Dec. 23, 1969 D. F. HOOPER, JR 3,485,951

SPEECH RECOGNIZING CIRCUIT

Filed March 6, 1967

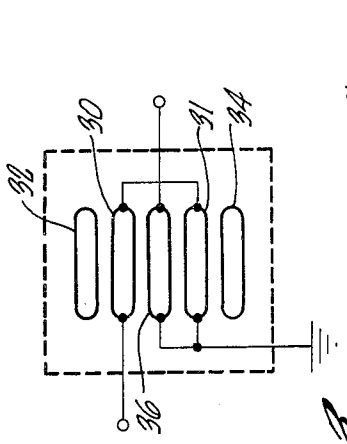


FIG 3

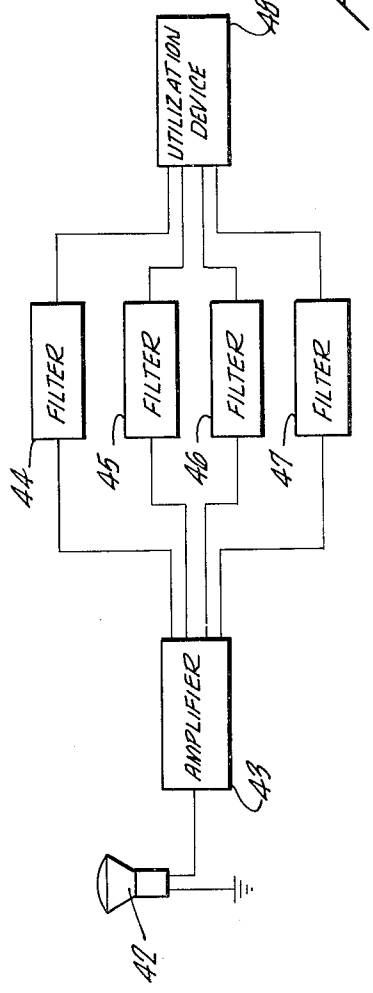


FIG 2

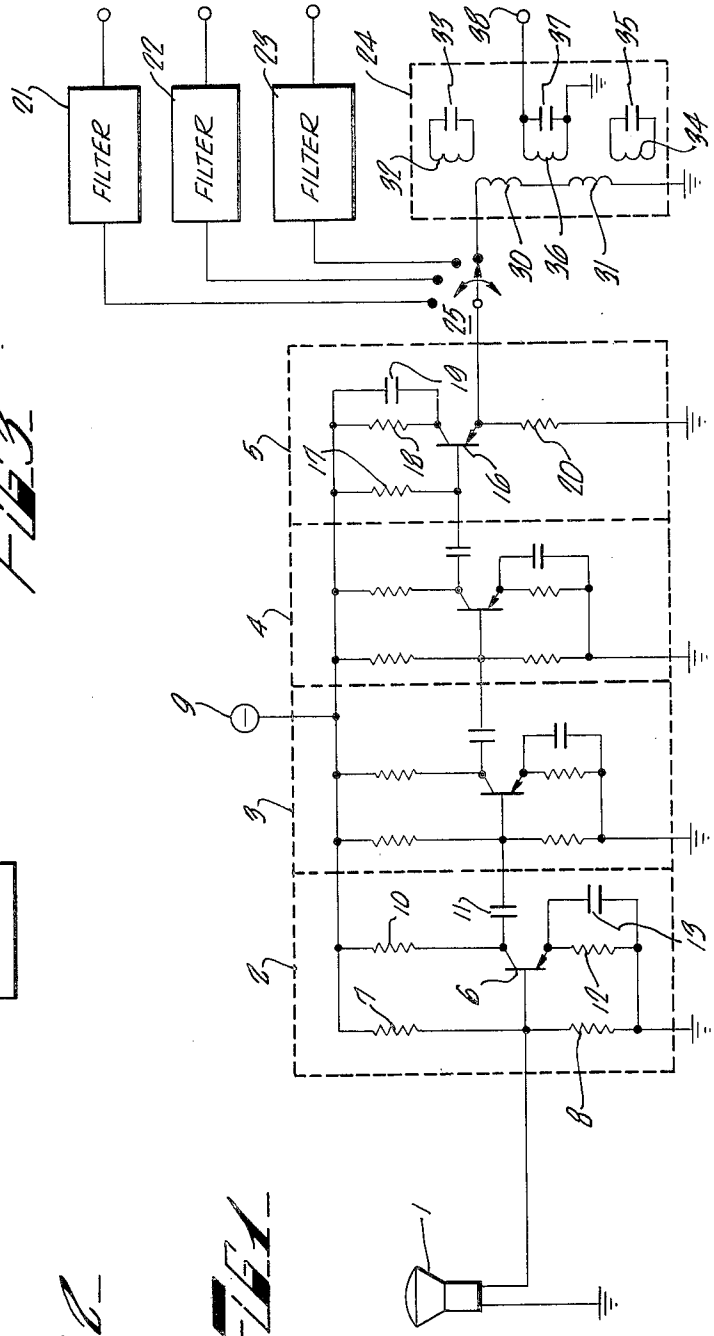


FIG 1

INVENTOR.
DONALD F. HOOPER, JR.
BY
Christie, Parker & Hale
ATTORNEYS.

