*International Journal of Advanced Smart Convergence Vol.6 No.4 19-25 (2017)*
*http://dx.doi.org/10.7236/IJASC.2017.6.4.3*

IJASC 17-4-3

# Design and Implementation of Salivary Electrical Stimulator for xerostomia

Jihyeon Lee*, and Hojun Yeom*

**Department of Biomedical Engineering, Eulji University, Korea*
*hyeom@eulji.ac.kr*

***Abstract***

*After 40 years of age, the saliva glands are aged and the saliva is not made enough to cause xerostomia symptoms. Side effects such as hypertension medication or diuretics that the elderly take mainly can cause xerostomia syndrome. In addition, autoimmune diseases, diabetes, anemia, depression and other common diseases that cause xerostomia symptoms. If the saliva secretion is insufficient, tooth decay and gum disease are likely to occur, and the digestive ability of the saliva is also reduced due to the lack of amylase, which is a digestive element. Once the degenerated salivary gland is restored to its normal state, it is difficult to recover. In this paper, we give electrical stimulation to the masseter which is in contact with the large pituitary gland, and stimulate the salivary gland to the utmost by using speech recognition using words corresponding to oral gymnastics. Use the STM32F407VG to implement a system to relieve xerostomia.*

**Keywords:** *Electrical stimulation, salivary gland, xerostomia, speech recognition, speech waveform, Cortex-M4*

## 1. Introduction

The development of modern medical technology has extended the average life expectancy. The number of elderly people aged 65 or older accounted for 11.3% of the total population in Korea in 2011, and it is now turning into an aging society, which accounts for 13.8% in 2017.

In the elderly due to aging, 80% of the elderly suffer from physical problems due to degenerative diseases. This leads to oral function degeneration, and most elderly pe ople are taking medication for a long time due to the disease. The side effects of the drug will result in decreased salivation and dry mouth.

Dry mouth causes pain in the oral cavity, malocclusion against dentures, reduced sensitivity to taste, increased oral infection such as gingivitis and salivary gland involvement. The number of elderly suffering from dry mouth is increasing significantly.

Currently, there are methods for treating oral dryness such as using a drug as a saliva secretion promoter, chewing gum, or using an artificial substitute such as artificial saliva. However, they also have disadvantages such as side effects or discomfort of the drug. To minimize these side effects, a method of improving oral

Manuscript Received: Sep. 15, 2017 / Revised: Oct. 27, 2017 / Accepted: Nov. 13, 2017
Corresponding Author: hyeom@eulji.ac.kr
Tel: +82-31-740-7421, Fax: +82-31-740-7360
Department of Biomedical Engineering, Eulji University, Korea

dryness is needed. In 2004, developed for the purpose of increasing saliva secretion, referring to the Aibe gymnastics of the Tokyo Metropolitan Senior Research Institute in Japan and the Health Promotion Movement of the elderly in Japan's Kochi City Public Health Center, the Korean word "clock" (ticking) 'And' oral gymnastics'. Oral gymnastics relaxes the muscles around the mouth and stimulates the salivary glands to create saliva. [1] [2]

In addition, speech has a waveform, which has a specific pattern for speech. In this paper, we will use the waveforms with patterns to identify the desired speech and use it as a speech recognition function.

The salivary gland is located in the parotid glands, submandibular glands, and submandibular glands. Recent studies have shown that when electrical energy is applied, saliva can be generated by reflex action by inducing parasitic leakage in salivary glands, parotid gland, mandible or sublingual.[3] In addition, the Aibe gymnastics at the Tokyo Metropolitan Senior Research Institute in Japan and the Health Promotion Center for the elderly at the Kochi City Public Health Center in Japan move the oral muscles to stimulate the surrounding salivary glands to secrete salivary glands. In Korea, we refer to this oral gymnastics and have developed it by combining the Korean word "watch sound (ticking)" and "telephone ringtone". It is a method of automatically injecting massage with a vibrating element and a wicking agent periodically.It stimulates the salivary gland by massaging the vibrating element at the location of the parotid gland and submandibular gland, which occupies the largest area of salivary glands. It is thought that the method of stimulating the salivary gland by using a massage machine is not effective because it has the same effect as oral gymnastics. In addition, they have the function of periodically injecting the injection agent automatically, but the disadvantage is that the product is fixed and inconvenient to use and there are limitations. [4]

The purpose of this paper is to increase the effect of oral gymnastics by pronouncing the muscles that stimulate the salivary glands by stimulating the muscles that touch the parotid gland, which occupies the largest area of the salivary glands.

