

Embedding of Internal and External Components of Cochlear Implant on to a Single Integrated Circuit

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Abstract: The Latest Cochlear Implant Naida CI Q70 With Advanced Wireless Feature Has Got Its Speech Processor And Transmitter In The Form Of Reliable Wire Communication Architecture. This Architecture Creates Problem For Deaf In Terms Of Maintenance And Cost For Its Complex Structure. The External Components Such As Transmitter, Sound Processor And Its Internal Components And Microphones Are Apart In Structure Both Internally And Externally. The Communication Among The External Devices Requires A Physical Wire, And This Structure Has Many Disadvantages One Is It Needs A Lot Of Care To Maintain And On Any Small Damage Requires Huge Money Needs To Be Spent On New Head Piece. Secondly Its Rare And Unique Structure Creates A Lot Of Nuisance With Multiple Enquiries From The People Leading To The Frustration While Answering Many People. Hence The Idea Is To Design A Circuit That Accommodates All Internal And External Components On To Single IC. This Technology Development Is To Provide Technological Solutions With Multidisciplinary Approach To Resolve The Problems And Improve Quality Of Life Of The Deaf Population (Specifically Deaf Children's) With Focused Initiative On Technology Interventions Which Leads Commercial Product, Also Aim In Providing Individual Autonomy And Independence To Persons With Deaf Through Holistic Development By Creating Enabling Environment For Their Empowerment Through Application Of Technology.

Keywords: Cochlear Implant, IC, Sound Processor, Transmitter, Head Piece, Electrode

I. Introduction

Cochlear Implant[2] system consists of a microphone, processor, headpiece, cable and implant. Sounds in the environment are captured through the microphone located on processor. The processor then converts this sound information into a distinctive digital code that is transmitted to implant by the head piece. The headpiece is held in place over the implant by a magnet that attracts to the implant magnet. Implant converts the digital code into electrical signals that are delivered to human auditory (hearing) nerve. Auditory nerve then carries this information to the brain, where it is interpreted as sound.

What is a Cochlear Implant?

Advanced Bionics[2][3] provides the world's most advanced cochlear implant system to help you or your loved one hear again—or experience the joy of sound for the first time. Hearing loss affects millions of people of all ages around the world. For many, hearing aids provide a viable solution, but if you or a loved one experience significant hearing loss, hearing aids may offer little or no benefit. That's when it's time to consider cochlear implants, a medical device technology that thousands of people around the world rely on, as a way to restore hearing.

What is a Cochlear Implant system?

A cochlear implant is a highly advanced medical device (Fig 1) and the only technology that is capable of functionally restoring one of the five senses. Cochlear implants provide an effective alternative to hearing aids because they don't use amplification. Instead, they bypass the damaged part of the ear and use electrical stimulation to enable you to hear.

Components of a cochlear implant system



Figure 1 Components of CI

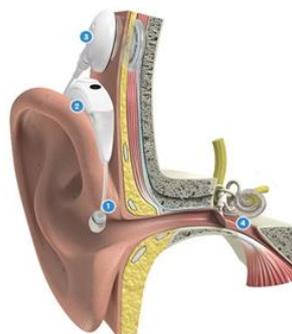


Figure 2 Working of CI

There are two main components to a cochlear implant system. The internal component is the implant. The external component is the sound processor, which can be worn on or off the ear.

How does a cochlear implant works?

1. First, the cochlear implant system captures the sound (Fig 2) around you, with one or more microphones. AB has microphones placed in the front and back of the processor and in the headpiece. Unique AB microphone technology allows you to use ear buds, headphones and telephones like everyone else, to hear in water, and to hear better in noise.
2. When the sound is captured, it is processed. AB sound processors use the industry's most advanced technology to make hearing easier and include the only sound processing strategy in the industry recognized by the FDA to improve speech understanding in noise.
3. The processed sound is transmitted through the headpiece to the implant. AB's implant family features the most advanced sound processing circuitry in the world, with programming flexibility that provides nearly unlimited ways to deliver sound.
4. The sound is sent through an electrode directly to your hearing nerve. Every AB electrode delivers focused stimulation through current steering technology – available only from AB – for hearing that more closely resembles normal hearing.

II. Literature Review

Access to cochlear implantation

Several new papers have addressed factors affecting patient access to cochlear implant services. Jacob & Stelzig³ (Mainz, Germany) point out that currently only some 10% of potentially suitable recipients receive a cochlear implant, in spite of medical guidelines stating that appropriate bilateral intervention should be provided.

Teschner et al.⁴ (Hanover/San Francisco) compared implantation procedures and cost-analysis in large clinics in Germany and the USA. The most notable difference in procedure was that preoperative diagnostic procedures and implantation in Germany require on average a total of six to seven days in hospital, while in the USA both are outpatient procedures. Total charges in the USA are about double than those in Germany, yet reimbursement is actually lower in the USA.

