the transducer 30. This is accomplished by adjusting the variable resistor 80 so as to provide for a longer time constant when combined with the capacitor 78. As shown in dotted outline in FIGS. 5C through 5F, proper adjustment of the variable resistor 80 provides a longer time constant and thereby an output pulse of greater duration. In the example shown in dotted outline, the time constant of the RC circuit has been changed to provide for a 40 microsecond interval after pulsing of the transistor 72 by the oscillator 52 before the capacitor 78 charges to a level sufficient to bias the transistor 77 into conduction and switch the monostable circuit 58 from the unstable state back to the stable state. The variable resistor 80 is coupled to be controlled by the volume control 20 on the outside of the housing 18 of the control unit 12.

The actual voltage of the transducer 30 in the case of a 20 microsecond output pulse is shown in greater detail in FIG. 6A. As previously noted, termination of the pulse results in a reverse voltage due to the flyback circuit comprising the diode 90 and the resistor 92, the effects of the driving coil 33 within the transducer 30 and the effects of the sound waves within the tube 32. In the case of the 20 microsecond pulse of FIG. 6A, the reverse voltage decays to zero about 100 microseconds after the current pulse was begun. FIG. 6B shows the case where the variable resistor 80 of FIG. 4 has been adjusted to provide for a relatively long voltage pulse of 200 microseconds duration. In that instance, the reverse voltage decays in a manner similar to that in the example of FIG. 6A except that the decay time is much longer and the voltage waveform is much more erratic due to the substantially greater impulsing of the transducer 30 by the much longer voltage pulse. In the example of FIG. 6B, the reverse voltage does not decrease to zero until approximately 3,000 microseconds after the initial pulse was begun.

As previously noted, FIG. 5G depicts the output of the sound unit 14 comprising the transducer 30 and the sound tube 32 when the driving pulses are of 20 microseconds duration. FIG. 5H depicts the output of the sound unit 14 in response to current pulses of 200 mi-

croseconds duration as shown in FIG. 6B. It will be noted that the longer drive pulses produce an acoustical waveform which is of greater amplitude and greater duration.

It will be noted from FIGS. 5G and 5H that artificial speech devices 10 in accordance with the invention produce sound, the waveform of which comprises a succession of damped sinusoids with harmonics. This results from the use of voltage pulses of selected duration to energize the transducer 30 in such a fashion as to create an impulse function. The electrical impulsing as provided by the voltage pulses is translated into an acoustical impulse function by the transducer 30. It is known by Fourier and other waveform analysis techniques that impulse functions have relatively broad frequency spectrums. This helps to explain the resulting acoustical waveforms as shown in FIGS. 5G and 5H where many harmonic components are present. As previously noted, the mouth of the user as well as the sound tube 32 have particular acoustical characteristics. Among other things, the mouth and the tube resonate at a certain frequency or frequencies characteristic of the particular mouth and tube in question. In the case of natural speech, the sound produced by the vocal cords contains many frequency components enabling it to resonate in a favorable manner within the mouth as the mouth is manipulated to convert the sound into speech. However a similar effect has heretofore not been possible with artificial speech devices because of the nature of the sound produced by such devices. For example, where a signal of essentially sinusoidal waveform is used to excite the transducer as in the case of many prior art devices, the resulting acoustical energy produced by the transducer is itself of generally sinusoidal waveform. Very few, if any, harmonic components are present in the resulting signal. As a result, the frequency of the generated sound and the location at which such sound is introduced within the mouth must be very critically selected in an attempt to maximize the resonate action as the mouth converts the sound into speech. However, even where the frequency characteristics and place of introduction of the sound are carefully chosen, the results are often marginal or unacceptable due to the variations in the characteristics of the mouth, variations in the frequency or location of the generated sound and other factors.

In the present invention, the drive pulse generated at the beginning of each period acts to move the diaphragm 35 of the transducer 30 in a selected direction and by a selected amount, at which point the pulse is terminated and the diaphragm 35 is thereafter free to move in response to the impulsing thereof for the remainder of the period. Where the pulses are of relatively short duration as in the case of the 20 microsecond pulse of FIGS. 5F and 6A, the transducer diaphragm 35 is driven in the selected direction as determined by the polarity of the pulse over only a relatively small extent of its possible travel. In the case of a very large pulse such as the 200 microsecond pulse shown in FIG. 6B, the transducer diaphragm 35 is driven to or almost to its limit of travel. This is shown by the relatively large initial value of the reverse voltage which is depicted in FIG. 6B and which is due to the very strong attempt by the diaphragm 35 to return from a greater displacement to its neutral position.

The digital rectangular technique employed to energize the transducer also results in relatively efficient

operation of the electrical circuitry, when compared with sine wave energizing techniques. This permits a relatively long period of operation with a compact power source.