## 2. Materials and Methods

In this paper, a microcontroller (STM32F407VG) was used to drive the electrical stimulator circuit and program the speech recognition using the analog values received from the microphone circuit.

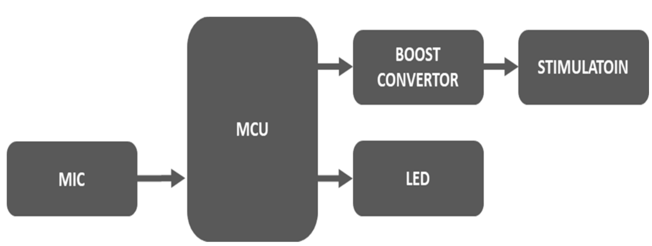


Figure 1. System diagram

### 2.1 Scenario

It is in contact with the parotid gland which occupies the largest area of the salivary glands, and it stimulates the parotid gland by giving electrical stimulation to the masseter used to move the oral cavity. The stimulated parotid glands will secrete saliva, and will use the monophonic language 'ddok', which definitely uses the masseter for the synergy of this action. If the pronunciation of 'ddok' sound is good or not, it will show the result and it will help to pronounce the correct 'ddok' sound. Here, the electric stimulator uses a boost circuit and outputs two input square waves from the STM32F407VG for circuit driving. This gives an output voltage of 80V 100Hz and connects the electrode to give a stimulus to the masseter. Through this, the parotid gland is stimulated and secretes saliva. Use the microphone sensor to receive the voice signal of the monophonic word 'ddok'. The STM32F407VG will cause the green LED to light when the red LED is off and the orange LED to light when the red LED is off and the 'red' LED is on. Through this, it is determined whether or not the user has pronounced 'ddok' well.

**2.2 Electric stimulator unit**

In this paper, the electric stimulator circuit uses a boost converter circuit.

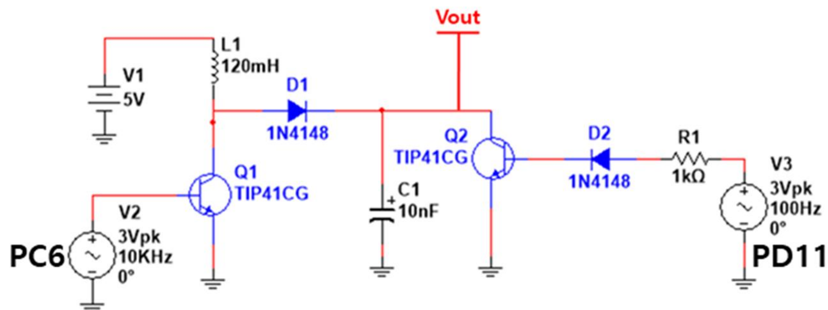


**Figure 2. Boost step up and pulse generation circuit**

The boost converter circuit is used to obtain an output voltage higher than the input voltage. Prior to the circuit description, connect V2 to pin 6 of the GPIO C port of the STM32F407VG, and V3 to pin 11 of the GPIO D port. This circuit serves as a switch of the transistor TR1. When the switch is ON, current flows in the inductor L1 to accumulate the magnetic field energy, and the energy stored in the capacitor C1 is consumed. At this time, the diode D1 blocks the charge of the capacitor C1 from flowing to the MOSFET. When the TR switch is OFF, V2 (PC6) is added together with the stored energy VL when the switch is turned ON by the counter electromotive force of the coil, so that the energy stored in the inductor is increased. Eventually, the output voltage will have Vout = V2 + VL. The boost converter circuit in Figure 6 uses MOSFETs to make switching very fast, which reduces the discharge time at C1 to maximize boost.
Therefore, Vout has a value of 80V DC. Also, by adding TR2, R1, V3 (PD11) to the Vout output line, DC output voltage having 80V value is made into 100Hz 80V AC output voltage and made into electric stimulator TENS.

