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EXTRACTION OF VOICE PITCH BY MEASURING IMPEDANCE VARIATION ACROSS THE THYROID CARTILAGE

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Abstract

Electroglottography is a non-invasive technique for measuring impedance variation across the thyroid cartilage of the larynx. This impedance variation provides information about the dynamics of the closure of vocal folds, and can be used for obtaining the voice pitch. We have developed a low-cost battery-operated instrument using this principle. A high frequency (300 kHz), low intensity (~3 mA) current is passed through the central discs (15 mm dia) of a pair of plate electrodes held in contact with the skin on both sides of the thyroid cartilage. A guard ring around each of the discs is actively driven to the same potential as the central disc, in order to minimise the superficial component of the sensing current. The impedance variations, caused by varying contact area between the vocal folds, result in amplitude modulated voltage waveform across the central disc electrodes. This waveform is demodulated to get the impedance variation. A low-cost microcontroller based signal acquisition, analysis, and LCD graphics display unit has been developed as a part of this instrument for displaying the impedance variation waveforms and pitch histograms for diagnosis of speech disorders.

Introduction

During the production of voiced speech segments, the vocal folds in the larynx are set into vibrations and the fundamental frequency of these vibrations is known as the pitch [1, 2]. Pitch detection and estimation finds wide use in speech analysis and recognition, for diagnosis of voice disorders, in speech training aids for the hearing impaired, and in sensory aids as compliment to lip-reading [3, 4, 5]. Pitch can be estimated using speech processing methods, but they are computation intensive, and may give erroneous results, particularly during cases of voicing disorders.

During phonation, the vocal folds are set into vibration. The movement of the vocal folds consists of three phases; contact, separation, and open. The variation in electrical impedance between the vocal folds gives information about the different phases of the contact between them. This information about the actual contact is very useful, since the nature of contact depends upon the physical condition of the vocal folds.

Electroglottography uses the measurement of impedance variations in the vicinity of the glottis, for sensing the vocal fold contact. The pitch can be obtained by measuring the time period of the impedance variation waveform [3]. The glottal pitch extractor measures the electrical impedance variations of the larynx using a pair of electrodes held in contact with the skin on both sides of the thyroid cartilage. The base-impedance across the thyroid cartilage is approximately 500 Ω and the change in the impedance due to vocal fold vibrations is less than 1 Ω [6, 7]. The usable frequency range of the current carrier is 100 kHz - 5 MHz [6, 7]. The voltage developed across the electrodes gets amplitude modulated due to the variations in the impedance in the current path, caused by the vibrations of the vocal folds. The modulation depends upon the change in the tissue impedance in the current path. The impedance is minimum when the vocal folds are in full contact, the effective tissue length for the RF current, is smallest between the electrodes for this vocal fold configuration. The impedance increases as the folds separate, and it is at its maximum when the folds are completely separated. The impedance level does not show any considerable change, even if the folds are wider apart [3].

We have developed a low-cost, battery-operated pitch extraction unit. A low cost microcontroller based signal acquisition, analysis, and LCD graphics display unit has been developed as a part of this instrument for displaying the impedance variation waveforms and pitch histograms for diagnosis of speech disorders. A serial interface has been provided for interfacing the instrument to a computer for downloading the measurement results.

Implementation

A. *The Impedance Detector Module*

Fig. 1 shows the block diagram of the impedance variation detector. The overall scheme consists of an oscillator which generates a carrier frequency of 300 kHz with a stabilized amplitude of 5 Vpp. It is then applied to the glottal impedance sensor (GIS). The amplitude modulated voltage waveform obtained from the GIS is then demodulated. The demodulator consists of an amplifier, a precision full wave rectifier, and a low pass filter. The demodulated signal is then amplified using two stages of low noise amplifiers to get the impedance variation waveform, and thereby the voicing and the pitch information.

The sensitivity of the circuit depends upon the design of the GIS. The GIS consists of a voltage-to-current converter, electrodes for applying the current and for sensing the voltage waveform, and a voltage buffer. The electrodes can be configured in different ways: a two-electrode system with a guard ring and a four-electrode system without the guard ring. In one of the methods, the current is passed through the outer conducting rings and the modulated voltage signal is picked up from the central ring. In another method, the current is passed through the central rings and the modulated voltage is also picked up at the same point and the guard rings are used as the current director rings. If the electrodes without guard rings are used, then the current flowing in the electrodes finds an easy path across the skin of the neck, hence, the sensitivity of the circuit reduces. We experimented with various electrode configurations. Maximum sensitivity was obtained when the voltages at the two sensing electrodes are buffered and used for actively driving the respective guard rings. In the V-I converter arrangement, this has been achieved by shorting the guard rings of electrodes 1 and 2 to ground and to the sensing electrode respectively, as shown in Fig. 2. The electrodes are made of a glass epoxy printed circuit board with a central ring diameter of 15 mm, and are gold plated.