FIG. 5I illustrates the waveform of sound which actually results when the waveform of FIG. 5G is introduced into the mouth and converted into speech by the mouth. The waveform shown is an accurate reproduction of an oscilloscope waveform which resulted from the user making a simple "ah" sound as in the case of FIG. 5A. It will be noted that the waveform of FIG. 5I is of considerably greater amplitude and duration than the corresponding waveform of FIG. 5G. This is principally due to the increased resonant effect which the mouth has on a signal of multiple frequencies as in the case of FIG. 5G. Like the waveform of FIG. 5A which is produced by the natural human voice, the waveform of FIG. 5I comprises a succession of damped sinusoids with harmonics.

As in the case of FIG. 5A, the waveform of FIG. 5I is divided into equal periods of 7 milliseconds duration. This is a further feature which makes speech produced with the aid of artificial speech devices according to the invention more intelligible and which is not found in prior art devices. For example, in those devices where the transducer is excited by a signal of generally sinusoidal waveform, the amplitude of the resulting acoustical wave of generally sinusoidal form at the output of the transducer is of generally constant amplitude and does not decay or decrease over the course of each period as in the case of the present invention.

A further feature provided by the invention is the relatively high frequency of the output sound. It will be seen in FIG. 5I that the frequency of the sinusoid thereof is considerably higher than the frequency of the sinusoid in FIG. 5A. Thus while the base frequency of 143 hertz is preserved, the frequency of the sinusoid or other basic waveform as produced by the present invention is increased. This frequency increase has been found to greatly enhance the intelligibility of speech produced using artificial speech devices according to the invention. Accordingly, for a given amplitude sound generated using the devices of the invention is more clearly understood than that of the natural human voice. This has been clearly demonstrated by actual listening tests in which speech produced with the help of devices according to the invention is compared with the natural human voice in terms of its ability to be understood over substantial distances at relatively low volumes.

As previously discussed, lengthening of the drive pulses from 20 microseconds to 200 microseconds produces an output sound as shown in FIG. 5H in which the sinusoids are of greater amplitude and duration than those of FIG. 5G. The waveform of speech produced using the sound of FIG. 5H is very similar to that shown in FIG. 5I except that it is about an order of magnitude larger in amplitude.

As previously described the volume of the sound produced by the artificial speech device 10 is changed by varying the pulse width via the variable resistor 80 using the control 20. The pitch or tone of the output sound can be varied by changing the base frequency. In this respect, however, the frequency is varied only to the extent that the pulse repetition rate is varied so as to change the period. The pulse width remains the same. The base frequency is varied via the pitch control

26 which adjusts the variable resistor 68 within the oscillator 52.

FIGS. 5J through 5P provide one example in which the resistor 68 is adjusted to shorten the period and thereby increase the base frequency. As shown in FIG. 5J, the oscillator pulses 96 are in the same size but occur with greater frequency than in the case of FIG. 5B. The RC time constant remains the same, and accordingly, the transistor 74 is turned on for the same amount of time as in the case of FIG. 5C as shown in FIG. 5K. Likewise the transistor 77 and the capacitor 78 behave in similar fashion as seen in FIGS. 5L and 5M to produce 20 microsecond current drive pulses as shown in FIG. 5N. The resulting output of the sound unit 14 is shown in FIGS. 5-O with the speech produced in response thereto being shown in FIG. 5P. The acoustical waveform of FIGS. 5-O is the same as that of FIG. 5G except that the sinusoids occur more frequently since the frequency is higher and the periods are correspondingly shorter. Likewise, the acoustical waveform of FIG. 5P is similar to that of FIG. 5I except that the sinusoids are shorter.

In actual practice, the pitch control 26 is typically used to vary the base frequency until a frequency or range of frequencies is found which seems to best complement the user's characteristics. Also the control 26 may be varied during the course of conversation to reduce the monotone effect of speech generated at a constant base frequency. For example, the variable resistor 68 may be coupled via internal wires to a hand-held unit which includes an on-off switch and a trigger control.

While the invention has been particularly shown and described with reference to a preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention. For example, the control unit 12 can be miniaturized such as with the help of integrated circuits so as to be combined with the sound unit 14 and contained completely within the mouth.

What is claimed is:

1. An artificial speech device comprising:

oscillator means for generating a succession of generally equally spaced timing signals;

monostable means responsive to the timing signals for assuming an unstable state for a selected period of time in response to each of the timing signals and for thereafter assuming a stable state;

an electro-acoustic transducer;

means coupled to energize the transducer whenever the monostable means is in the unstable state; and a flyback damping circuit coupled between the monostable means and the transducer and comprising the serial combination of diode means and resistor means.

2. An artificial speech device comprising:

an electro-acoustic transducer adapted to introduce acoustic waves into the mouth of a user, the transducer having a pair of input terminals;

pulse generating means for repetitively generating pulses of generally rectangular waveform at a pair of output terminals thereof;

means coupling one of the output terminals of the pulse generating means to one of the input terminals of the transducer; and

a flyback damping circuit coupled between the other one of the output terminals of the pulse generating means and the other one of the input terminals of the transducer, the flyback damping circuit comprising the serial combination of a diode and a resistor.

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