United States Patent Office 3,485,951
Patented Dec. 23, 1969

3,485,951

SPEECH RECOGNIZING CIRCUIT

Donald F. Hooper, Jr., 6803 Lotus Ave.,
San Gabriel, Calif. 91775

Filed Mar. 6, 1967, Ser. No. 620,699
Int. Cl. H03h 7/46
U.S. Cl. 179—1 11 Claims

ABSTRACT OF THE DISCLOSURE

The formant frequencies characteristic of a vowel are automatically modified to compensate for changes in pitch of the speaker by biasing an audiofrequency amplifier so as to distort the electrical signal representing the vowel sound. A tank circuit configuration for indicating the presence of a particular vowel sound comprises a plurality of L–C parallel circuits, one tuned for each formant frequency. The inductors of all the parallel circuits are inductively coupled to an inductor connected across the output of the audiofrequency amplifier. The inductors are toroidal coils stacked in alternating fashion one on top of the other.

BACKGROUND OF THE INVENTION

This invention relates to electrical circuits and, more particularly, to a circuit for recognizing and indicating the presence of human sounds.

The mode of operation of one class of speech recognizing circuits is based on the phenomenon that the pure vowel sounds are each uniquely characterized by certain combinations of frequency components. Thus, each vowel sound includes at least three frequency components, called formants in the art, which are not found in the same combination in any of the other pure vowel sounds. The English language contains at least ten such pure vowel sounds, each of which is uniquely characterized by its three formant frequencies. To recognize and indicate the presence of a particular vowel in one prior art arrangement, the sound energy is converted to an electrical signal that is applied to three tank circuits tuned to the formant frequencies characteristic of the vowel. The tank circuits are connected to the input of an AND gate. When the vowel sound is spoken, all the tank circuits resonate, with the result that the AND gate produces an output.

Although each vowel sound is uniquely characterized by three formant frequencies regardles of the pitch of the speaker, the particular values of these formant frequencies are dependent upon the pitch of the speaker. Accordingly, to accommodate male, female, and juvenile speakers, speech recognizing circuits based on the formant phenomenon must be adjustable. If the speech recognizing circuit is set to operate upon a low-pitched speaker and it is desired to change to a high-pitched speaker, the tank circuits associated with each vowel must be returned so they resonate at the new, higher formant frequencies.

SUMMARY OF THE INVENTION

According to the invention, the formant frequencies characteristic of a vowel are automatically modified to compensate for changes in pitch of the speaker, so regardless of the speaker's pitch, no adjustment of the tank circuits that detect the formant frequencies is necessary. It has been discovered that compensation for pitch occurs in an audiofrequency amplifier when it is biased to distort the electrical signal representing the vowel sound. As a result, a mixing action takes place and modulation components are generated that remain substantially constant for a particular vowel sound regardless of the pitch of the speaker. Consequently, each tank circuit must only be tuned to a single frequency value. Preferably, the tank circuits are tuned to accommodate an average male speaker.

A feature of the invention is an advantageous tank circuit configuration to indicate the presence of a particular vowel sound. As a tank circuit for each formant frequency, an L-C parallel circuit is provided. The inductors of all parallel circuits are inductively coupled to an inductor connected across the output of the audiofrequency amplifier. If any of the tank circuits is not resonating, it loads the output of the amplifier so a small signal is inductively coupled to each of the tank circuits. Only in the case where all of the tank circuits are resonating is the output of the audiofrequency amplifier not loaded. Then, a large signal appears across the tank circuits to indicate the simultaneous presence of the three formant frequencies characteristic of the vowel sound. Most advantageously, the inductors are toroidal coils stacked one on top of the other within a shielded housing. The inductor connected across the output of the audiofrequency amplifier comprises series-connected coils positioned between each tank circuit coil in the stack.

BRIEF DESCRIPTION OF THE DRAWING

The features of the invention are illustrated in the drawing of a specific embodiment, in which:

FIG. 1 is a schematic circuit diagram of a speech recognizing circuit embodying the principles of the invention;

FIG. 2 is a block diagram of a modification of the speech recognizing circuit of FIG. 1; and

FIG. 3 is a schematic diagram representing the physical relationship between the coils employed to detect formant frequencies.

