A Portable Research Platform for Cochlear Implants

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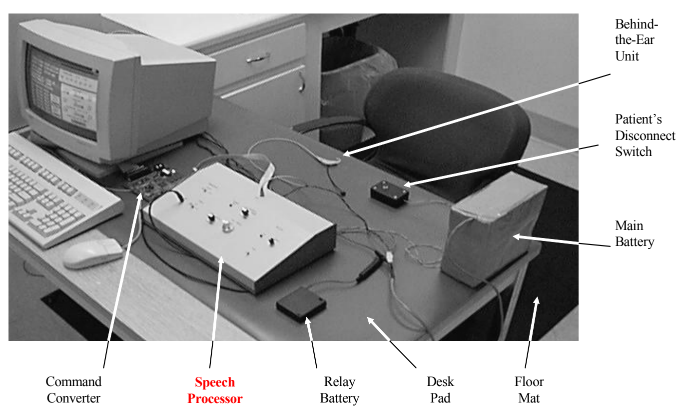
Introduction

- Having access to a flexible research platform is critical for the advancement of cochlear implants or neural interface devices in general.
- Aims of a recent contract from NIDCD/NIH are to develop a research processor that is:
  - **Portable** – to allow for realistic assessment of new algorithms after long-term use
  - **Flexible** – to allow for quick development and evaluation of new research ideas
  - **Easy to use** – accessible to all researchers interested in clinical and animal studies
- To achieve the above aims, we sought for a research platform which requires minimal investment in hardware development.

Research processors: Then …



Existing research processors: Now

Research processor	Advantages	Disadvantages
SPEAR3 (Nucleus) 	• Portable • Allows for real-time processing • Suitable for bilateral experiments	• Not easy to program (requires assembly language programming) • Not flexible in implementing complex algorithms • Does not allow for offline implementation of complex algorithms
CRI (Clarion)	• Allows for real-time processing • Allows for offline implementation of complex algorithms • Can be programmed in C	• Not portable • Not suitable for bilateral studies
RIB (Med-El)	• Allows for offline implementation of complex algorithms • can be programmed in MATLAB	• not portable • not suitable for real-time processing • not suitable for bilateral studies

Existing research processors

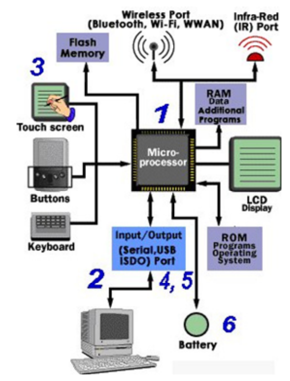
SPEAR3 processor made by Hearworks Pty/CRC for Nucleus users.

Limitations of SPEAR3:
- Lack of programming flexibility
- Lack of wireless connectivity to assistive devices
- Expensive
- "Static" design
  - Not easily adaptable to new and emerging technologies

Rationale for proposed PDA processor

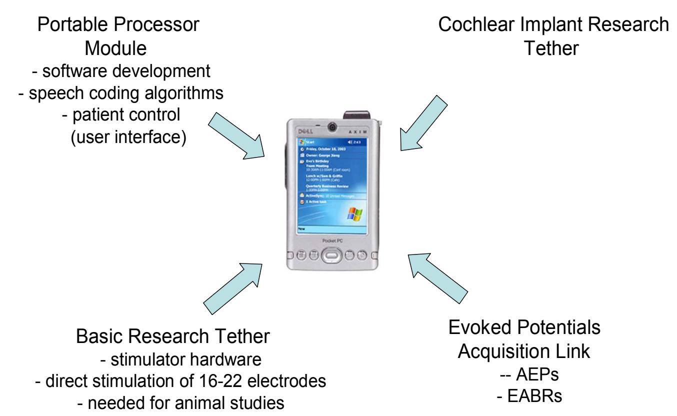
- Programming flexibility
  - C, LabView, assembly language (for optimization)
- Low cost ($300-$600)
- Wireless connectivity
  - Ideal for assistive listening devices
- Integrated cellphones
- Internet access, multimedia players, GPS

PDA hardware capabilities



Capabilities suitable for neural interfaces:
- Input ports (single & multiple channel) suited for multi-channel recordings.
- Output ports suitable for sending data for stimulation
- Wireless connectivity
- Graphical interfaces for patient controls (e.g., via stylus)
- Portability for chronic studies
- Powerful computing capability