Hamerschmidt et al.⁵ (Parana, Brazil) report successful implantation under local anaesthesia. There were no significant differences between the local and the general anaesthesia group in terms of complications or subjective patient reports, yet procedure times and costs were all lower for the local anaesthesia group.

Positive Outcomes in the Elderly

Several recent studies^[4] have demonstrated very positive outcomes from cochlear implantation in the elderly, which suggest that age should not be a contra-indication. A new study from Lundin et al.¹ (Uppsala, Sweden), in which outcomes from cochlear implant recipients implanted below and above 79 years of age were compared, supports these views. Slightly poorer performance and subjective outcomes were recorded for the older group, but this may have been an effect of duration of deafness rather than chronological age. There was no difference in complication rates between the groups.

Clark et al.² (Baltimore, USA) reviewed publications on cochlear implant outcomes in the elderly and concluded that aspects of social behaviour and isolation have an important influence on quality of life benefits, and these should always be considered alongside hearing performance outcomes. The authors proposed a conceptual model of the influences of several factors on quality of life, including characteristics of the

individual (other than hearing loss) and characteristics of the cochlear implant user's environment. They suggest that this model should be considered when planning or researching rehabilitation strategies and in cost-benefit analysis.

Positive outcomes in children with early and late implantation

Many previous studies have shown the benefits of early implantation of congenitally deaf children, but often conclusions have been clouded by heterogeneous subject characteristics. A recent study by Fulcher et al.⁶ (Sydney, Australia) demonstrated that outcomes in a group of children with stable hearing levels, appropriate rehabilitation and without additional disabilities, who were implanted with Cochlear™ Nucleus® Freedom® devices before the age of 18 months out-performed children with the same characteristics but identified between one and five years of age. More important, 93% of the early intervention subjects were shown to perform within normal limits for speech recognition and production by three years of age.

While children implanted late following their loss of hearing generally show poorer outcomes, a report by Cadieux et al.⁷ (St Louis, USA) found that subjects implanted in adolescence can obtain good levels of cochlear implant benefit under certain circumstances and suggests that use of a hearing aid extends the time window for implantation.

A study by Kim et al.⁸ (Busan, Korea) suggests that use of a cochlear implant in one ear also extends the window of opportunity for implantation of the second side. Paediatric unilateral cochlear implant users were given a trial with a contralateral hearing aid, and 42 subjects who did not show benefit were implanted on the second side after a mean gap of 5.5 years. After one year, mean speech understanding using the second device alone was not significantly different from performance using the first cochlear implant alone, and bilateral use further enhanced performance in spatially separated noise.

Evidence to support cochlear implants in Single Sided Deafness builds up in adults and also in children

Two recent papers add evidence of benefits from cochlear implants in Single Sided Deafness (SSD). Firszt et al.⁹ (Washington, USA) describe experiences from three adults with SSD implanted with Cochlear Nucleus devices in a pilot study. Duration of deafness was less than five years and tinnitus was the primary motivation in two subjects. Cochlear implant-alone scores for monosyllables after 17 months were between 30% to 75% and localization was improved for all subjects. Subjective reports were very positive and all subjects used the device at all times, with substantial relief from tinnitus.

Another pilot study by Hassepas et al.¹⁰ (Freiburg, Germany) is collecting outcomes in children with acquired SSD. Three children, aged four, 10 and 11 years have been reported on to date, with outcomes after six to 12 months similar to those reported in adults, i.e. improved speech understanding in noise, better localization and clear subjective benefits.

III. The Present Hardware Structure of the CI

At present Cochlear Implant System[13] (Fig 3) primarily encompasses external components with implantable internal components. The internal Components are implanted on Cochlea of the inner ear. And the external components are located out side the year warred on the ear and headpiece is held in place over the implant by a magnet that attracts to the implant magnet. Implant converts the digital code into electrical signals that are delivered to human auditory (hearing) nerve. Auditory nerve then carries this information to the brain, where it is interpreted as sound.

Internal Receiver:- Part of the implant that is placed under the skin behind the ear that is includes thatmagnet and antenna (Chute & Nevins,2002.)

