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DESIGN OF AN INTRAORAL ARTIFICIAL LARYNX

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ABSTRACT

In this study,an electronic intra-oral artificial larynx system is designed. The objective of this study is to provide an alternative speech rehabilitation method to the totally-laryngectomized patients that will generate vibrations of fundamental frequency of human vocal cords. A prototype based on that design that is mounted into a dental prosthesis is established. The design of that system is presented in this paper.
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Keywords: *Speech rehabilitation, vocal cords, artificial larynx, total-laryngectomy, laryngeal cancer*

1. INTRODUCTION

Malignant larynx tumours are encountered frequently in Otorhinolaryngology clinics. Provided that they are diagnosed in early stages of the disease, radiotherapy can be applied efficiently [1]. On the other hand, in case of the existence of tumors that do not respond to the radiotherapy and that tend to spread adjoint tissues, or tend to make metastasis have to be exised by means of a surgical procedure called "total laryngectomy" in order to survive these patients [2][3]. However, since the vocal cords are also excised with larynx, those patients loose their ability of speech production. As a result, they may experience some psychological problems [4].

Some methods such as esophageal speech (ES), tarcheoesophageal prosthesis (TEP), electrolarynx (EL) are available to overhelm that problem [5]. In ES, boli of air are swallowed into esophagus and then regurgitated into vocal system. The inferior constrictor muscle of pharynx is acts as a vibrator [6][7][8][9]. Since it can sound natural and fluent, ES is a good substitute for lost voice. Nevertheless, three to twelve months must be spent for the intensive training to become proficient [7][8]. Furthermore, success of the patients in mastering this method depends on their ability in developing over the muscles of the pharynx and one third of them fail to acquire ES [7]. Due to the small volume of air trapped in the esophagus, it is not possible to achieve a continuous speech [7]. The second method is TEP that is inserted into the fistula constructed between trachea and the posterior wall of the esophagus [2]. The vibrations are created by air flowing through the prosthesis and then transmitted to the upper vocal cord to be modulated into an intelligible speech by the articulators of the patient [10][11][12][13]. TEP posseses a valve

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mechanism to prevent food and saliva to pass into lungs when speech does not occur []14][15]. TEP provides a fast and spontaneous voice rehabilitation [16]. However, due to the moisture and the heat of the mediım, fungal colonization occurs causing valve dysfunction and then resulting in leakage fluids through the TEP [16][17][18]. Therefore, these prostheses have to be replaced periodically on average every five months in a out-patient clinic. These procedures are neither time-effective nor cost-effective. Beside they restrict the quality of life of the patients [10][11][12][13].

Another method preferred by the patients that cannot succeed to acquire ES, is electrolarynx that possesses a low-frequency oscillator and a vibrating diaphragm [19]. It creates vibrations by means of a diaphram acted by an electromechanic vibrator that are transmitted through the neck tissue into the pharynx to be modulated into speech by oral cavity and the articulators , when placed againist the neck and energized [7][8][20]. It is an easier method to learn how to use it, and hence EL may be considered as an alternative method. An efficient acoustic transmission cannot be achieved due to the edematous and inelastic tissue after a radical surgery until the healing process is completed [21][22]. EL should be placed on the right and the same location when EL is intended to use [7][8][22]. This situation does not seem to the patient very practical. Furthermore, since the patient must hold the device using one of their hands, one hand is incapacitated during the speech [23][24]. Therefore, an alternative method that may eliminate all of the drawbacks should be developped for the speech rehabilitation of these patients [25].

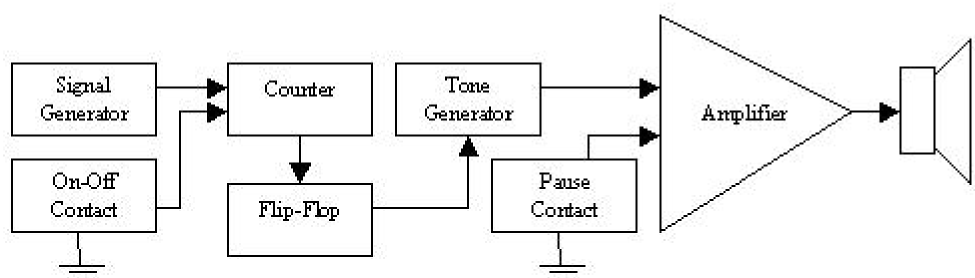

Figure 1. Block diagram of the system

In this study, the design of an intra-oral artificial larynx that will generate vibrations of fundamental frequencies of vocal cords and that will be worn be easily as a dental prosthesis is presented.