Project Overview

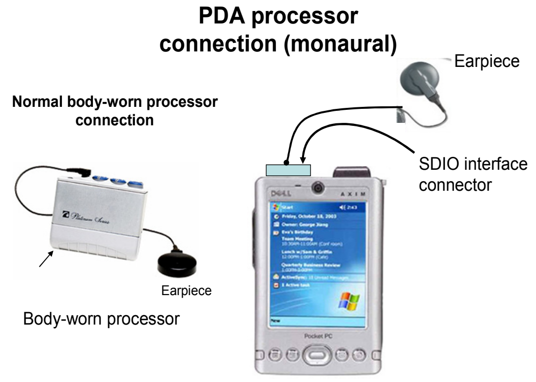


Patient controls and interface

Example user interface designed using LabVIEW

Cochlear Implant Research Interface

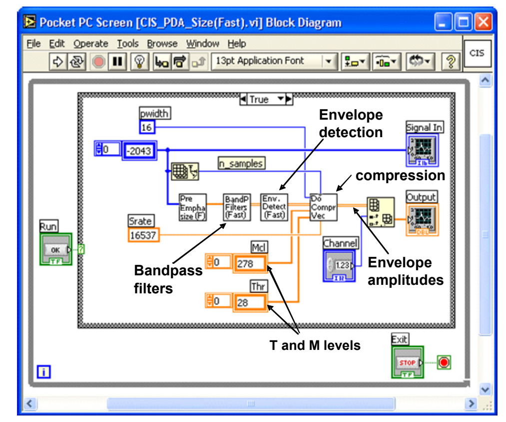
PDA processor connection (monaural)



Software Development

- LabVIEW implementation
  - Block driven approach
  - Ideal for research/educational purposes
- C implementation using Intel's IPP library
  - IPP signal processing library optimized for Intel's PXA270 processor
  - Compact code making it easy to develop novel algorithms for cochlear implants
  - Allows for assembly (ARM) implementation of intensive or repetitive signal processing algorithms

LabVIEW implementation



- Easy and flexible to program (block driven)
- Code easily portable to PDAs running different operating systems
- Easy to develop graphical user interfaces.
- Easy to develop speech coding algorithms
- Interfaces well with hardware

Work done so far

1. Implemented a 16-channel CIS and ACE strategies in real-time on the PDA
   - Used Intel's IPP routines optimized for PXA270
   - Digital signal processing library for CIs (ongoing)
2. Implemented a 16-channel noise vocoder in real-time on the PDA (audio demo)
   - Useful for studies investigating learning effects following changes to processor (e.g., frequency maps)
3. Implemented a 16-channel noise vocoder in real-time on the PC using LabVIEW
4. PDA stimulation of the Freedom implant via Secure Digital IO interface (see demo)

Real-time implementation on PDA using LabVIEW

- 16-channel CIS implementation runs in real-time (46.4 ms frames get processed in about 16 ms on a Windows Mobile 5.0 PDA).
- Developed an interactive, easy-to-use Graphical User Interface (GUI) - can vary various input control parameters such as number of channels, filter type, filter order, frame length and synthesis parameters
- Supports two methods for acoustic simulations:
  – Noise-Band Vocoder Simulation
  – Sinusoidal Simulation

ACE profiling on PDA

Function	Time (uS)/128 sample subframe @ 22.05 kHz)*	Time (ms)/46.4 ms super frame @22.05 kHz with block shift =9
Windowing	6.83	0.78
FFT	9.80	1.12
Squared magnitude	2.36	0.27
Weighted sum of bin powers (wsum)	16.33	1.86
Square root(wsum)	4.15	0.47
Shell sort	5.08	0.58
Loudness Growth Function	2.30	0.26
Apply patient map (MCL, THR)	1.94	0.22
Total	48.78	5.56

*Average over 114 subframes

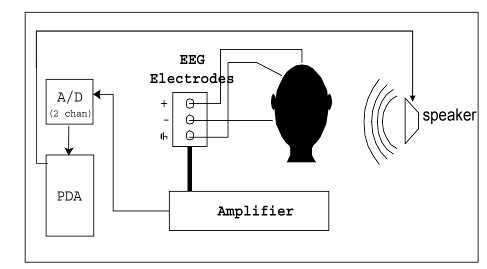
PDA performance for monaural processing = 8.3 times faster than real time

Evoked Potentials

Evoked Potentials Set Up

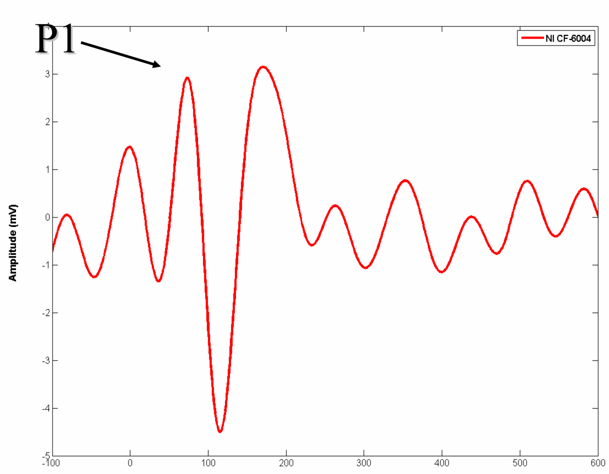
Setup for recording EABRs.
1. headstage or pre-amplifiers,
2. amplifier unit,
3a. trigger pulse connection
3b. recorded data path,
4. presentation of electrical stimulus.

