AN ASSISTIVE TECHNOLOGY FOR

SPEECH-IMPAIRED –TONGUE TALK TECHNOLOGY

A PROJECT REPORT

Submitted by

RACHEN R (312314105074)

RAGHUL V (312314105075)

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BONAFIDE CERTIFICATE

Certified that this project report "**AN ASSISTIVE TECHNOLOGY FOR SPEECH-IMPAIRED –TONGUE TALK TECHNOLOGY"** is the bonafide work of "**RACHEN R (312314105074), RAGHUL V (312314105075)**" who carried out the project work under my supervision.

SIGNATURE	**SIGNATURE**
Dr. JAYARAMA PRADEEP, M. E., Ph.D.	**Mr. CHIDAMBARARAJ N, M. E. (Ph.D.)**
HEAD OF THE DEPARTMENT	**SUPERVISOR**
Professor	**Associate Professor**
Electrical and Electronics Engineering	**Electrical and Electronics Engineering**
St. Joseph's College of Engineering	**St. Joseph's College of Engineering**
Chennai - 600119	**Chennai - 600119**

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S.No	Name of the Student	Title of the Project	Name of the Supervisor with Designation
1 2	**RACHEN R** **(312314105074)** **RAGHUL V** **(312314105075)**	**AN ASSISTIVE TECHNOLOGY FOR SPEECH-IMPAIRED – TONGUE TALK TECHNOLOGY**	**Mr.CHIDAMBARARAJ N, M. E. (Ph.D.)** **ASSOCIATE PROFESSOR**

The report of the project work submitted by the above students in partial fulfilment for the award of Bachelor of Engineering degree in Electrical and Electronics Engineering of Anna University were evaluated and confirmed to be reports of the work done by the above students.

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ABSTRACT

Speech-impairment not only affects communication but also depreciates the sensory perception of a victim. This project enables mute/speech-impaired, especially for those who cannot move their torso or limbs but can move their head, to communicate by means of tongue input. Touch sensors, insulated from saliva, are placed on the inner periphery of the teeth. Each sensor on the teeth is assigned a particular character. When the wearer touches a tooth sensor using tongue, the corresponding character is sent to the receiver from the transmitter. The characters are concatenated, until the space character is touched, after which the string of characters are output as sound through a speaker positioned comfortably anywhere on wearer’s body. Since tongue movement does not cause fatigue, in most cases, this is far more advantageous than present technologies assisting the speech-impaired. Moreover, other than providing sound output, the device can be used to operate wheelchairs, mobile phones, computers etc.

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LIST OF SYMBOLS, ABBREVIATIONS AND NOMENCLATURE

AT	Assistive Technology
TTT (T^3)	Tongue Talk Technology
TSA	Teeth Sensor Array
EOG	Electrooculographic
SMD	Surface Mount Devices
ADC	Analog to Digital Converter/Conversion
TX	Transmitter
RX	Receiver
SAW	Surface Acoustic Wave
SPU	Speech Processing Unit
GND	Ground
Vcc	DC Power Supply
R	Resistors of bottom layer of Teeth Sensor Array
R’	Pull down resistor
V_{in}	Voltage level read by ADC input of ATtiny85 microcontroller IC
n	Resistors in parallel with pull down resistor/ n^{th} segment of Teeth Sensor Array
V_{ref}	Reference voltage for ADC of ATtiny85 microcontroller IC
R_p	Equivalent resistance of parallel combination of resistors
R_{eq}	Total equivalent resistance
ƚ	Not drawn to scale

CHAPTER 1
INTRODUCTION

Muteness/speech-impairment is an inability to speak caused by a speech disorder, hearing loss, or surgery. The percentage of disabled population by type of disability in India [1] is given in Fig. 1.1.

TYPE OF DISABILITY	PERSONS
Total disabled population	**21,906,769**
In seeing	10,634,881
In hearing	1,261,722
In speech	1,640,868
In movement	6,105,477
Mental	2,263,821

Source: Table C-20, Census of India, 2011

Table 1.1: Percentage of disabled population by type of disability in India

It can be noted that 7.5% and 5.8% of disabled population are with speech-impairment and hearing-impairment respectively. These people, totaling to 13.3% of disabled population, are the primary focus of this project.

Assistive technology (AT) is a term that includes assistive and adaptive devices for people with disabilities to improve their functional capabilities. It allows them to overcome their disability. Tongue Touch Technology is a novel idea conceived by the authors to assist speech-impaired. It is an Assistive Technology which allows the wearers to type letters using their tongue and produces a sound output of the word typed through a speaker.

The wearer can be any person with muteness, hearing-impairment, wheelchair impairment, muscular dystrophy, motor neuron disease, mobility impairment (non-working limbs and/or torso) etc. provided their tongue movement is intact and can be controlled by their brain.

In this paper, the need for Tongue Touch Technology (TTT) and the methodology adopted to solve them are focused.

CHAPTER 2

PROBLEMS ADDRESSED

There are many ATs to help the speech-impaired. Some of them are keyboard-enabled speech synthesizers, eye-tracking speech synthesizers, tongue track pad etc. Consider a type of speech synthesizer with keyboard as an input (Fig. 2.1) in which the user types a word to be communicated on a small keyboard and the speaker connected to the keyboard produces voice output for the word entered. This device, even though might look like a simple solution for speech-impairment, suffers a serious disadvantage of not being handy, heavy and more importantly, disables the user's ability to multitask. For example, the users while typing the word have to concentrate more on the keyboard rather than their surroundings/listeners. Moreover, a person, who is unable to use his limbs, cannot use this AT.

Another type of AT is the one used by Professor Stephen Hawking in recent years. Professor Hawking has a type of motor neuron disease which left him immobile and speech-impaired. Intel® scientists [2] helped him with a device which controls a computer cursor and produces voice output by scanning the

Fig. 2.1: A type of speech synthesizer with keyboard input

Fig. 2.2: Stephen Hawking using his AT created by INTEL®

movement of his cheek muscles (Fig. 2.2). ATs of this type can cause fatigue of cheek muscles after long usage other than being prone to errors.

Previously, Stephen Hawking used an AT which detects and tracks the movement of his eyes using Electrooculographic (EOG) potentials to access a computer and to communicate (similar to one used in Fig. 2.3). Such ATs limit the users to look at the computer screen losing their eye contact with the listeners and consume more time to speak even a single word. Moreover, the setup is bulky and most of the time requires an expert or an assisstant to install the device on the user.

A type of AT explicitly used to control wheelchairs and mobiles [3] is shown in Fig. 2.4. It consists of an array of Hall effect sensors (4 to 6) attached to teeth. An iron element is pierced on tongue using adhesive. A magnetic field detector attached to a helmet determines the coordinates of the piercing of the tongue which moves in the array of sensors and drives the wheelchair accordingly. This device is bulky and can be used to control only wheelchairs.

All these type of ATs are bulky, expensive, and causes fatigue over long usage. TTT provides an easy method to communicate for speech-impaired.

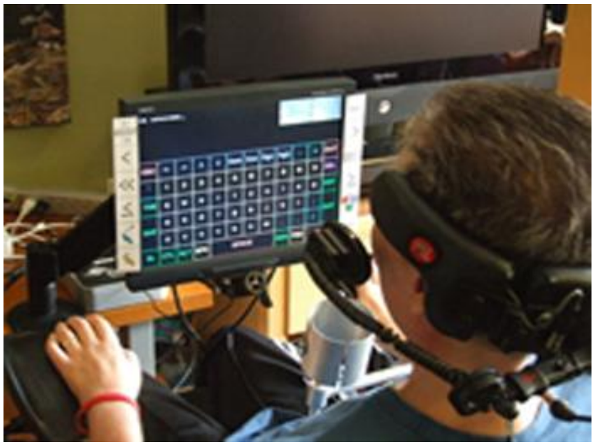

Fig. 2.3: An AT based on EOG potentials

Fig. 2.4: An AT with Hall Effect sensors

CHAPTER 3

LITERATURE SURVEY

Tongue Operated Assistive Technologies, Maysam Ghovanloo, Proceedings of the 29th Annual International Conference of the IEEE EMBS [6]

Assistive technologies help improving the quality of life for severely disabled individuals by enabling them to pursue self-care, educational, vocational, and recreational activities. Tongue has a set of unique characteristics that makes it a suitable appendage for manipulating paralyzed individuals environments through the use of tongue-operated assistive devices.