**2.3 Voice recognition section**

The human voice has a value between 50 Hz and 4000 Hz. In this paper, we set the high pass filter (HPF) at 159.2Hz designed at 1uF and 1K and the low pass filter (LPF) at 2895.2Hz designed at 24K and 2.2nF in the microphone circuit in this paper.

To amplify the size of a small voice signal, three non-inverting amplifiers with 10 times amplification are connected to the STM32F407VG GPIO C port pin 2 to make a gain of 1000 to convert the analog signal received from the microphone into a digital signal.

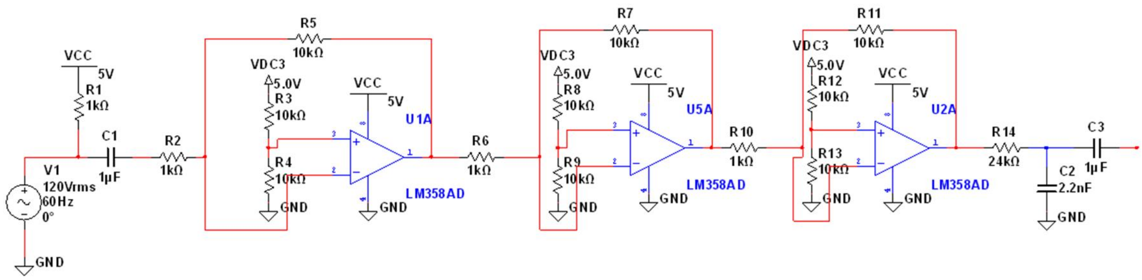


**Figure 3. Speech recognition circuit**

The audio signal received by PC2 is ADC and programmed in STM32F407VG. GPIO port D on pin 12 turns green LED2 if 'ddok' sounds and turns orange LED2 on GPIO port D pin 13 if 'ddok' Designed to be on. Also, at pin 14 on GPIO port D, the red LED1 blinks every two seconds to distinguish between the time it takes to pick up the sound and the time it takes to determine the 'ddok' sound.

### 2.4 Electrical Stimulator Section

Enable the port to be used in the main function, and set the details of pin input / output, speed, and pull-up resistor for each pin. Enable clock for TIM and GPIO to be used. Generating high voltage pulses for the electromagnet pole. In order to increase the voltage, we need a pulse signal for the inductance circuit and the transistor to generate the pulse. We implemented PWM1 and PWM2 using the PWM (pulse-width modulation) function of STM32F407VG. We set TIM3 to be used to generate PWM1, and declare TIM_Period to be 160 and TIM_Prescaler to 10. Since the current system clock of STM32F407VG is 16MHz, the frequency of TIM3 is 10KHz. PWM1 is used as the input source 1 to drive the boost converter circuit and PWM2 as the input source 2 to switch the DC voltage generated by the boost converter circuit to 0 and 1 so that the final output of the circuit is 105 Hz, A voltage of 80V with a pulse width will emerge. The output voltage will be used as a TENS electrical stimulator.

### 2.5 Speech Recognition

Enable the port to be used in the main function, and set the details of pin input / output, speed, and pull-up resistor for each pin. Enable clock for ADC, DMA, NVIC, GPIO, TIM to be used.

The variable to be used for coding to determine the speech signal is set as the initial value. In the infinite repeat while statement, the ADC value to be converted into real time is declared as Newxx value by the microphone circuit, and the COUNT function is executed. The stm32f4xx_it function toggles TimerON every 2 seconds using TIM2 with a frequency of 2 Hz.

In the main function, initialize the variable to be used for coding the algorithm to distinguish the voice signal. Thres is the reference voltage of the counter value to distinguish the voice signal with the threshold. In other words, if the voice analog signal coming through port 2 of GPIO C exceeds 3.25V, it will count the counter.

1) The COUNT function accepts the voice signal to be determined when the TimerON is toggled between 1 and 0 every 2 seconds, and turns on the LED according to the counter value of the voice signal when the TimerON is 0.