EEG data acquisition on the PDA



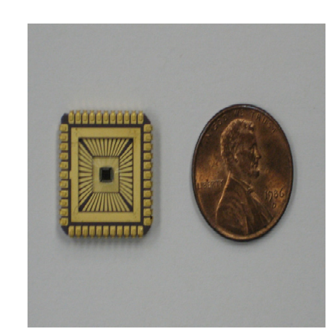
Schematic representation of the EEG/EP acquisition setup. The A/D block contains a Dataq-CF2 data acquisition card which plugs into the compact-flash (type 2) slot of the PDA. Only two of the four analog input lines of the A/D card were utilized for EEG recording.

CAEP recording on PDA

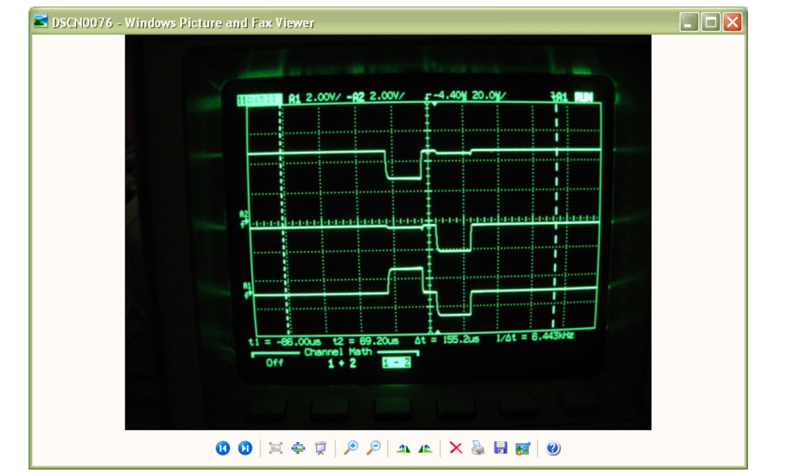


Stimulator

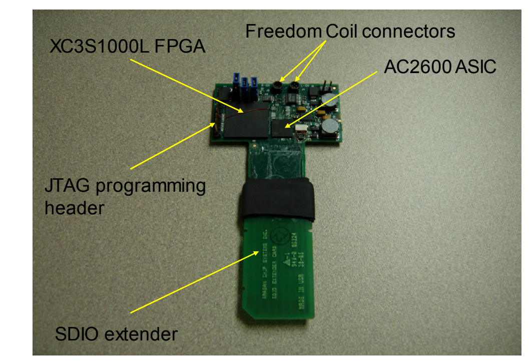
- Fabricated and tested a single-channel stimulator
  – 9-bit resolution
  – Range: 1 μa-1mA
  – Good linearity of output current
  – High output impedance



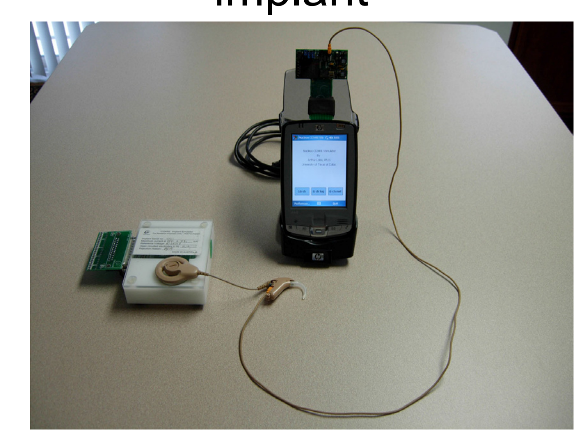
Stimulator output



SDIO card



PDA stimulating Freedom cochlear implant



Dissemination of information & workshops

- Following the processor development (3rd year), we will distribute PDA processors to 5 research Centers
- Will disseminate code and signal processing libraries
- Will organize workshops
  - Provide software training and documentation
  - Provide examples (speech coding algorithms, EP measurements, etc.) – hands-on labs
  - Receive feedback from Centers
  - Identify possible problems, enhancements and improvements to PDA functionality
- Maintain a website posting technical reports, software updates

Summary

- The PDAs can provide for a portable, flexible and easy-to-use research platform for cochlear implant research.
- PDAs have sufficient computing power to implement speech coding algorithms in real-time.
- PDAs can possibly be used in other neural prostheses.
- Other applications will require a different input and a perhaps different output neural interface.
- In retinal implants, for instance, the input will come from a small camera rather than a microphone. Image processing/analysis can be performed in real-time on the PDA.

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