Tongue Drive: A Tongue Operated Magnetic Sensor Based Wireless Assistive Technology for People with Severe Disabilities, Gautham Krishnamurthy and Maysam Ghovanloo, ISCAS 2006 [9]

The "tongue drive" system is a tongue-operated assistive technology developed for people with severe disability to control their environment. The tongue is considered an excellent appendage in severely disabled people for operating an assistive device. Tongue Drive consists of an array of Hall-effect magnetic sensors mounted on a dental retainer on the outer side of the teeth to measure the magnetic field generated by a small permanent magnet secured on the tongue. The sensor signals are transmitted across a wireless link and processed to control the movements of a cursor on a computer screen or to operate a powered wheelchair, a phone, or other equipments. The principal advantage of this technology is the possibility of capturing a large variety of tongue movements by processing a combination of sensor outputs. This would provide the user with a smooth proportional control as opposed to a switch based on/off control that is the basis of most existing technologies. They modeled the effects of position and orientation of the permanent magnet on the sensors in FEMLAB and experimentally measured them. They built a prototype system using off-the-shelf components and tested it successfully by developing a graphical user interface (GUI) in LabVIEW environment. A small battery powered wireless mouthpiece with no external component is under development.

Tongue size, oral cavity size, and speech, R.G. Oliver and S.P. Evans, The Angle Orthodontist, pp. 234-243, 1986 [8]

Methods of measuring tongue size are evaluated, and protruded tongue size is related to sex, malocclusion, and speech. Significant correlations are found with sex and speech.

CHAPTER 4

COMPONENTS USED

4.1. RF BASED TRANSMITTER AND RECEIVER

4.1.1. Transmitter Circuit

The transmitter operates from a 3-12V supply, making it ideal for battery-powered applications. It is capable of transmitting radio wave and modulating that wave for data transmission. It employs a SAW-stabilized oscillator, ensuring accurate frequency control for best range performance. SAW Oscillators are comprised of an input transducer that converts an electric signal into acoustic waves and an output transducer that reconverts the waves into electrical signals. In between the input and output transducers, the waves travel through a solid propagation medium. This process gives SAW oscillators great flexibility to achieve a wide range of signal processing functions.

4.1.2. Circuit diagram

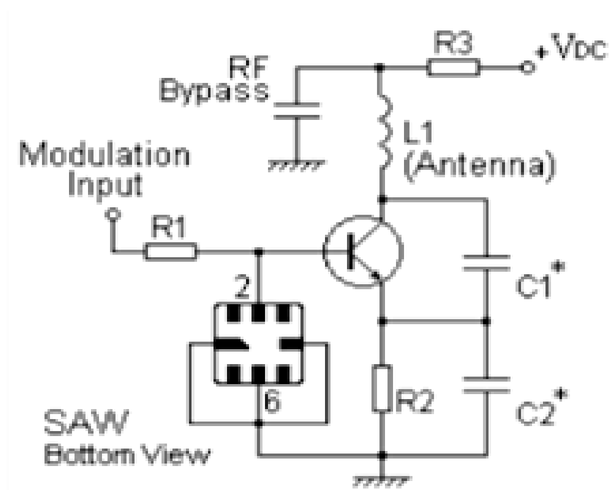

Fig. 4.1: Circuit diagram of a typical Transmitter with SAW oscillator

4.1.2. SAW based Oscillator

An oscillator is a network comprising an active stage (amplifier) and a frequency sensitive feedback stage (resonator, filter). Part of the output signal is fed to the input of the amplifier passing the feedback. The insertion loss and the phase of the feedback depend on the frequency. For oscillation, the insertion loss of the feedback is at a minimum and the total phase in the oscillator loop must be n*360°. In this case, there is a positive feedback and an oscillation can be generated.The total gain G in the loop is greater than 1. So the gain of the amplifier must be greater than the attenuation of feedback and power dissipation in the RF load.

The total phase in the circuit must be n*360° to achieve positive feedback. The phase slope of the resonator is very steep in the area of the resonance frequency. This steep phase slope is necessary for good frequency stability. To start up an oscillator, the thermal noise is amplified in the active stage. This very low broadband noise continuum is fed to the amplifier's input by the feedback loop. In this continuum, there are frequency components at the desired oscillating frequency. These frequency components pass the frequency-sensitive feedback stage without strong attenuation. If the phase condition is met, the feedback signal is added to the input signal. This procedure is repeated cycle by cycle, and the output signal increases.

The maximum oscillating level is limited by nonlinear effects of the amplifier. When the signal amplitude and the oscillation frequency are fixed, the oscillator is in the steady-state mode. The transient time (start-up time) depends primarily on the SAW resonator's loaded Q-factor and the characteristic of the active circuitry.

4.2. RECEIVER CIRCUIT

The receiver circuit gets the modulated 433 MHz wave and then de-modulates it. There are two types of receiver modules: super-heterodyne receivers and super-regenerative receivers. Super-regenerative modules are usually low cost and low power designs using a series of amplifiers to extract modulated data from a carrier wave. Super-regenerative modules are generally imprecise as their frequency of operation varies considerably with temperature and power supply voltage. Superheterodyne receivers have a performance advantage over super-regenerative; they offer increased accuracy and stability over a large voltage and temperature range. This stability comes from a fixed crystal design which in the past tended to mean a comparatively more expensive product. The one used here is of super-regenerative type.

4.3. PINOUTS

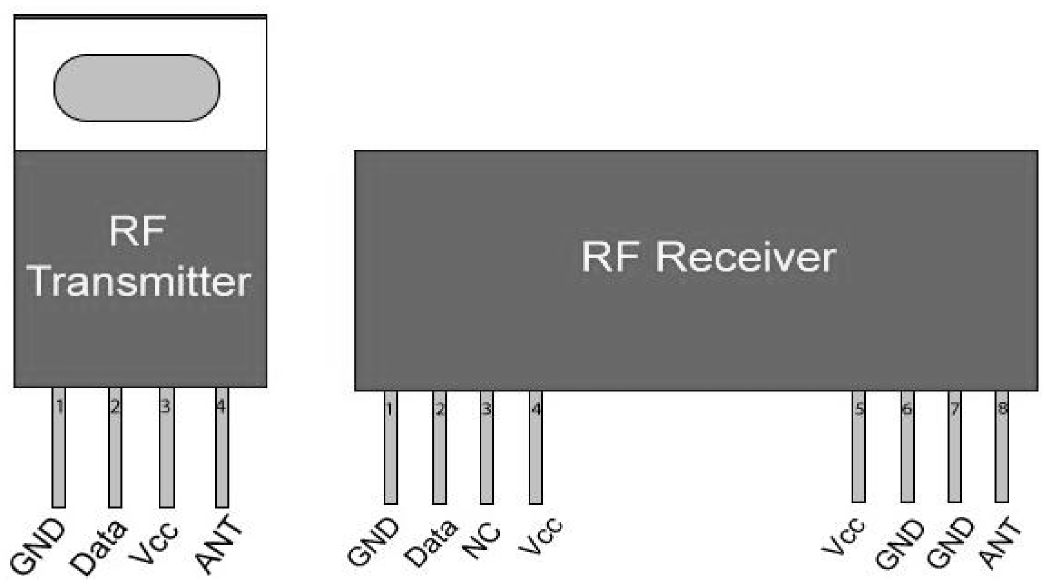

Fig. 4.2: Pin diagram of transmitter-receiver circuit

4.3.1. Pin Description

Transmitter Module

Pin Number	Name	Function
1	GND	Ground (0V)
2	DATA	Serial Data Input Pin
3	VCC	Supply Voltage (5V)
4	ANT	Antenna Output Pin

