

Modeling and Signal processing for Cochlear Implant to improve speech recognition

D. V. Bhoir¹, Dr M. S. Panse²

Abstract: Cochlear implant Prosthesis device is implanted in the inner ear and restore partial hearing to profound deaf people. A microphone that picks up the sound waves is applied to a signal processor, which then converts the sound into electrical signals. Then, the electrical signals are given to transmission system which transmits the pulses to the implanted electrodes. The laboratory speech processor is modeled and simulated for improved signal processing for different conditions. The speech processor is capable of providing high rate stimulation to the variable number of electrodes. The model offers flexibility in frequency as well as number of electrodes. The Continuous Interleaved Sampling scheme offers least interference between the pulses applied to the electrodes. The test was carried out for different test signals such as vowels, consonants and sentences. The main challenges were to test the model under different conditions such as open stage and monosyllabic words for its accuracy. The model performs very well under sound proof conditions. The open-set speech recognition was also plotted for different patients. From the results it is quite clear that the implant obtained moderate to excellent open-set speech-recognition scores. The results shows the orderly decrease in normal hearing performance as speech -to- noise ratio(SNR) decreases. Normal class room (Open stage) SNR is kept at 6dB whereas the sound proof room will have SNR ratio more than 15 to 20dB. The mean scores for the cochlear implant user decreases as SNR decreases.

Index Terms—Biphasic pulse, Cochlear Implant, CIS, DAQ, LabVIEW, SNR, Speech processor

1. INTRODUCTION.

In an ear that functions normally, the basilar membrane in the inner ear divides an acoustic signal into different frequencies that cause vibrations at different points in the cochlea. High frequencies cause vibrations at the base and low frequencies cause vibrations at the apex of the cochlea. When damage to the connection between hair cells and the basilar membrane causes deafness, cochlear implants are used to perform the hair cell functions to directly stimulate the neurons. Cochlear implant restores normal hearing to the deaf by electrical stimulation of the auditory nerve. A prosthetic device can be implanted in the inner ear and can restore partial hearing to profoundly deaf people. The excitation used to produce voiced sounds is periodic and is generated by the vibrating vocal cords.

- Author D V Bhoir is Research Scholar in Dept. of Electrical Engineering, V.J.T.I. and Associate Professor, Dept. of Electronics, Fr. CRCE, Bandra, Mumbai-400050. , India e-mail:bhoir@frcrce.ac.in
- Co-Author Dr M. S. Panse is Professor, Dept. of Electronics, V.J.T.I., Matunga, Mumbai-400019, India. E-mail:mspans@vjti.org.in

The frequency of the voiced excitation is commonly referred as the fundamental frequency (F0). The vocal tract shape defined in terms of tongue, velum, lip and jaw

position acts as a filter of the excitation to produce the speech signal. The frequency response of the filter has different spectral characteristics, depending on the shape of the vocal tract. The broad-spectrum peaks in the spectrum are the resonance of the vocal tracts, are commonly referred to as formants [1],[2]. The frequencies of three formants (denoted as F1,F2 and F3) contain sufficient information for the recognition of vocals as well as other voiced sound. The formants movement has also been found to be extremely important for the perception of sounds (i.e. consonant). The neurons communicate with the central nervous system and transmit information about the acoustic signal to the brain. The hair cells in conjunction with the basilar membrane[3] are responsible for translating mechanical information into neural information. If the hair cells are damaged the auditory system has no way of transforming acoustic pressure waves (sound) to neural impulses, resulting in hearing impairment. The hair cells can be damaged by certain disease (e.g. meningitis[4], Meniere's diseases), congenital disorders by certain drug treatment or many other causes. Damaged hair cells can subsequently lead to degeneration of adjacent auditory neurons. If a large number of hair cells or auditory neurons are damaged then the condition is called profound deafness. Research has shown that the most common cause of deafness is the loss of hair