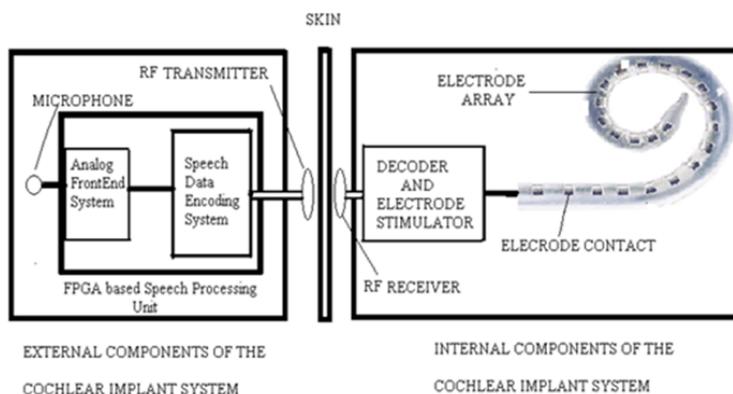


Figure 3 Simplified Diagram of present Cochlear System

The Cochlear Implant system works by using the tonotopic organization of the basilar membrane, the basilar membrane within the cochlea of the inner ear is a stiff structural element that separates two liquid-filled tubes that run along the coil of the cochlea, the scala media and the scala tympani of the inner ear. "Tonotopic organization", also referred to as a "frequency-toplace" mapping, is the way the ear sorts out different frequencies so that our brain can process that information. The cochlear implant bypasses the hair cells and stimulates the cochlear nerves directly using electrical impulses. This allows the brain to interpret the frequency of sound as it would if the hair cells of the basilar membrane were functioning properly. The Cochlear Implant System primarily encompasses external components with implantable internal components as

External Components – The microphone, speech processor, transmitter and power supply are all parts of the external devices of the cochlear implant.

Batteries – Are the power supply for the cochlear implant. They can be either rechargeable or alkaline depending on the type of device that is used.

Cables – Deliver the sound from the microphone to the speech processor,

Coils – Contain magnets that hold the implant to the head and transfer the signals from the speech processor via radio waves through the skin into the internal device.

Microphone – Picks up the incoming signals.

Speech Processor – The speech processor is an electronic device using VLSI technology and to provide FPGA solution, that filters the input signal from the microphone and converts it into a series of electrical signals to be delivered to the internal device within the cochlea.

Internal Components – The Internal parts of the cochlear implant system are placed under the skin behind the ear (Chute & Nevins, 2002).

Channels – A channel is a single electrode (Christiansen & Leigh, 2002). Electrodes – “Actively delivers the signal to the cochlear nerve endings”(Chute & Nevins, 2002).

Electrode positioning system – Guides the electrodes into the cochlea (Advanced Bionics, 2000).

Internal electrode array – “Electrodes placed in pairs on a carrier wire and inserted.

Internal receiver – part of the implant that is placed under the skin behind the ear that includes that magnet and antenna (Chute & Nevins, 2002).

IV. Problem Statement

The latest cochlear Implant Naida CI Q70 with advanced wireless feature [1] has got its speech processor and transmitter in the form of reliable wire communication architecture. This architecture creates problem for deaf in terms of maintenance and cost for its complex structure. The External components such as Transmitter, Sound processor and its internal components and microphones are apart in structure both internally and externally. The communication among the external devices requires a physical wire, and this structure has many disadvantages one is it needs a lot of care to maintain and on any small damage requires huge money needs to be spent on new head piece. Secondly its rare and unique structure creates a lot of nuisance with multiple enquiries from the people leading to the frustration while answering many people.

4.1 Thought Process

To investigate a circuit[1] design that embeds all external components on to a single IC. This Technology development is to provide technological solutions with multidisciplinary approach to resolve the problems and improve quality of life of the deaf population specifically deaf children’s with focused initiative on Technology interventions[5], also aim in providing individual autonomy and independence to persons with disability through holistic development by creating enabling environment for their empowerment through application of Technology.

V. The Proposed Hardware Structure for the CI

The idea is to investigate a circuit design that accommodates all internal and external components on to a single IC where the communication flow will be the Sounds in the environment are captured through the microphone located on processor. The processor then converts this sound information in to a distinctive digital code that is transmitted to implant by the head piece. The headpiece is held in place over the implant by a magnet that attracts to the implant magnet. Implant converts the digital code into electrical signals that are delivered to human auditory (hearing) nerve. Auditory nerve then carries this information to the brain, where it is interpreted as sound. This Technology development is to provide technological solutions with multidisciplinary approach to resolve the problems and improve quality of life of the deaf population specifically deaf children’s with focused initiative on Technology interventions, also aim in providing individual autonomy and independence to persons with disability through holistic development by creating enabling environment for their empowerment through application of Technology.

The block diagram shows (Fig 4, 5) how both both internal and external devices are embedded in a single IC. Here the entire IC with all components implanted on to cochlear inside the ear. Capturing of sounds from the nature is done by the sensor based microphone. The design of this special requires some design considerations which are explained below.