Table. 4.1: Pin out description of transmitter module

Receiver Module

Pin Number	Name	Function
1,6,7	GND	Ground (0 V)
2	DATA	Serial Data Output Pin
3	NC	No Connection
4,5	VCC	Supply Voltage (5 V)
8	ANT	Antenna Input Pin

Table. 4.2: Pin out description of receiver module

4.4. ATTINY85

The high-performance, low-power Microchip 8-bit AVR RISC-based Attiny85 microcontroller combines 8KB ISP flash memory, 512B EEPROM, 512-Byte SRAM, 6 general purpose I/O lines, 32 general purpose working registers, one 8-bit timer/counter with compare modes, one 8-bit high speed timer/counter, USI, internal and external Interrupts, 4-channel 10-bit A/D converter, programmable watchdog timer with internal oscillator, three software selectable power saving modes, and debugWIRE for on-chip debugging. The device achieves a throughput of 20 MIPS at 20 MHz and operates between 2.7-5.5 volts. By executing powerful instructions in a single clock cycle, the device achieves throughputs approaching 1 MIPS per MHz, balancing power consumption and processing speed.

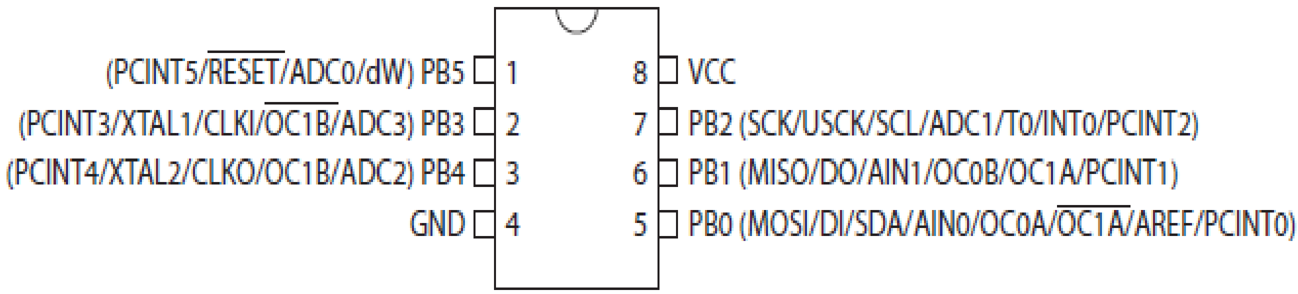

Fig. 4.3: Pin diagram of ATTiny85

4.4.1. Pin Descriptions

Pin Number	Name	Function
1 – 3, 5 - 7	(PB0 – PB5)	Port B
4	GND	Ground (0 V)
8	VCC	Supply Voltage (5 V)

Table. 4.3: Pin out description of ATTiny85

Port B (PB5:PB0):

Port B is a 6-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port B output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port B pins that are externally pulled low will source current if the pull-up resistors are activated. The Port B pins are tri-stated when a reset condition becomes active, even if the clock is not running.

CHAPTER 5

METHODOLOGY

5.1. INTRODUCTION

A block diagram of approached methodology for TTT is shown in Fig. 5.1.

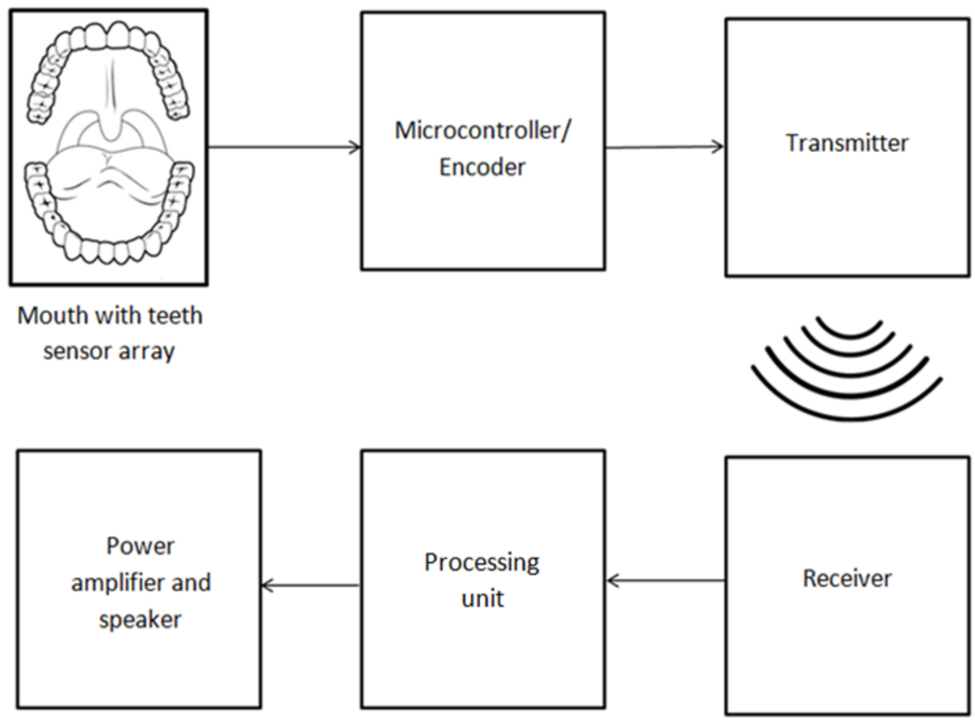

Fig.5.1: Block diagram of TTT

Touch sensors, insulated from saliva, are placed on the inner periphery of the teeth. Each sensor on the teeth is assigned a particular character. When the wearer touches a tooth sensor using tongue, the corresponding character is sent to the receiver from the transmitter through encoder/microcontroller circuit. The characters, received, are concatenated by a processing unit at the receiver side. Once the space character is pressed, the string of characters is output as sound through a speaker, after amplification by a power amplifier, positioned comfortably anywhere on wearer’s body.

5.2. TEETH SENSOR ARRAY

The Teeth Sensor Array (TSA) used here is basically a voltage divider network with number of resistors in series. It consists of three layers: bottom or key layer, insulating layer and top or Analog_Input layer.

5.2.1. Bottom or key layer

The bottom or key layer consists of copper or any conductive strip of high conductivity and good elasticity. Resistors are intercepted between the strips which divide them into 16 segments, as in Fig. 5.2. These resistors are Surface Mount Devices (SMD) so that they are compact and can be placed within the mouth. There are totally 16 resistors numbered from 1 to 16. The first segment of strip is connected to VCC and the adjacent segments by the SMD resistors. The last resistor is connected to ground (GND).