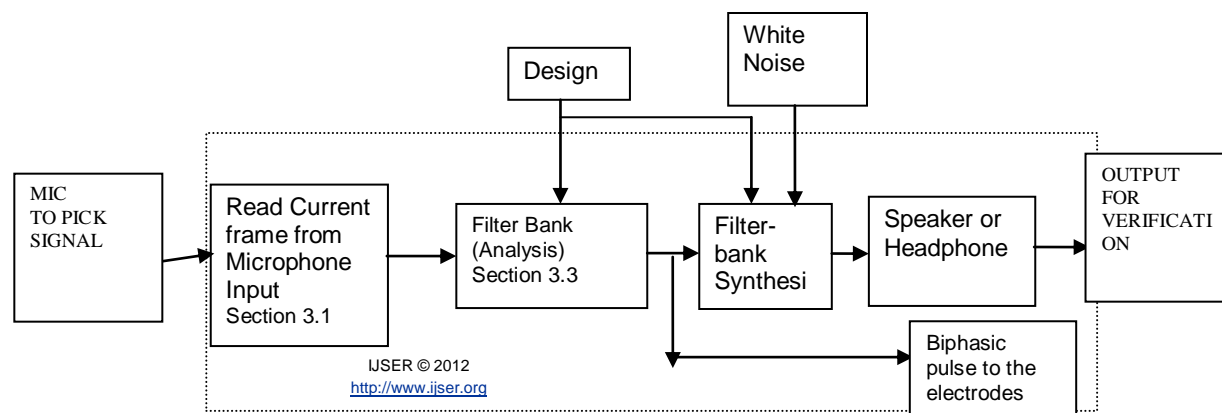


Fig 1 Real time Implementation of the CI

cells, rather than loss of auditory neurons[5],[6] The speech processor described here is the scheme to provide laboratory experimentations with the help of setup using data processing and generating a current pulse to stimulate the auditory nerves. The electronic components of the laboratory speech processor, which receive the audio signal, process it and generate electrical stimuli for cochlear implants. This circuit sends current pulses to the electrodes implanted in the cochlea of the patient. As a result, the auditory nerve is excited and transmits nerve pulses to the brainstem and brain, where they are interpreted as sound.

In this paper the section 2 includes Development of model in LabVIEW: It deals with design and development of model in LabVIEW. It is developed with the help of mathematical equations and simulated with the help of LabVIEW[7] code, to verify the results. The section 3 discusses about the system Implementation which deals with design & implementation of the scheme. It also includes the verification of the basic features of the scheme such as flexibility, low cost and accuracy. Section 4 deals with the experimental results with the specifications at which the tests were carried on. The comparison of the results was graphically presented and inference drawn from the results. Final section is Conclusion which gives overall conclusion and future scope of modifications.

2. DEVELOPMENT OF MODEL

The laboratory speech processor is first modeled for the development of CI. The speech processor is capable of providing high rate stimulation to the number of electrodes. In order to process acquired speech frames from a microphone in real-time, the coefficients of the filters[8] need to be computed. The real time implementation is as given in Fig.1

In the Real-Time phase[9], all the computed filter coefficients together with the white noise sequence are fed back continuously within a real-time loop. In the Real Time loop, an input frame is first acquired from a microphone at a given sampling rate. The pre-emphasized output is then passed through the filter bank decomposition and synthesis [10] stages. Finally, the synthesized frames are sent to a speaker or headphone to provide audio feedback. This process is repeated continuously within the real-time loop until the user halts the process.

3. SYSTEM IMPLEMENTATION

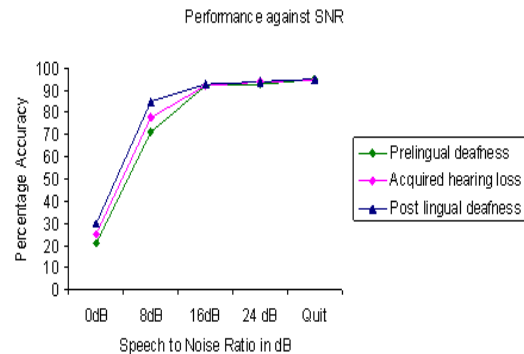
The heart of this building block is the Digital signal processor block where the algorithm is generating the signal which produces the biphasic pulses [11] with the help of current sources to offer very high output resistance as desired. The whole system implementation is shown in Fig.2.