DESCRIPTION OF THE SPECIFIC EMBODIMENT

In FIG. 1, a microphone **1** is connected to the input of an audiofrequency amplifier having stages **2**, **3**, **4**, and **5** connected in tandem. Stages **2**, **3**, and **4**, which are all identical, each comprise a transistor connected in the common emitter configuration. In the interest of simplicity, only stage **2** is provided with reference numerals, it being understood that stages **3** and **4** each have the same circuit components. The base of a transistor **6** constitutes the input of stage **2** to which microphone **1** is coupled. A voltage divider comprising resistors **7** and **8** is connected between a source **9** of negative potential and ground. The base of transistor **6** is tied to the junction of resistors **7** and **8**, so the ratio of resistance thereof determines the applied base bias. A load-resistor **10** is connected between source **9** and the collector of transistor **6**, while a coupling capacitor **11** is connected between the collector of transistor **6** and the input to stage **3**. A resistor **12** and a capacitor **13** are connected in parallel between the emitter of transistor **6** and ground.

Stage **5** comprises a transistor **16** connected in the common collector configuration. The base of transistor **16** forms the input of stage **5** to which the output of stage **4** is coupled. The base of transistor **16** is also connected by a resistor **17** to source **9**. A resistor **18** and a capacitor **19** are connected in parallel between source **9** and the collector of transistor **16**. The emitter of transistor **16**, which is coupled to ground by a resistor **20**, is connected to the movable arm of a selector switch **25**.

The stages of the audiofrequency amplifier are biased so the electrical signals representing the vowel sounds are distorted while passing through the amplifier. Preferably, linear amplification takes place in stages **2**, **3**, and **4**, while

the signal is greatly distorted in stage **5**, preferably so both peaks of the signal are substantially clipped. It has been discovered that the distortion results in the generation of modulation components that remain substantially constant for any particular vowel sound irrespective of the pitch of the speaker's voice. Typical component values for the circuit are as follows: microphone **1** is 500 ohms; resistor **7** is 100,000 ohms; resistor **8** is 10,000 ohms; resistor **10** is 4,700 ohms; resistor **12** is 1,000 ohms; capacitor **11** is 5 microfarads; capacitor **13** is 10 microfarads; resistor **17** is 1 million ohms; resistor **18** is 4,700 ohms; resistor **20** is 39,000 ohms; capacitor **19** is 10 microfarads; source **9** is 18 volts; and transistors **6** and **16** are Type 2N1414.

The signal developed at the output of the audiofrequency amplifier is directed to one of a plurality of filters **21**, **22**, **23**, and **24** by means of selector switch **25**. Filters **21** through **24** each correspond to a different vowel sound and are identical except for the resonant frequencies to which they are tuned. Filter **24** is shown in detail. It comprises an inductor **30** and an inductor **31** connected in series between one contact of selector switch **25** and ground. An inductor **32**, which is connected in parallel with a capacitor **33** to form a tank circuit, is inductively coupled to inductor **30**; an inductor **34**, which is connected in parallel with a capacitor **35** to form a second tank circuit, is inductively coupled to inductor **31**; and an inductor **36**, which is connected in parallel with a capacitor **37** to form a third tank circuit, is inductively coupled to inductors **30** and **31**. Most advantageously, inductors **30**, **31**, **32**, **34**, and **36** are toroidal or so-called Rowland coils physically arranged in axial alignment with one another in a stack, as represented in FIG. 3. The inductors are electrically isolated from, but magnetically coupled to, one another. In addition, all the circuit components of the filter are enclosed in a magnetically shielded housing. Toroidal coils have a high Q value, i.e., a large inductance to resistance ratio. Therefore, very selective filtering of the formant frequencies is possible. Generally, it is difficult, however, to couple energy magnetically between toroidal coils. The physical arrangement of toroidal coils shown in FIG. 3 provides exceptionally good magnetic coupling. Each of the three tank circuits of filter **24** is tuned to a different formant frequency of the vowel associated with filter **24**. Preferably, the tank circuits are tuned to the formant frequency values for a typical male voice. If one or more of the tank circuits is not resonating, filter **24** loads the output of the audiofrequency amplifier. This is indicated by a low signal level at an output terminal **38** of filter **24**, which is connected to one of the tank circuits (arbitrarily taken as the tank circuit comprising inductor **36** and capacitor **37**). Only when all of the tank circuits are resonating does filter **24** fail to load the output of the audiofrequency amplifier. At this time, a high signal level appears at output terminal **38**.

To indicate the presence of a different vowel sound, selector switch **25** is moved to connect the filter corresponding to that vowel sound to the output of the audiofrequency amplifier. The arrangement of FIG. 1 in which the filters are coupled to the audiofrequency amplifier through a selector switch is particularly well adapted to use in teaching deaf persons to speak. In such case, selector switch **25** is placed in the position corresponding to the vowel sound to be practiced by the deaf person who speaks into microphone **1**. When the vowel sound is correctly uttered, a high signal level appears at the output terminal of the filter. This condition could be observed by the deaf person by reading a voltmeter connected to the output of the filter.