Block diagram of Proposed Hardware Structure for the CI

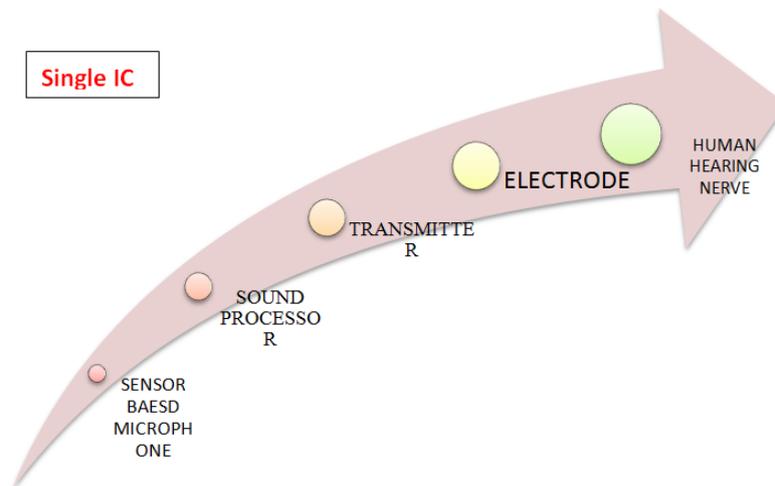


Figure 4 block diagram that shows embedding of internal and external components of CI

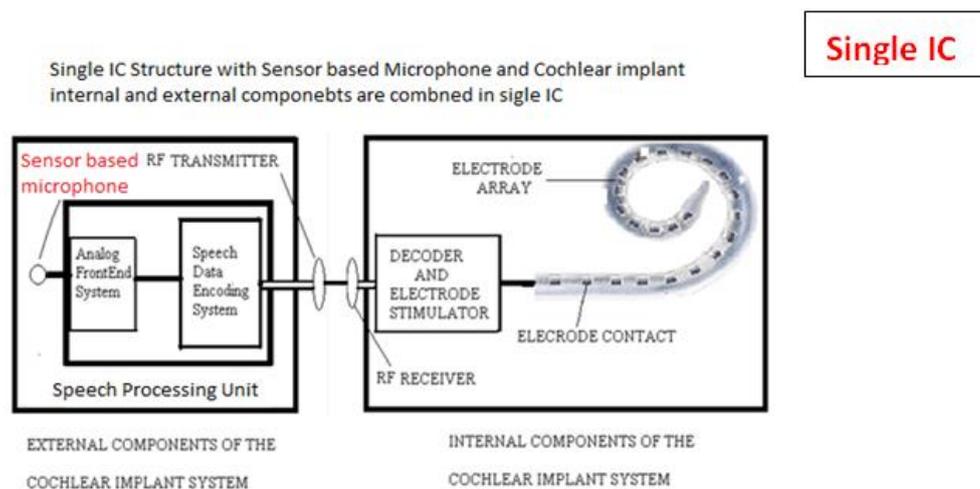


Figure 5 Simplified block diagram which shows both internal and external CI components are connected in single IC

5.1 Scope of the Innovation

This Technology will investigate a focused initiative on Technology interventions[1][6][7] for the benefit of deaf persons (specifically children's) in the country and across the globe. This Proposal will surely come out with technological solutions and products with a multidisciplinary approach to improve the quality of life of deaf persons (specifically children's) and in making them self-sufficient.

1. Design and Development of Technological solutions and devices required for deaf persons (specifically children's) in different built environments in the urban/peri-urban/rural areas characterized by:

- Cost-effective and affordable assistive devices for improving functionality, cognitive, assisted safety measures, methods for speech and hearing learning for deaf persons (specifically children's).
- Cost-effective Hardware/Software for Cochlear Implants.
- This includes the designs which bring out the products' potential for commercialization.

5.2 Design Considerations for Sensor based Microphone

A sensor-based built-in microphone[8][13] which can detect and sense the various sounds available in nature. The microphone must be specifically designed for the purpose of voice communication, and the

frequency band is optimized for the speech and other all sounds those exists in nature. In this section, we discuss the challenges of capturing and recognizing speech and sounds. We also describe how we tackled these challenges in the design of sensor based microphone. The following are the design requirements sensor based microphone:

1. The microphone should capture a wide array of speech and sounds lying in different Portion of the frequency spectra.
2. The microphone should be robust against any external sound or ambient noise.
3. The microphone should have mechanisms compensating friction noise due to user's body movement.

VI. Conclusion

Designing a circuit that embeds all internal and external components on to single IC is a need of deaf population. This Technology development is to provide technological solutions with multidisciplinary approach to resolve the problems and improve quality of life of the deaf population (specifically deaf children's) with focused initiative on Technology interventions which leads commercial product, also aim in providing individual autonomy and independence to persons with deaf through holistic development by creating enabling environment for their empowerment through application of Technology.

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