2. DESCRIPTION OF THE SYSTEM:

The block diagram of the intra-oral artificial larynx system is illustrated in Figure 1. When on-off contact is grounded, the counter driven by the signal generator is initiated. Then, the counter triggres the flip-flop circuit. Afterwards, the output of the flip-flop becomes high-state (state-1) to initiate the tone generator. Tone-generator generates pulses at audible frequencies. These pulses are then amplified by the amplifier and are used to drive the speaker in order to obtain vibrations of fundamental frequency of the vocal cords at audible intensities. Provided that the pause contacts are short-circuited, the amplifier stops to drive the speaker and no vibrations are generated by the speaker until the short-circuit on the pause contact is removed. These pause contacts are used for instantaneous stops between words. In order to switch-off the system, the start-stop contacts are grounded again until the the vibrations are terminated.

For the signal generator and counter circuitry, an integrated-circuit CD4060 is used. This is a 14-Stage Ripple Carry Binary Counter. It divides the frequency of the input signal by the power of 2 according to the pin selected as the output. These output signals are used to drive the Flip-flop.For the Flip-flop, a timer integrated circuit such as 7555 is used.

For the tone-generator and the amplifier, a timer integrated circuit such as 555 is used. Since there is not enough place for an additional switch to control them due to the morphology of the dental prosthesis, both 4060 and 7555 that require few current, are allowed to work in stand-by mode. Because of the same reason, the signal generator is designed to generate signals of higher frequency. Hence, small resistors and small capacitors in size are used in the circuit.

On ther other hand, the 555 integrated circuit require much current, and it is controlled by the output signals of the counter that is controlled by start-stop contacts.

The experimental setup shown in Figure 2 is established on a breadbord to achieve some measurement and adjustments in order to obtain a convenient fundamental frequency. Therefore, the appropriate values of components are determined before manufacturing the prototype.

The prototype is manufactured using the SMD components of the those used used in experimental setup in order to minimize the circuitry. All the SMD electronic components are mounted on a flexible PCB. Then this PCB is mounted on a dental prosthesis with the battery pack and with the start-stop and pause contacts. They are all covered with acrylic in order to protect them from the moisture of the oral cavity. The power supply of the system is provided by means of two CR1220 used for digital watches.

The start-stop switch is established by using rubber keys that are used in remote control device. It is controlled by pressing on it by tongue or tooth.
The buzzers used in cellular phones are used as the source of vibration.

3. DISCUSSION:

One of the important point to be considered in the design is the size of the circuit that will be inserted into the dental prosthesis. For an efficient speech generation , the restriction of the movements of the articulators especially those of the tongue must be minimized. The printed circuit board (PCB) that contains all the components of the circuit should compatible with the morphology of the palate and with that of the dental prosthesis. A flexible PCB and SMD components have been used for that purpose. After covering the circuit with acrylic, the prosthesis becomes thicker. Due to the individual variations in the morphology of the oral cavities of the patients, it seems to manufacture standard PCB’s for each patient.