Input Circuit consist of a microphone along with a preamplifier circuits. After proper signal conditioning it is given to the DAQ card where the data is converted into corresponding digital data. The heart of this building block is the Digital signal processor[12] block where the algorithm is generating the signal which produces the biphasic pulses with the help of current sources[13] to offer very high output resistance as desired.

4 EXPERIMENTAL RESULTS

The implantation at age 12 months is now considered ideal, and, in some instances, implantation at an earlier age is performed. Adults with progressive loss that ultimately fails to be managed via amplification also may present for implant consideration. The results show the orderly decrease in normal hearing performance as speech -to-noise ratio (SNR) decreases. Normal class room (Open stage) SNR is kept at 6dB whereas the sound proof room will have SNR ratio more than 15 to 20dB The mean scores for the cochlear implant user decreases as SNR decreases

A basic current mode converter is constructed using the weighted current sources. This produces the desired current. The output current is varied between 0 and 1 mA. The control lines are derived from the DAQ card. Fig 3 Performance against Speech to Noise Ratio



The repetition rate can be varied from 600Hz to 1600 Hz. The test was carried out at repetition rate[40] of 1200Hz. The pulse rate is fixed to 0.83 ms so that the DAC can

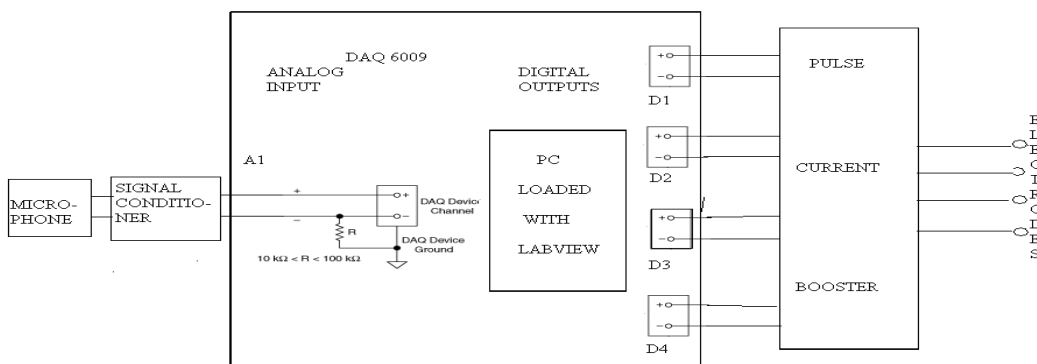


Fig. 2 System Implementation

generate a current pulse of the required width (variable from few microseconds to 100 μ S).

5. CONCLUSION

The experimental setup for speech processor is prepared using LabVIEW environment. The effect of several parameters of the CIS speech processing strategy on the speech recognition performance of the patients has been investigated. These parameters include the rate and the width of the current pulses sent to the electrodes, the shape of compression functions, the order of digital filters, the resolution of the output and the order in which the electrodes are stimulated. All these parameters can be set which gives flexibility in the system. The speech processor is providing added features such as flexibility in selection of signal processor as per patient requirement. Selection of number of electrodes required for patients and test is carried out under both sound proof as well as open stage. The factors which contribute to the variability in performance among patients can be determined. These factors will help to develop signal-processing techniques that are Patient-specific. Patients will be fitted with the appropriate signal processors as a new eye glasses by an optometrist. The success of the new signal ultimately narrow the gap in performance between "poorly performing" and "better-performing then be optimally fitted with specific signal processors, much like people are fitted" patients.

This is a development of preoperative procedures that can predict how well a patient will perform with a particular type of cochlear implant. This will continue investigating the effects of electrical stimulation on encoding of speech in the auditory nerve. Such investigations will help to select better signal processing strategies. The experimental setup is invaluable for creating a modular, reusable test framework for the LabVIEW test modules.