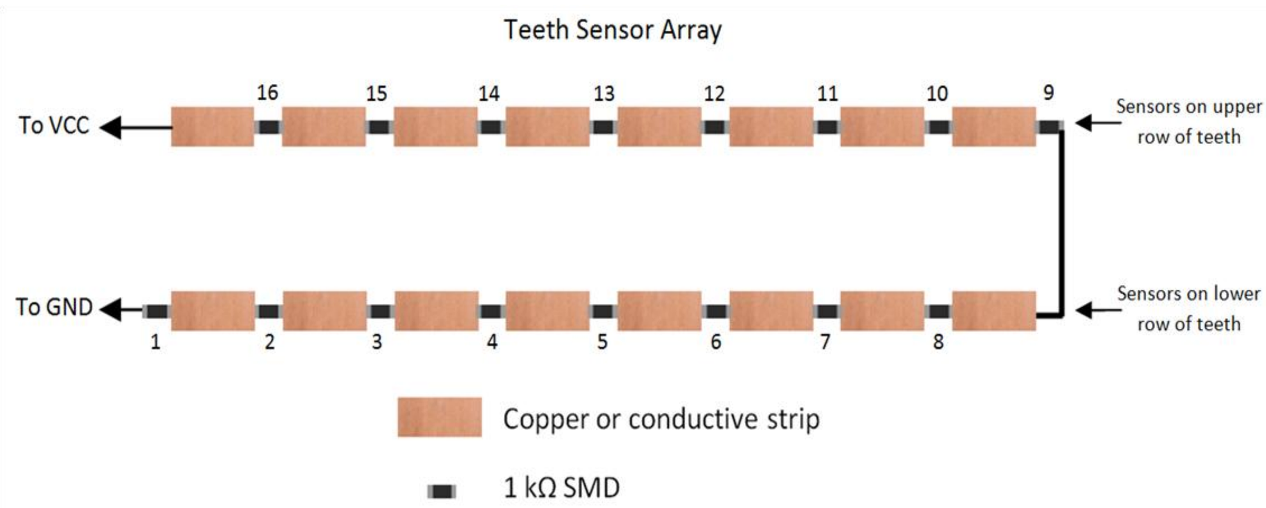

Fig.5.2: Bottom or key layer with TSA [†]

The 16 conductive segments are divided into two sections of 8 segments each; one on the teeth of the upper jaw and the other on the lower jaw. The two sections are inter-connected at one end. The resistors are chosen to be of equal values, here 1 kΩ. The material chosen for the segments should be elastic and conductive and hence, copper strip is the primary choice to suit the requirements. Here, each segment corresponds to a character and therefore, totally 16 characters can be accommodated. Hence, this layer is also named key layer.

5.2.2. Top or Analog_Input layer

The top layer, as in Fig. 5.3, is made of conductive strip of same material as bottom layer and is divided into two sections (connected at one end to each other); one for the teeth of the upper jaw and the other for the lower jaw. One end of the strip is connected to the ADC input/Analog_Input pin of the microcontroller ATtiny85.

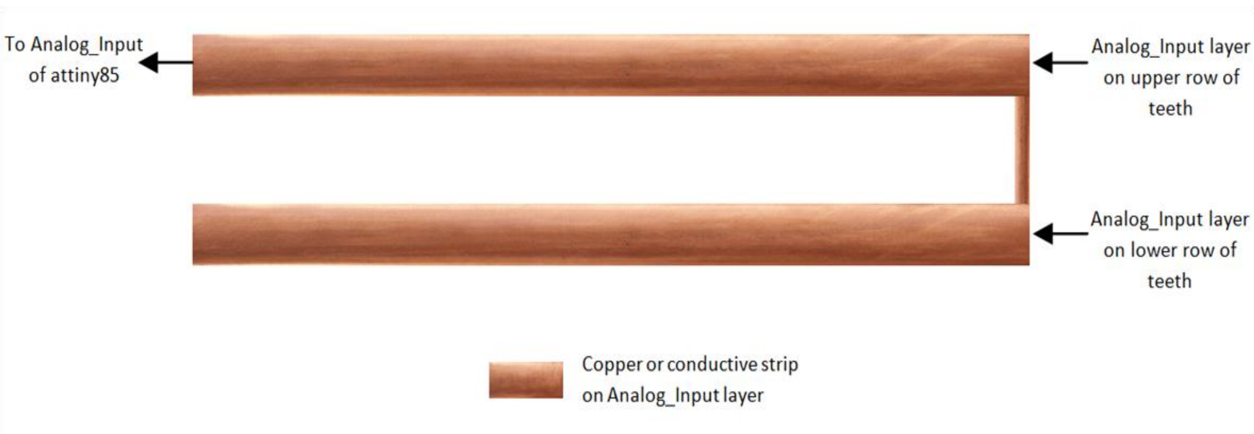

Fig. 5.3: Top or Analog_Input layer [ǂ]

5.2.3. Insulating layer

The insulating layer, as in Fig. 5.4, lies between the key and Analog_Input layer. It is a thin layer made of an insulator and is slightly larger than the other two layers to completely insulate them. It has 16 holes placed exactly above the 16 conductive segments of the key layer (shown as dashed square in Fig. 5.4)

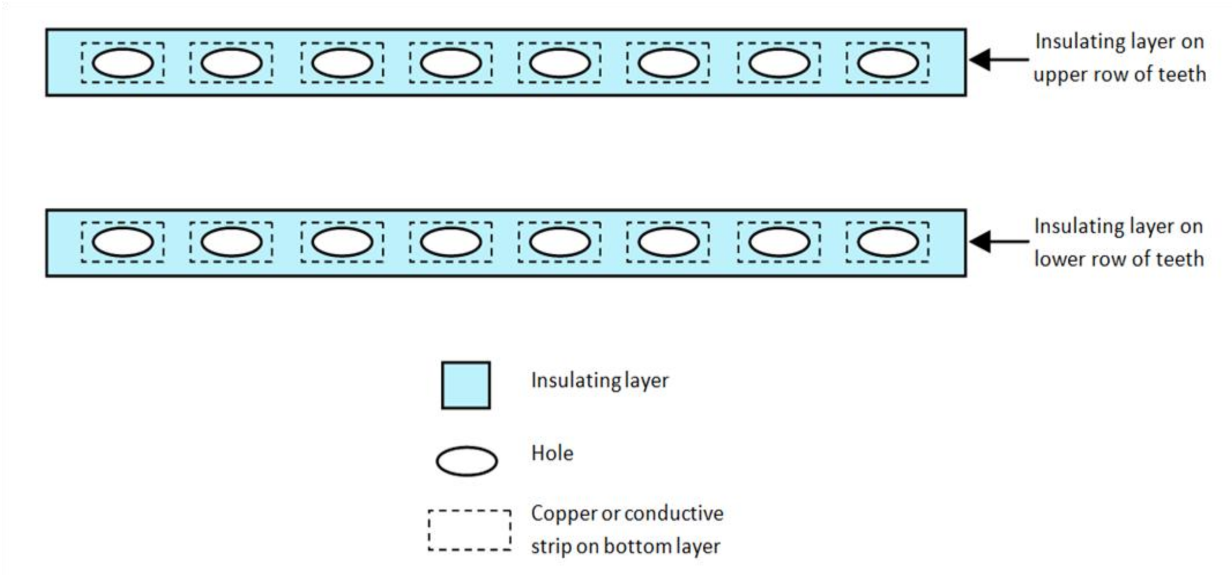

Fig. 5.4: Insulating layer †

A side view of the approach is shown in Fig. 5.5. The bottom or key layer is placed over the inner periphery of the teeth (the side facing the interior of the mouth). Insulating and top layers are successively placed over the key layer. The three layers are encapsulated in a leakage-free package to prevent saliva from entering. This package can be placed over the teeth like a cap which is removable when not required (like eating or sleeping).