Timer ON 1 turns off the red LED connected to pin 14 of GPIO D port and turns on the red LED when it becomes 0. This allows you to make a 'ddok' sound to the microphone when the red LED is off and to see if the 'ddok' sound is pronounced when the release color LED is on.

2) If the analog signal voltage in real time exceeds 3.25V, execute the following if statement. This if statement counts the counter over 3.25v. Since ss is 0, the CNT counting counter value increases by one. Since the algorithm counts the counter value when the analog signal voltage exceeds 3.25V, put the value of ss that cannot be greater than Newxx to prevent CNT increase until the signal voltage drops below 3.25V.

3) When the signal voltage is lower than 3.25V, the ss value is set to 0, and the counter value is counted when the signal voltage exceeds 3.25V. Also, to compare the CNT variable counting the counter value clearly, use the CNT1 variable that is not confused to compare the counter value of the 'ddok' sound stored in the program.

4) If TimerON is 0, compare the CNT1 value of TimerON 1 day with the range of counter value of 'ddok' sound stored in the program. If CNT1 is the number of the applicable range, the green LED connected to GPIO D port pin 12 If not, the orange LED connected to GPIO D port pin 13 will light.

After the corresponding LED is lit, reinitialize the CNT.

## 3. Results and Discussion

As shown in the Fig. 18, the output voltage is increased about 30 times from 3V to 84V. The idea came out successfully with a voltage close to 80V, a commonly used voltage for TENS electrical stimulators. Also, unlike the input voltage, which was 10KHz in frequency, the output voltage was 105Hz close to the desired 100Hz due to the characteristics of the circuit. Therefore, the 84V 105Hz TENS electric stimulator was completed and electrodes could be attached to the connecting wire and the ground wire at the output voltage. In addition, when the pulse width of PWM1 of 10KHz is increased, the final applied voltage is increased to 84V, and when the pulse width is decreased, the voltage is reversely decreased. The most influential factor in boosting was the frequency of PWM1, and the second was the ratio of L1 to C1. The output voltage increases when the L value increases with the same C value, but the output voltage decreases when the L value decreases. In addition, when the L and C values and the PWM2 frequency do not reach the appropriate values, the output waveform with a high noise is obtained. The most influential factor in boosting was the frequency of PWM1, and the second was the ratio of L1 to C1. The output voltage increases when the L value increases with the same C value, but the output voltage decreases when the L value decreases. In addition, when the L and C values and the PWM2 frequency do not reach the appropriate values, the output waveform with a high noise is obtained.

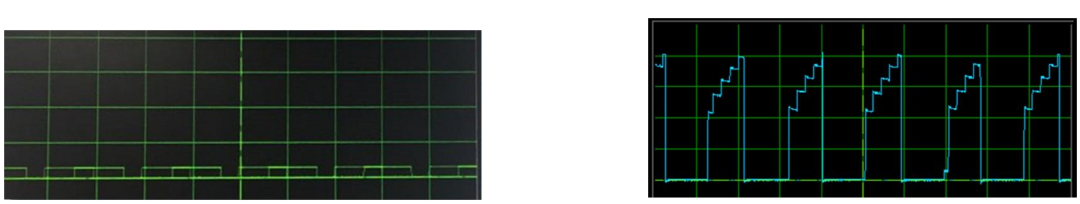

**Figure 4. Input pulse as 10Hz 3V (Volt-div : 5V / Time-div : 1ms, left ) and boost step up pulse 84V (Volt-div : 20V / Time-div : 1ms, right)**

Comparing Figure 8 with Figure 9, we can see that there is a certain waveform in the pronunciation. Once pronounced, the waveforms take about 300 ms. We have created an algorithm that distinguishes 'ddok' sounds using a feature that has a specific waveform.

The algorithm determines a constant voltage and counts the number of moments over that voltage as a number. If you look at the two pictures with time-div of 1ms and volt-div of 1v, compare them to the number of stored 'ddok' sound when the signal exceeds 1.5V within 300ms. It is an algorithm to distinguish.