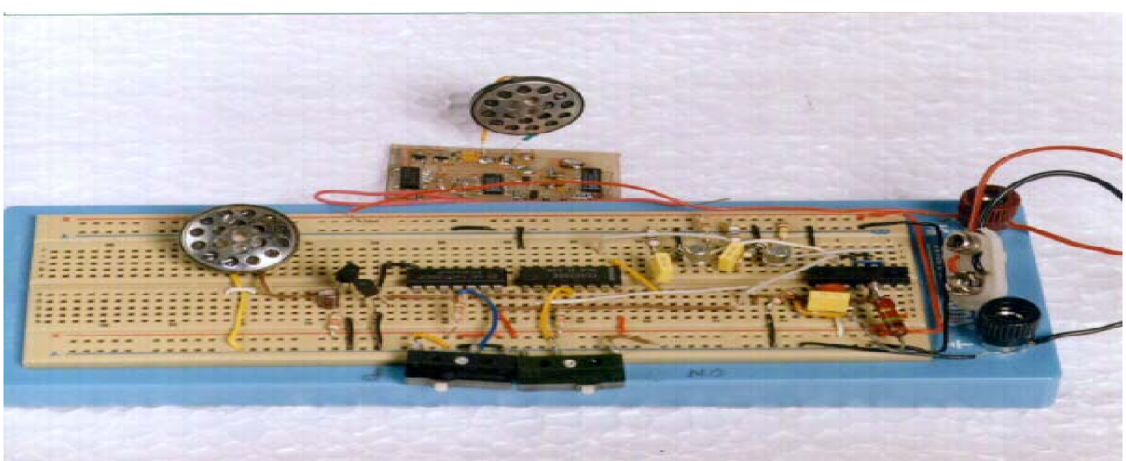

Figure 2. Experimental Setup of the Intraoral Artificial Larynx System

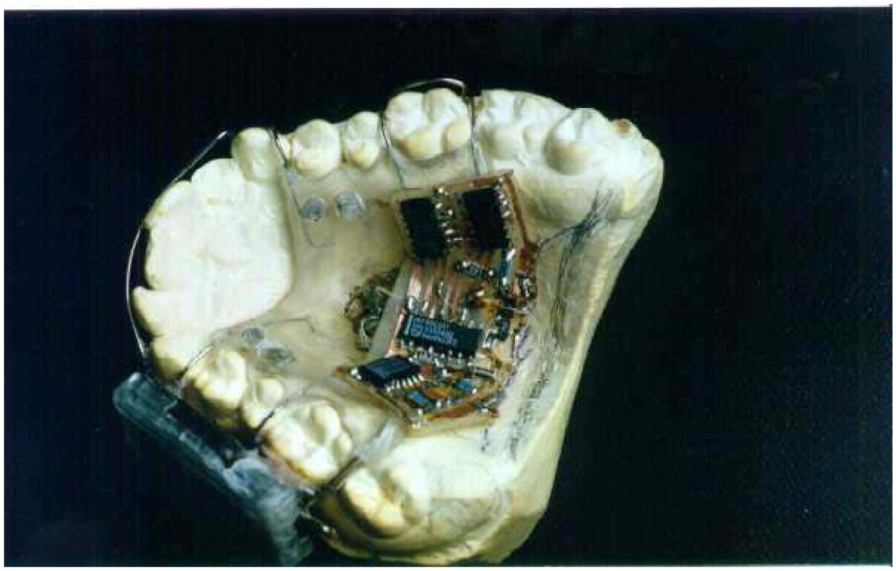

Figure 3. Prototype of the Intra-oral Artificial Larynx System

Therefore, the circuit has to be as thin as possible. So, the design and the manufacture of a single chip that might contain all the circuitry should be considered in the future not only to prevent the restriction of movements of the articulators but also to provide a standard circuit design for oral cavites of different morphologies.

Since they use more powerful batteries when compared with CR1220 batteries of digital watches that are used as power supply in intra-oral artificial larynx, the sound intesity of the output of the electrolarynx is more powerful than that of intra-oral artificial larynx. Due to the thickness of the rechargeable batteries, the use of CR1220 has been obligatory even though they have to be replaced frequently by the new ones.

To find a consistent power supply for the intraoral artificial larynx system is one of the technical problem that has to be focused on.

Another aspect that should be considered is the location of the speaker used as a source of vibrations of intra-oral artificial larynx that is placed on the upper palate. So, the acoustical transfer function of the vocal tract cannot be used efficiently during the speech generation. [26].The source of vibrations of the electrolarynx is placed next to the original larynx of the patient on the neck. On the other hand, the speaker of the intra-oral is placed at the upper part of the vocal tract. Therefore intra-oral artificial larynx cannot profit the whole acoustic transfer function of resonant cavities of the vocal tract.

4. CONCLUSION:

In this study, the design of a intra-oral artificial larynx is presented. The aim of that system is to offer to the totally-laryngectomized patients an alternative speech rehabiltitation method that can be worn and that can be mastered easily by the patients who cannot acquire esophageal speech. On the other hand, the size of the circuit must be minimized in order to manufacture standard circuitry for each patient despite the variations of morphologies of the patients. This will enable us also to minimize the thickness of the palate,
and hence the restriction of the movements of the articulators. Alternative power supplies such as RF coils should be investigated not only to provide to the system a consistent energy source but also to obtain a powerful sound intensity. Since the speaker as a vibrator of the system is at the upper part of the vocal system, the defiencies of the acoustic transfer function of the vocal tract might be compansated by an training That problem can be compansated by means of a program that will teach exaggereted articulations prepared by a specialist.

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