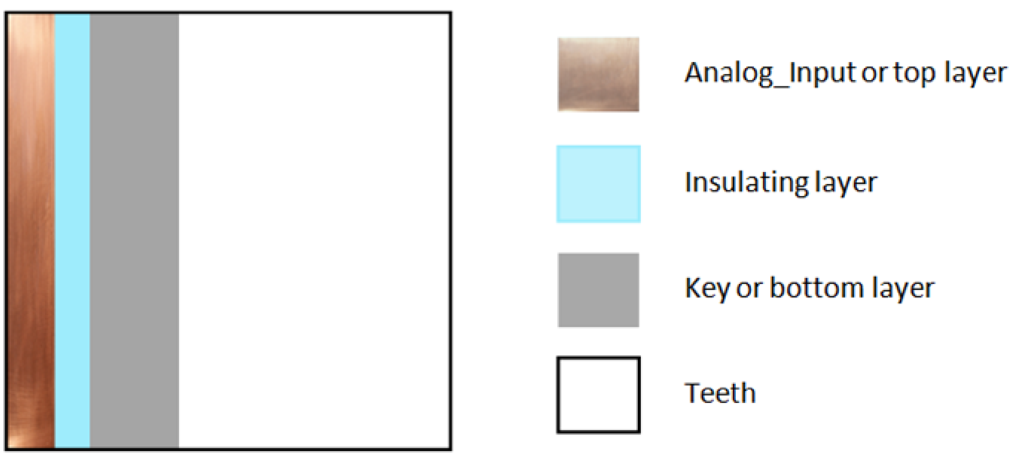

Fig. 5.5: Side view of the sensor †

5.3. WORKING PRINCIPLE OF TEETH SENSOR ARRAY

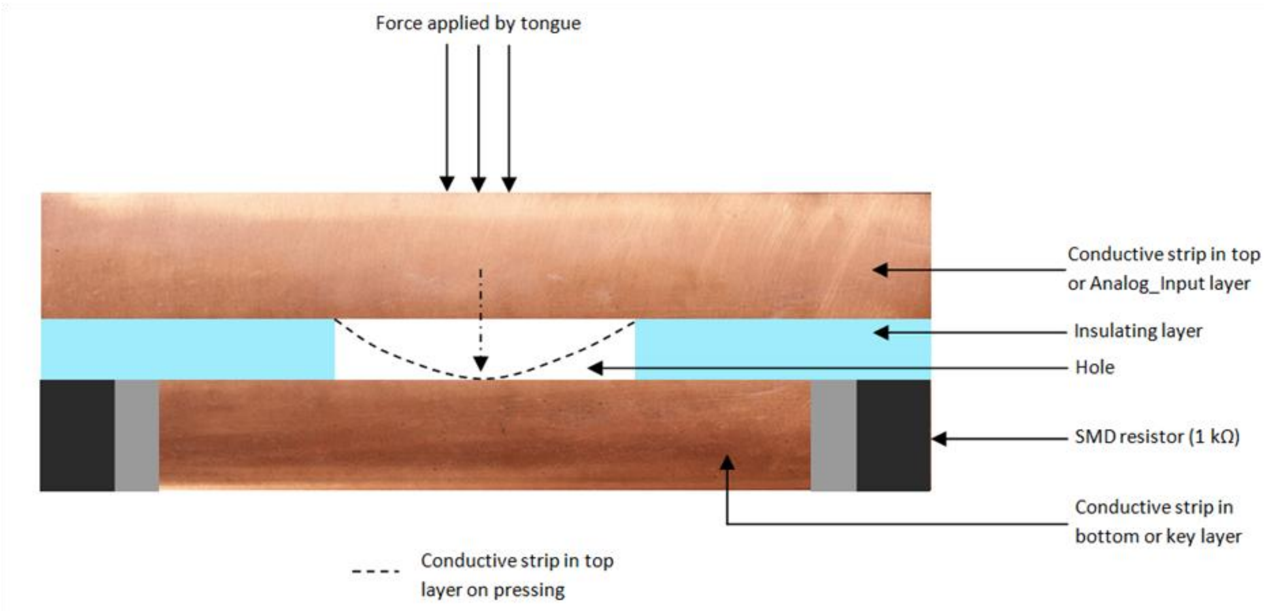

Fig. 5.6: Working of the sensor †

The tip of the tongue faces the top layer. The conductive segments of the key layer form a voltage divider network with a voltage drop across each segment due to resistors between them. When the tip of the tongue pushes the top layer through the hole, the top layer comes in contact (shown by dashed lines in Fig. 5.6) with the conductive segment of the bottom layer. The corresponding segment voltage with respect to ground is read by the ADC input of ATtiny85 microcontroller through the Analog_Input or top layer in contact.

The top layer should not touch the bottom layer through the hole when it is not pushed by tongue. So, the conductive strip of top layer is made of highly elastic material to allow it to return to its original position immediately after the pressure is removed.

5.5. CIRCUIT DIAGRAM ON THE TRANSMITTER SIDE

The equivalent circuit diagram is given in Fig. 5.7. One end of the bottom layer is connected to VCC, here 3V, and the other end to ground, GND. The top layer is connected to Analog_Input or A1 pin of ATtiny85.

ATtiny85 [3] is a low power, 8 pin and 8 bit microcontroller with 10 bit Analog to Digital Conversion (ADC) capability. This microcontroller is chosen for its compactness, extensive features supported, low power consumption and reliability. The operating voltage is between 2.7 – 5.5 V and hence, a small 3 V coin/button cell can be used power up the entire circuit with increased compactness and circuit density.

When the top layer is not in contact with the key layer, the Analog_Input pin is said to be in floating state and might read noises and interference signals. Thus, a pull down resistor of 10 kΩ is connected between Analog_Input pin and GND which pulls down the Analog_Input pin to 0 V during floating condition. A bypass capacitor of 0.01 μF is used to remove any noises and voltage spikes in input DC voltage of 3 V from the coin/button cell.

The Analog_Input pin reads the voltage level (with respect to GND) of conductive segment of the key layer in contact with the top layer. The read data is encoded to corresponding character of the segment by ATtiny85. This is fed as serial digital data from Digital_Output/PB1 pin of ATtiny85 to data pin of RF-433 MHz SAW resonator [4] based transmitter. The transmitter circuit uses Amplitude Shift Keying technique to transmit digital bits and allows redundant bits to be added for error checking and correcting.

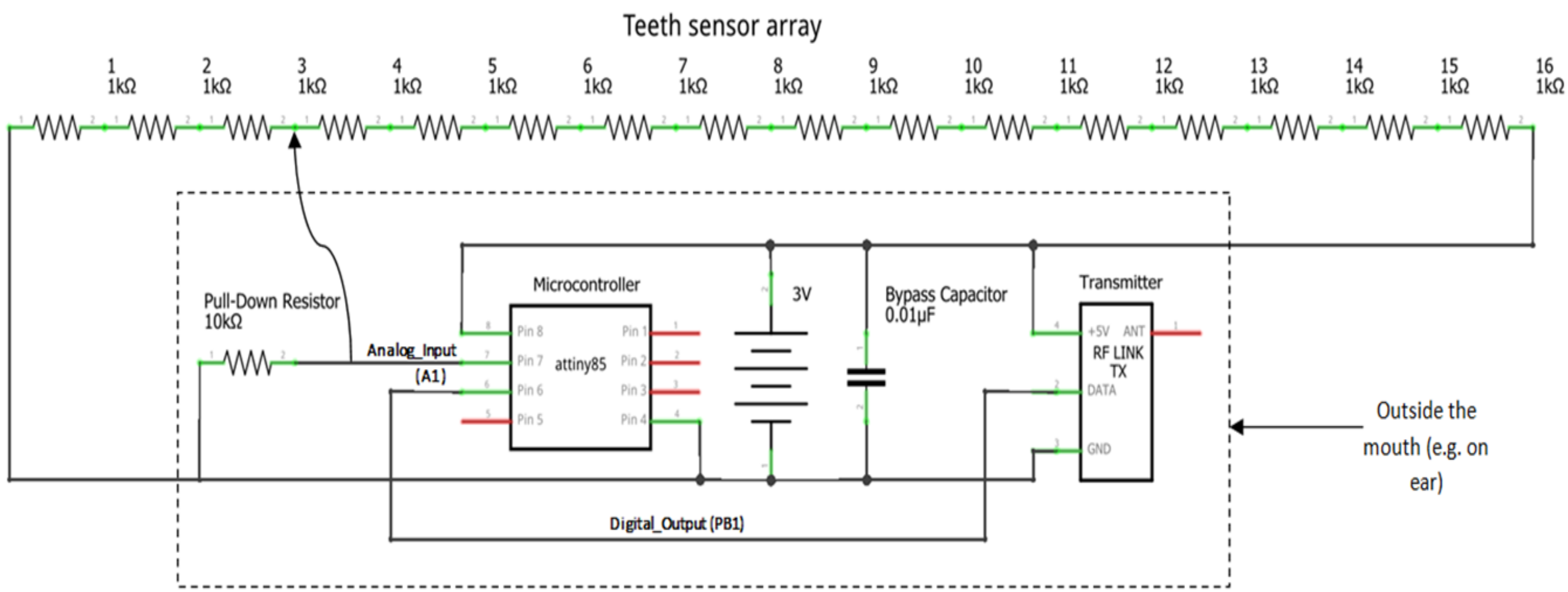

Fig. 5.7: Circuit diagram on the transmitter side

Surface Acoustic Wave (SAW) resonator is used to modulate the data. These transmitters are highly reliable due to digital modulation and error checking capabilities, and are compact in design suitable for our application. This wireless transmitter transmits the serial data from Digital_Output pin of microcontroller to the receiver.