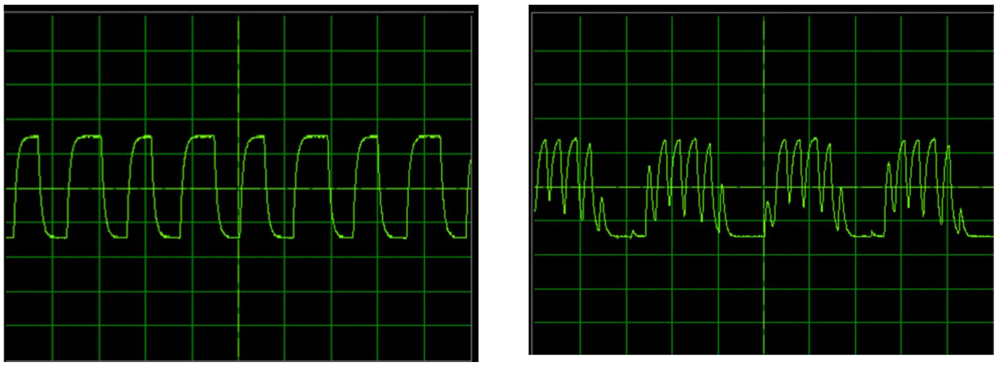

**Figure 5.'Ddok sound(left) and 'Dik'sound(right) wave form**

If the red LED flashes every two seconds and the microphone is 'ddokped', the counter value CNT1 shown in the left of [Table 1] appears and the corresponding green LED lights up. Almost green LED lights on the "ddok" sound, and the algorithm that counts the counter value over the voltage with the reference voltage. We selected 'ddok' sound and comparator to see the result more objectively. The microphone sounded 'ah' and the CNT1 value shown on the right side of [Table 1] appeared. In general, the CNT1 value of 'ah' ranged from 650 to 1500 and showed a big difference from the counter value of 'ddok' sound. Also, the orange LED turned on because it exceeded the range of 'ddok' sound. The CNT1 value average of 'ddok' is 299 and the standard deviation is 34, so the interval of 'ddok' corresponds to 265 < CNT1 < 333. However, since there are many variables in the speech signal and noise must also be considered. And an interval of the value obtained by the standard deviation is given, and a section of 232 < CNT1 <365 was set.

**Table 1. Comparison of 'DDok' and 'Ah' sound as 5 subject**

| Subect | The value of CNT1 Of 'Ddok' | The value of CNT1 Of 'Ah' |
|---|---|---|
| 1 | 271 | 776 |
| 2 | 254 | 715 |
| 3 | 359 | 684 |
| 4 | 324 | 917 |
| 5 | 268 | 1572 |
| Average | 299 | 882 |

This study focuses on the oral gymnastic effect by adding the oral muscle massage by adding convenience and speech recognition, unlike the previously studied products. We use electrodes that can be attached directly to the masseter directly from the product of solid material considering that the position of muscle of face size is different for each person. By vibration massage, it is maximizing the stimulus to stimulate the parotid gland which is in contact with the masseter muscle.

In addition, by receiving an electric stimulator, one of the oral gymnasts, pronouncing 'ddok' sound, can help the muscles to be more correct, thus synergizing the saliva stimulation to the electric stimulator.

In this study, we created an algorithm that can distinguish only 'ddok' sound in speech recognition part, but if we add an algorithm that can distinguish more various sounds such as 'ddok' and 'tweet', we can maximize stimulation of oral muscles . In addition, this study adds the advantage of preventing the aging of the muscles by using a lot of oral muscles because the elderly are targeted.

## References

[1] Fox, P.C., van der Ven, P.F., and Sonies, B.C. : Xerostomia : Evaluation of a symptom with increasing significance. J. Am. Dent. Assoc., 110(4):519-525, 1985.
[2] Screebny, L.M. and Schwartz, S.S. : A reference guide to drugs and dry mouth. Gerodontology, 5:75-99, 1986.
[3] Fox, P.C. : Management of dry mouth. Dent. Clin. North Am., 41(4):863-875, 1997.
[4] Cohen, R.E. and Levine, M.J. : Salivary Glycoproteins. In Human Saliva : Clinical Chemistry and Microbiology Vol. 1, Tenovuo, J.O. Ed., Boca Raton, 1989, CRC Press, Inc., pp. 101-130.