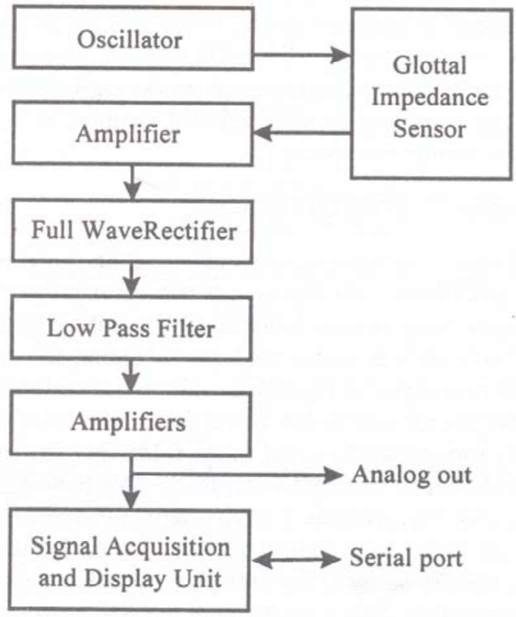

Fig. 1 Block diagram of the impedance variation detector

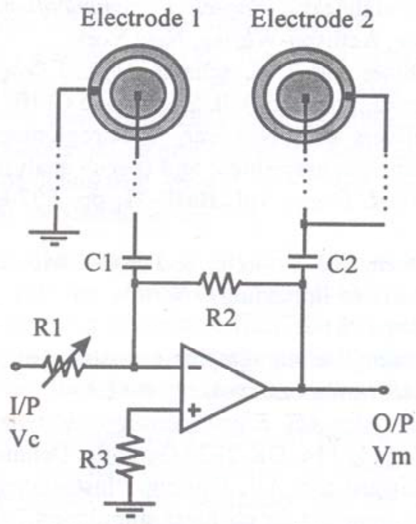

Fig. 2 Configuration of electrodes for maximum sensitivity

B. *The Signal Acquisition and Display Unit*

A dedicated hardware for digitizing the impedance waveform and displaying it, using a microcontroller, has been built. This unit can be interfaced to a computer through a serial port for data transfer, storage, and further processing, making the glottal pitch extractor portable.

The signal acquisition and display (SAD) unit has been designed and developed such that it can function as an inexpensive 8-channel digital storage oscilloscope. Fig. 3 shows the overall block diagram of the SAD unit. The analog section consists of an 8-bit A/D converter ADC0809, with built-in 8-channel multiplexer. The digital section is built using a microcontroller ATMEL 89C55-24PC with 20 K internal EEPROM for program memory, 256 bytes RAM, and four 8-bit I/O ports. In addition to this, it consists of a 240x128 graphics display (Oriole OGM-24011), 2 K bytes RAM data memory, and a 4x4 keypad. The microcontroller controls the analog section for digitizing the inputs, with a maximum sampling rate of 20 k samples/sec. The digitized signals are displayed on the graphics display and can be stored into the data memory. All the operation of the SAD unit can be controlled by the keypad. A RS-232 serial interface has been provided for downloading the digitized samples to a computer for further processing.

Results & Discussion

The glottal impedance detector unit and the signal acquisition and display unit have been tested for proper functioning by using an impedance simulator and a signal generator. The unit is being used for recording the speech waveform and glottal impedance variation waveform. Fig. 4 shows the recordings for vowel /a/ by two male speakers: (a) subject with normal vocal folds, and (b) subject with paralysis of the right vocal folds. This low-cost, battery-operated instrument will be useful for assessing the status of vocal fold contact phases, for pitch measurements, and for study of histograms of instantaneous pitch measurements.

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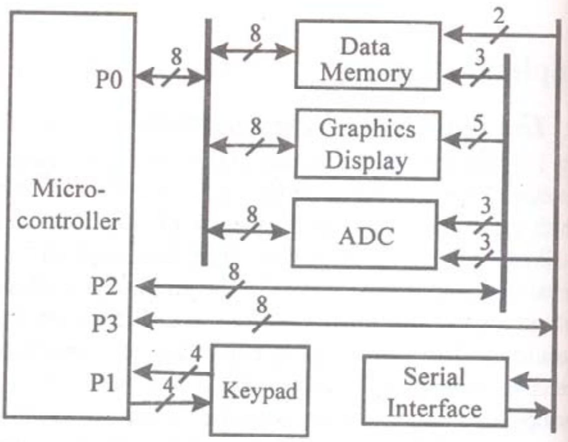

Fig.3 Block diagram of the SAD unit

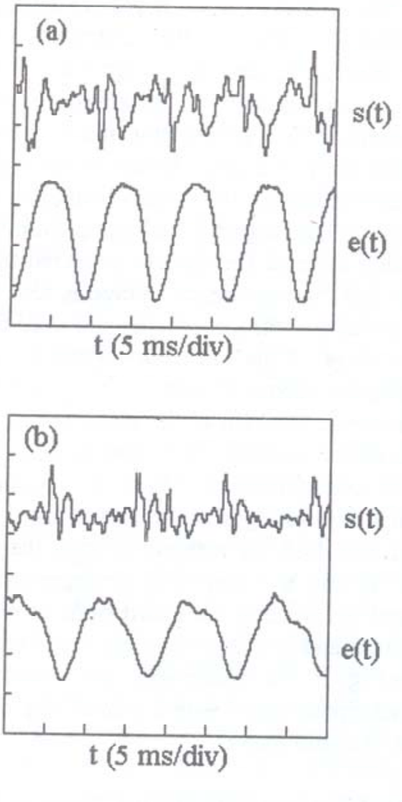

Fig.4 Recordings of speech waveform $s(t)$ and the impedance variation waveform $e(t)$ during the utterance of /a/ by (a) a subject with normal vocal folds, (b) a subject with paralysis of the right vocal fold.