The entire setup as shown as dashed square in Fig. 5.7 is placed in a small box or a suitable container outside the mouth (e.g. over the outer surface of pinna of ear). The TSA is placed inside the mouth and the three insulated wires - VCC, GND and Analog_Input – are taken out of the mouth as a single cable, enclosing the wires, and are connected to the external circuitry appropriately.

5.5. BLOCK DIAGRAM ON THE RECEIVER SIDE

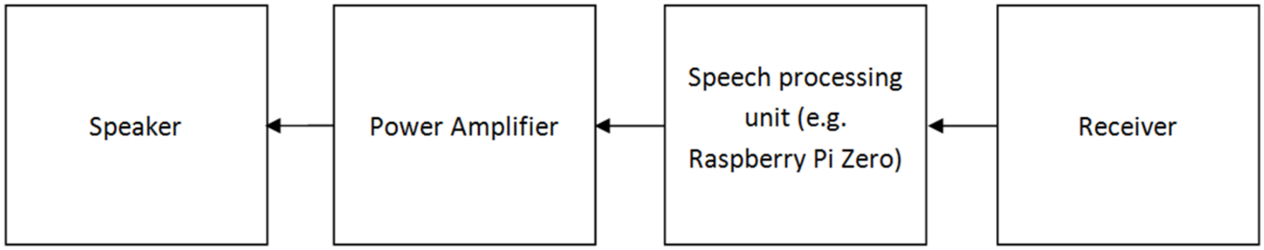

Fig. 5.8: Block diagram on the receiver side

The receiver side (Fig. 5.8) consists of a RF-433 MHz receiver which receives the data sent by the transmitter. The encoded data received is sent to a Speech Processing Unit (SPU) which converts it to raw data. The SPU concatenates each letter received until the space key is pressed at the transmitter end. Once space key is pressed, the string of characters or the word is processed into speech signals, amplified by a power amplifier and sent to a loudspeaker which outputs the sound corresponding to the word. The SPU might have a library of audio files which converts the word typed into speech. Speech prediction through automatic saving of frequently used words by the user will result in efficient, faster and accurate text-to-speech synthesis. The SPU can be any processing unit like Digital Signal Processor with speech processing capability.

For example, Raspberry Pi Zero [5], which is basically a low power computer, supports a huge open source library for text-to-speech synthesis and speech prediction. It is much smaller in size than its previous versions (e.g. Raspberry Pi 3). Any loudspeakers used for PCs, laptops etc. can be connected to it. It can also be configured to operate mobile or computer.

The transmitter and receiver are wireless so that the receiver circuitry can be practically placed anywhere within the signal coverage limit of transmitter; e.g. on the waist belt enclosed in a box or on a wheel chair in case of mobility impaired users. This wireless transmission prevents the need of a long wire between the TSA and SPU and hence removing the discomfort from such arrangement.

Considering the size, cost and number of components used, it can be concluded that the entire transmitter and receiver circuitry is compact and cheap compared to other ATs.

5.6. PLACEMENT OF SENSOR

A top view of the arrangement of sensors in mouth is given in Fig. 5.9. As shown in Fig. 5.5, the 3 layers are arranged successively over the inner periphery of the teeth. 8 segments of the upper section of key layer are placed on the upper jaw while other 8 segments of the lower section are placed on the lower jaw; both sections are connected to each other at one end. Similarly, the upper and the lower section of the top layer are placed in upper and lower jaw respectively. The three wires - VCC, GND and Analog_Input - are taken out of the mouth as a single cable.

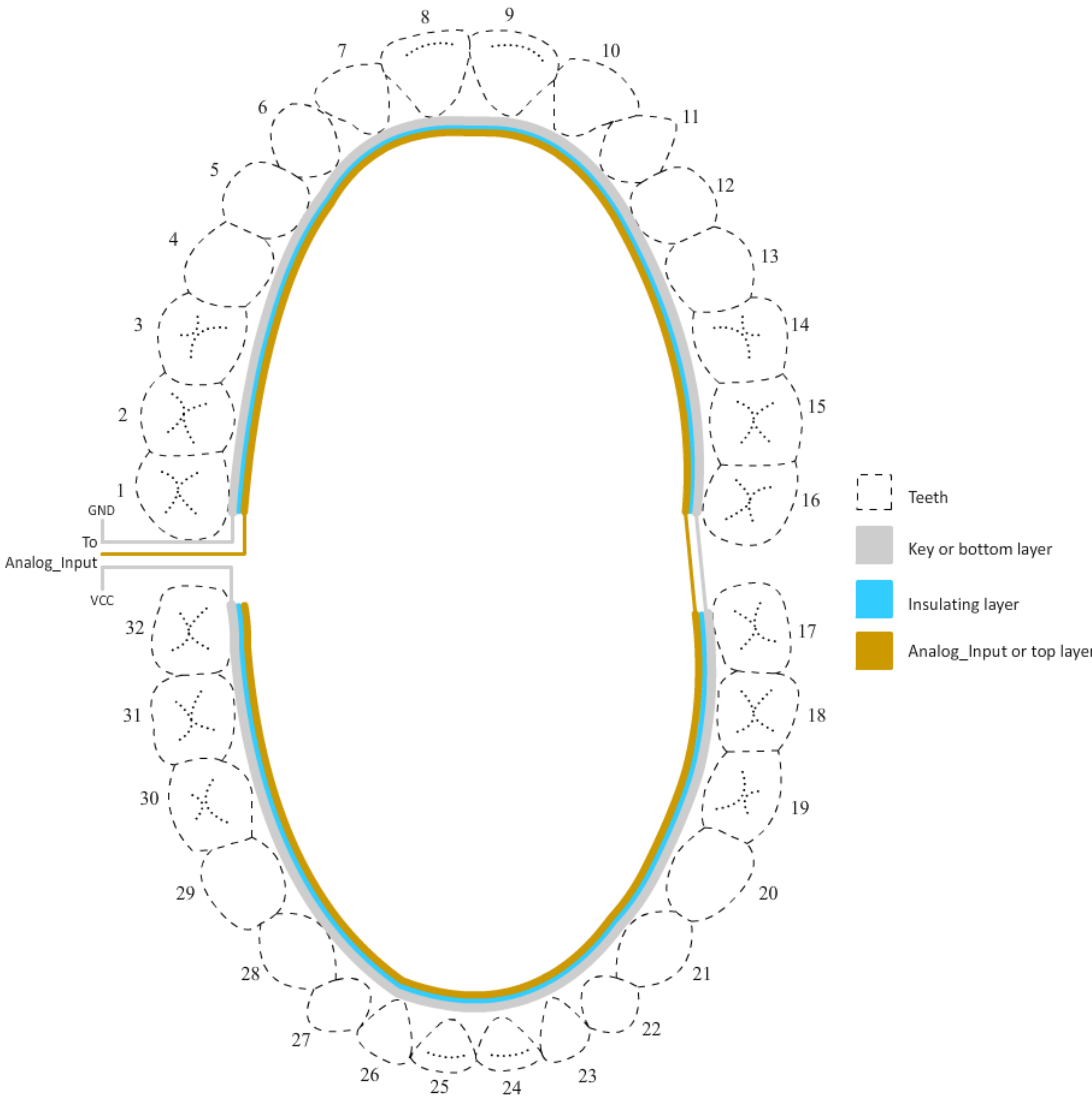

Fig. 5.9: Placement of TSA †

There are 32 teeth in an adult healthy human mouth – 16 in the upper jaw and 16 in the lower jaw. For ease of access by tongue tip, only 8 characters/segments are chosen for each jaw, i.e. 2 teeth for each character. An example for assigning characters to the teeth is shown in Table 5.1.