The experimental setup is tested for different age group patient. The test is carried on for different test signals as well as conditions. The performance of the designed cochlear implant shows that the accuracy of the unit is better for sentences over consonant. The vowels recognition is yet to be improved with increase in order of the filter and number of electrodes. Post-lingually deaf adults show better response over the Acquired hearing loss and post-lingual deafness. Congenital hearing loss and pre-lingual deafness naturally gives poor performance. Open stage response is much more improved and the performance is very close to the one carried out under sound proof conditions. The results shows the orderly decrease in normal hearing performance as speech -to- noise ratio(SNR) decreases. Normal class room (Open stage) SNR is kept at 6dB whereas the sound proof room will have SNR ratio more than 15 to 20dB. The mean scores for the cochlear implant user decreases as SNR decreases.

The proposed strategy has flexible repetition rate from 600Hz to 1200 Hz a variable current from few microamperes to 1mA and pulse width of 50 to 500

microseconds. The test is carried at repetition rate of 1000Hz and pulse width of 100 μ s and current of .5 mA. The model provides flexibility in setting different parameters such as order of the filters, repetition rate, and variable current to electrodes, number of electrodes. This opens a gateway for virtual instrumentation in clinical applications.

ACKNOWLEDGMENT

The authors wish to thank the management of Fr. Conceicao Rodrigues College of Engineering for continuous support and infrastructure. This work was carried out at biomedical lab at V.J.T.I and tested in sound proof lab supported by Dr. Uppal Clinic.

REFERENCES

- 1) Loizou P C "Introduction to Cochlear Implants", IEEE transaction on Engineering in Medicine and Biology , Jan/ Feb 1995 Vol. 15 No.5, pp. 11-130
- 2) Loizou P C "Signal Processing Techniques for Cochlear Implants", IEEE transaction on Engineering in Medicine and Biology, May/June 1999, pp.34-46
- 3) O. POROY and P C Loizou "Development of speech processor for Laboratory Experiments with Cochlear Implant Patients", Proceeding ICASSP '00 Proceedings of the Acoustics, Speech, and Signal Processing, 2000. on IEEE International Conference - Volume 06, pp. 3626-3629,
- 4) James M. Kats "A time -Domain Digital Cochlear Model", IEEE transaction on signal processing, 1991, Vol. 39 No. 12 pp. 2573-2592.
- 5) Suat U.Ay. , Fan -Gang Zeng , Bing J Sheu "Hearing with bionic ears: Speech processing strategies for cochlear Implant Devices" ,IEEE transaction on Circuits and Devices, May1997, p.18-23. 6) Loizou P C "Signal Processing for Cochlear Prosthesis: A tutorial Review", Proceedings of the 40th Midwest Symposium on Circuits and Systems, Vol.2, 1997, pp.881-885.
- 7) Robert H. Bishop: Learning with LaVIEW TM7 Express Pearson Education Publication, 2005
- 8) Chris Silva "Cochlear Implants", Proceedings of Electrical Insulation Conference and Electrical Manufacturing Expo, 2005, pp. 442-446.
- 9) M Dorman and P Loizou "Improving consonant intelligibility for Ineraid patients fit with Continuous Interleaved Sampling (CIS) processors by enhancing contrast among channel outputs", Ear and Hearing magazine,1996, Vol. 17 no.4 pp. 308-313,
- 10) Neal Bhadkamkar Boyd Fowler "A Sound Localization System Based on Biological Analogy", IEEE International Conference on Neural Networks,1993. pp. 1902-1907.
- 11) Zwolan T.A , Kilney P. R. "Cochlear Implant for profoundly Deaf" , Proceedings of Sixth Annual IEEE Symposium on Computer-Based Medical Systems, 1993. pp.241-247.

12) NI Education Laboratory Virtual Instrumentation Suite (NI ELVIS) Hardware User Manual

13) Hugh J. McDermott “How cochlear implant have expanded our understanding of speech perception”, Proceeding of the 20th annual International conference of IEEE Engineering in Medicine and Biology Society Vol. 20 No 5: pp.2251-2256, 1998