There are, of course, many other applications for the speech recognizing circuit of the invention. For example, it could be employed to actuate an adding machine verbally by assigning a number to each vowel sound. In such case, the arrangement of FIG. 2 might be employed. The speaker talks into a microphone **42** which is connected to the input of an audiofrequency amplifier **43**. Audiofrequency amplifier **43** is identical to the amplifier shown in FIG. 1 except it has a plurality of common collector stages (corresponding to stage **5** in FIG. 1), each connected to the output of the preceding stage (corresponding to stage **4** in FIG. 1). One common collector stage is provided for each vowel sound to be recognized. A filter (one of filters **44** through **47**) is connected to the output of each common collector stage to produce an indication upon the appearance of corresponding vowel sounds. Thus, the filters are isolated from one another by the common collector stages. Filters **44** through **47** could be constructed like filter **24**. The outputs of filters **44** through **47** are all coupled to a utilization device **48**, which could be an adding machine.

What is claimed is:

1. A speech recognizing cirucit comprising: a source of audiofrequency signals; an audiofrequency amplifier to which the source is coupled, the amplifier being biased to distort the audiofrequency signal in the course of amplification; and means coupled to the output of the audiofrequency amplifier for producing an indication upon the simultaneous appearance of the formant frequencies of a vowel.

2. The circuit of claim **1**, in which the source is a microphone.

3. The circuit of claim **1**, in which the means for producing an indication is a plurality of tank circuits, one tuned to each formant frequency, the tank circuits being arranged to produce an output only when they are all resonating.

4. The circuit of claim **1**, in which the means for producing an indication comprises: a plurality of inductors connected in series across the output of the audiofrequency amplifier; a plurality of parallel resonant circuits, each tuned to a formant frequency of a vowel, each resonant circuit including an inductor and a capacitor; each of the series-connected inductors being inductively coupled to two of the resonant circuits so that any of the resonant circuits not resonating loads the output of the amplifier.

5. The circuit of claim **1**, in which the means for producing an indication comprises: an inductor connected across the output of the audiofrequency amplifier; a plurality of tank circuits, each including an inductor and a capacitor in parallel; and means for coupling each of the tank circuits to the inductor so that any of the tank circuits not resonating loads the output of the amplifier.

6. The circuit of claim **1**, in which the means for producing an indication is a plurality of tank circuits, one tuned to each formant frequency of an average male speaker, the tank circuits being arranged to produce an output only when they are all resonating.

7. In a speech recognizing circuit the combination comprising: a source of electrical signals representing vowel sounds; an inductor connected across the source; a plurality of tank circuits each tuned to a different formant frequency of a vowel, each tank circuit including the parallel combination of an inductor and a capacitor; and means for coupling the inductor of each of the tank circuits to the inductor connected across the source so that any of the tank circuits not resonating loads the source.

8. The combination of claim **7**, in which: the inductor connected across the source is divided into a first part and a second part; the plurality of tank circuits includes a first tank circuit, a second tank circuit, and a third tank circuit; the first part of the inductor connected across the source is inductively coupled to the inductors of the first and second tank circuits; and the second part of the inductor connected across the source is inductively coupled to the inductors of the second and third tank circuits.

9. The combination of claim **8**, in which the inductors of the tank circuits and the first and second parts of the inductor connected across the source are each toroidal coils arranged in axial alignment with one another in a stack with the first part lying between the inductors of

the first and second tank circuits and the second part lying between the inductors of the second and third tank circuits.

10. The combination of claim **7**, in which the source is an amplifier that distorts electrical signals representing vowel sounds.

11. A speech recognizing circuit comprising: a source of audiofrequency signals including a given vowel sound; tank circuit means tuned to the formant frequencies of the given vowel sound produced by a speaker with a particular pitch, the tank circuit means generating an indication upon the simultaneous application thereto of all the formant frequencies to which the tank circuit means are tuned; means for producing modulation components from the audiofrequency signal that remain substantially constant at the formant frequencies to which the tank circuit means are tuned as the pitch of the speaker varies; and means for coupling the modulation components to the tank circuit means.

References Cited

UNITED STATES PATENTS

3,188,566 6/1965 Bullene.

OTHER REFERENCES

W. C. Dresch: Improved Vowel Separation for Speech Recognition Applications; IBM Technical Disclosure Bulletin; vol. 5, No. 5, October, 1962.

KATHLEEN H. CLAFFY, Primary Examiner

C. JIRAUCH, Assistant Examiner

U.S. Cl. X.R.

324—77