The characters assigned can be anything and can be easily modified according to the user needs as it lies only in the software design. Some segments can even represent sentences like “Help me”. A shift key, space key and ON/OFF key – 3 status keys – is used in addition to characters ‘a’ through ‘w’ and ‘y’ – 24 characters. Characters ‘z’ and ‘x’ are not supported in TTT as they are not used much in literature and can be simply replaced by s whenever required. Since only 16 characters are supported of which 3 keys are status keys, the remaining 13 (= 16-3) segments support 13 recurrently used characters as in Table 5.1.

Teeth no. (Refer Fig. 5.9)	**Segment or resistor no. (Refer Fig. 5.2)**	**Status and recurrently used characters (SHIFT disabled)**	**Character after shift key is pressed (SHIFT enabled)**
1,2	16	ON/OFF	q
3,4	15	m	y
5,6	14	e	I want to sleep
7,8	13	a	u
9,10	12	SHIFT	Disables SHIFT key
11,12	11	b	k
13,14	10	t	I am hungry
15,16	9	o	w
17,18	8	g	Call emergency no.
19,20	7	n	h
21,22	6	r	v
23,24	5	c	i
25,26	4	SPACE	Help me
27,28	3	d	p
29,30	2	s	f
31,32	1	l	j

Table 5.1: An example for assigned characters

Other less frequently used 11 (= 24-13) characters can be used immediately after shift key is pressed. Once such less frequently used character is pressed, the shift key is disabled automatically. Some of the segments support sentences, e.g. “Help me” in segment 4, when shift key is enabled. If GSM/calling capability is present, calling a previously fed emergency number is also possible as in segment 7. Note that the Table 5.1 is one of the approaches for assigning the characters and hence, the classification of characters into frequently and less frequently used, the sentences and the status keys can be modified in the software design according to requirements.

5.7. FLOWCHART

An algorithmic representation of the proposed methodology in transmitter and receiver side is given as flowchart in Fig. 5.10 and Fig. 5.11 respectively.

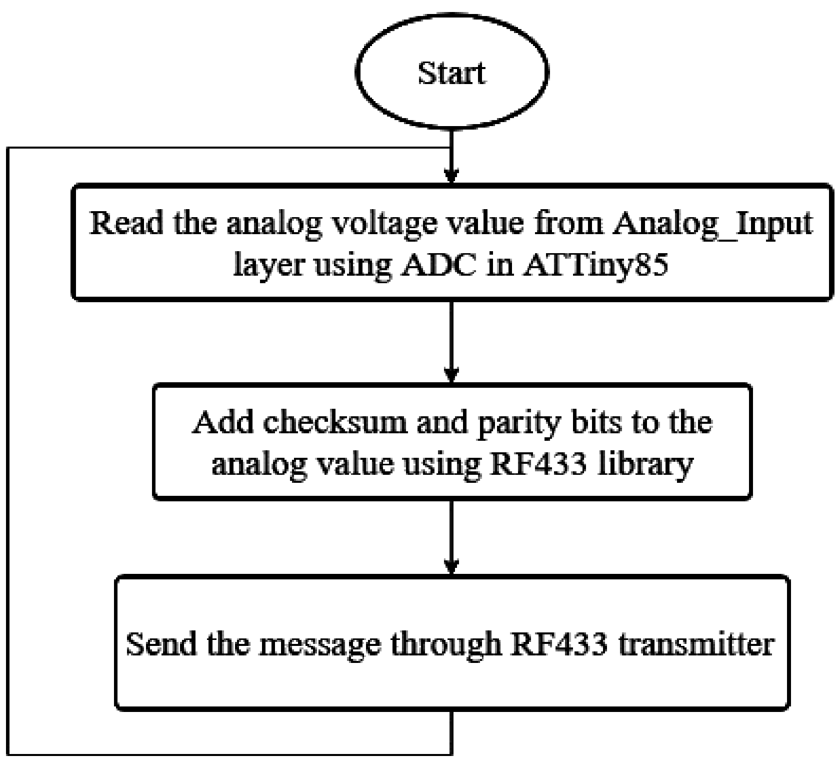

Fig. 5.10: Flowchart of transmitter section

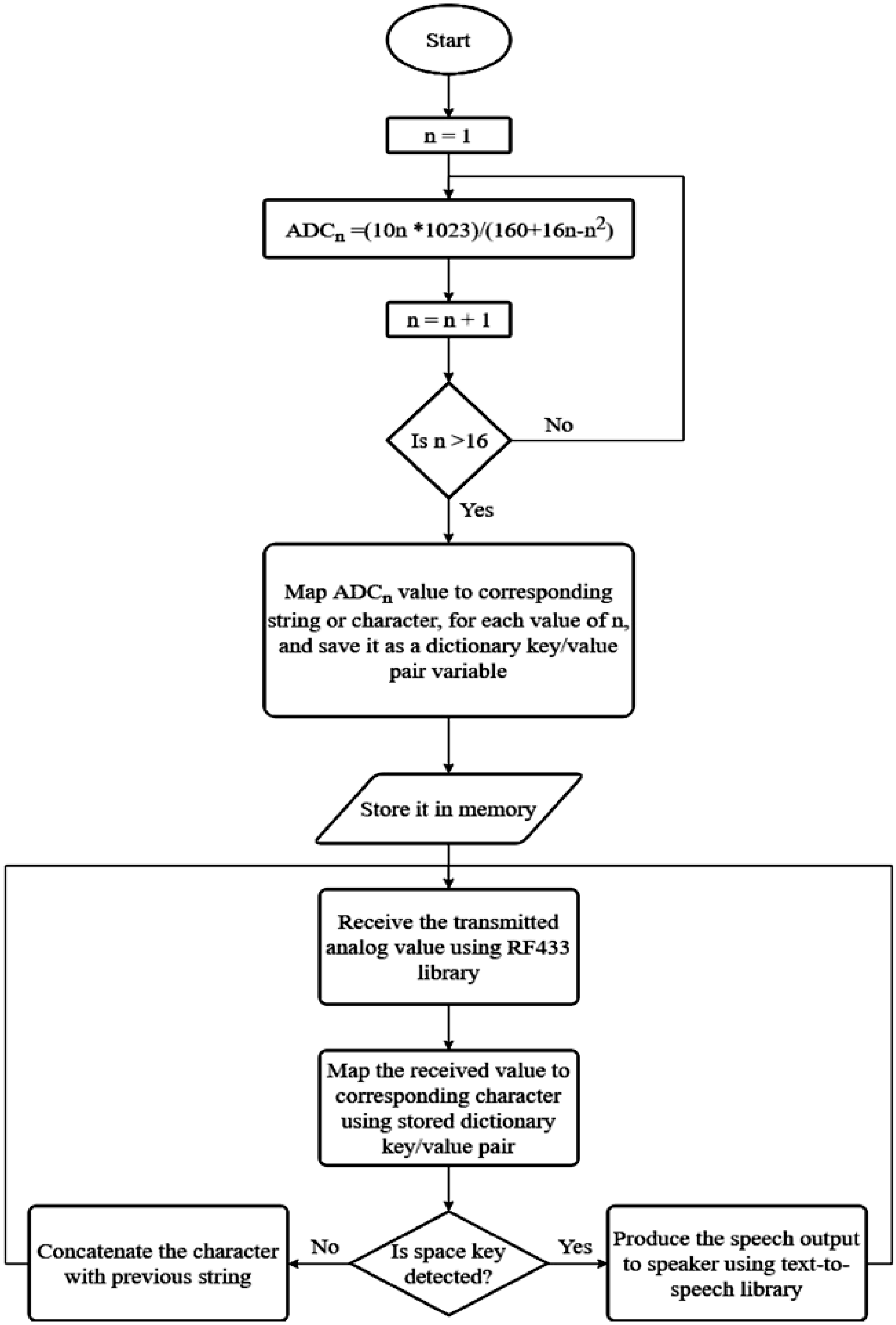

Fig. 5.11: Flowchart of receiver section

CHAPTER 6
MATHEMATICAL ANALYSIS

The total number of segments/resistors (1 kΩ) is 16. Let the resistors of bottom layer be denoted by R and the pull down resistor (10 kΩ) by R'. The segments/resistors are numbered from 1 to 16 as in Fig. 6.1.

Suppose the top layer is in contact with the n^{th} segment of the bottom layer, then 'n' resistors are in parallel with the pull down resistor.

Let V_{in} be the voltage level read by Analog_Input of ATtiny85 with respect to GND. It is also the voltage across the parallel combination of 'n' resistors or across the pull down resistor R'. Let V_{ref} = VCC be the reference voltage for ADC of ATtiny85 (here VCC is taken as the reference voltage).

Equivalent resistance of the parallel combination, $R_p = (n*R) \| R'$

$$= \frac{n*R*R'}{nR+R'} \qquad \text{--- (1)}$$

Here, R=1 kΩ and R'=10 kΩ and substituting these values in (1), we get R_p as in equation (2).

$$\text{Therefore, } R_p = \frac{n*1k*10k}{((n*1k)+10k)} = \frac{10n}{n+10}*10^3\ \Omega \qquad \text{--- (2)}$$

This parallel combination of resistor is in series with (16-n) resistors.

Therefore, equivalent total resistance, $R_{eq} = R_p + ((16-n)*R)$ --- (3)

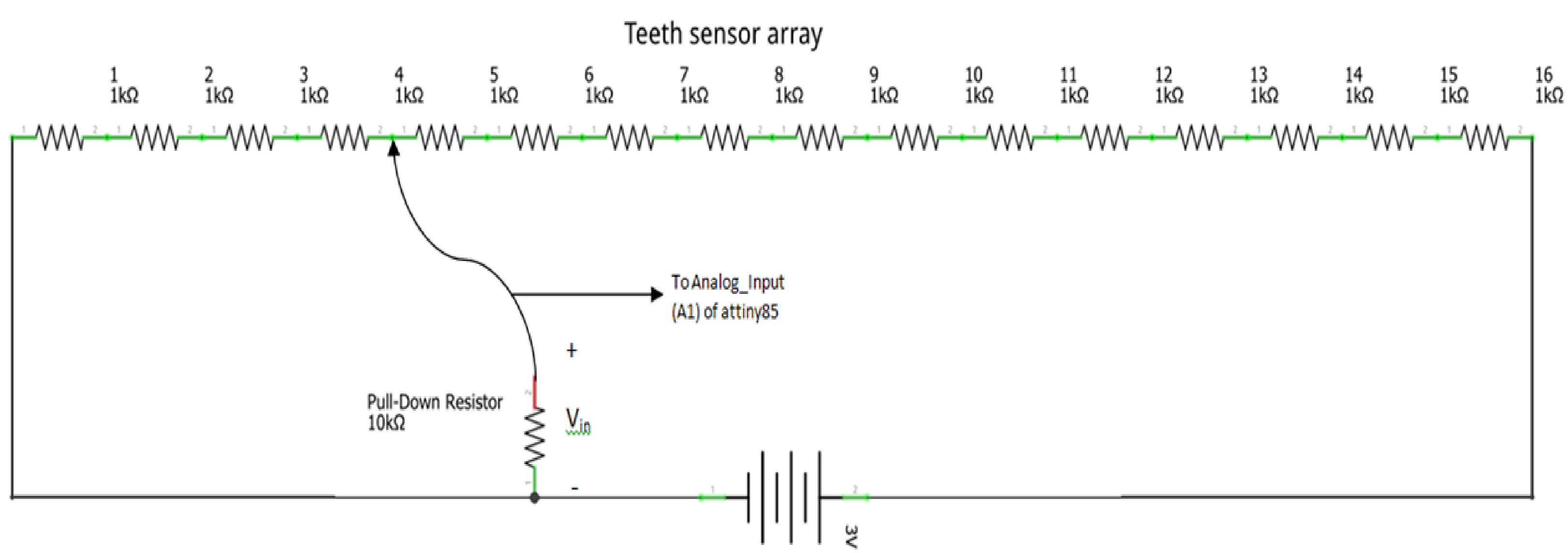

Fig. 6.1: Equivalent circuit when top layer is in contact with segment n = 4 of key layer

Substituting (2) in (3), $R_{eq} = (\frac{10n}{n+10} + (16\text{-}n)*1)*10^3$

$$= \frac{10n+16n-n^2-10n+160}{n+10} *10^3$$

$$R_{eq} = \frac{160+16n-n^2}{n+10} *10^3\ \Omega \qquad \text{--- (4)}$$

By voltage division rule, $V_{in} = V_{ref} * \frac{R_p}{R_{eq}}$ --- (5)

Substituting (2) and (4) in (5), we get,

$$V_{in} = V_{ref} * \frac{10n}{160+16n-n^2} \text{ (in V)} \qquad \text{--- (6)}$$

Now, equivalent digital value for V_{ref} = 1023

Therefore, equivalent digital value for V_{in}, ADC = $V_{in} * \frac{1023}{V_{ref}}$ --- (7)

Substituting (6) in (7), we get,

$$\mathbf{ADC = \frac{10n}{160+16n-n^2} *1023} \qquad \text{--- (8)}$$

Table 6.1 gives the Analog_Input values or ADC (given by equation (8)) values read by ATtiny85 for each key based on Table 5.1.

Segment or resistor no. (Refer Fig. 5.2)	ADC value approx. using equation (8) (±5 for practical values)	Status and recurrently used characters (SHIFT disabled)	Character after shift key is pressed (SHIFT enabled)
16	1023	ON/OFF	q
15	877	m	y
14	762	e	I want to sleep
13	668	a	u
12	590	SHIFT	Disables SHIFT key
11	523	b	k
10	465	t	I am hungry
9	413	o	w
8	365	g	Call emergency no.
7	321	n	h
6	279	r	v
5	238	c	i
4	197	SPACE	Help me
3	154	d	p
2	109	s	f
1	58	l	j

Table 6.1: Typical ADC values for each key

CHAPTER 7
CONCLUSION AND DISCUSSIONS

Tongue Talk Technology requires lesser components and makes them less expensive and less bulky than other ATs. However, the use of TTT requires practice like other ATs and the users are required to practice TTT using computer software which displays the key pressed. One might come to a conclusion that using tongue is slower than typing. On the contrary, tongue can do complex motor control and manipulation tasks with increased dexterity due to its large occupancy of motor-cortex region of the brain.

Maysam Ghovanloo states in his paper [6] that, *Tongue can move very fast and accurately [7], letting us touch every single tooth in our mouth with the tip of our tongue [8]. Furthermore, the tongue muscle is similar to the heart muscle in that it does not fatigue easily.*

Considering the above facts, TTT poses greater advantage than its rival ATs. The speech synthesis can be made faster by using auto-prediction and storing recurrent words used by the wearer. In addition, the device can be used to control computers and mobiles. Thus, TTT will help speech-impaired people to a greater extent.

CHAPTER 8
FUTURE SCOPE

The battery used in transmitter section limits the entire circuit from being compact placing it inside the mouth becomes difficult. Providing passive RFID network in place of voltage divider network, for each segment, might solve the issue. Passive RFID tags do not need a power source for their operation and thus allow the complete removal of power source circuitry. However, miniature passive RFID tags are still in research which can be considered for deployment in the future when the research is complete.

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