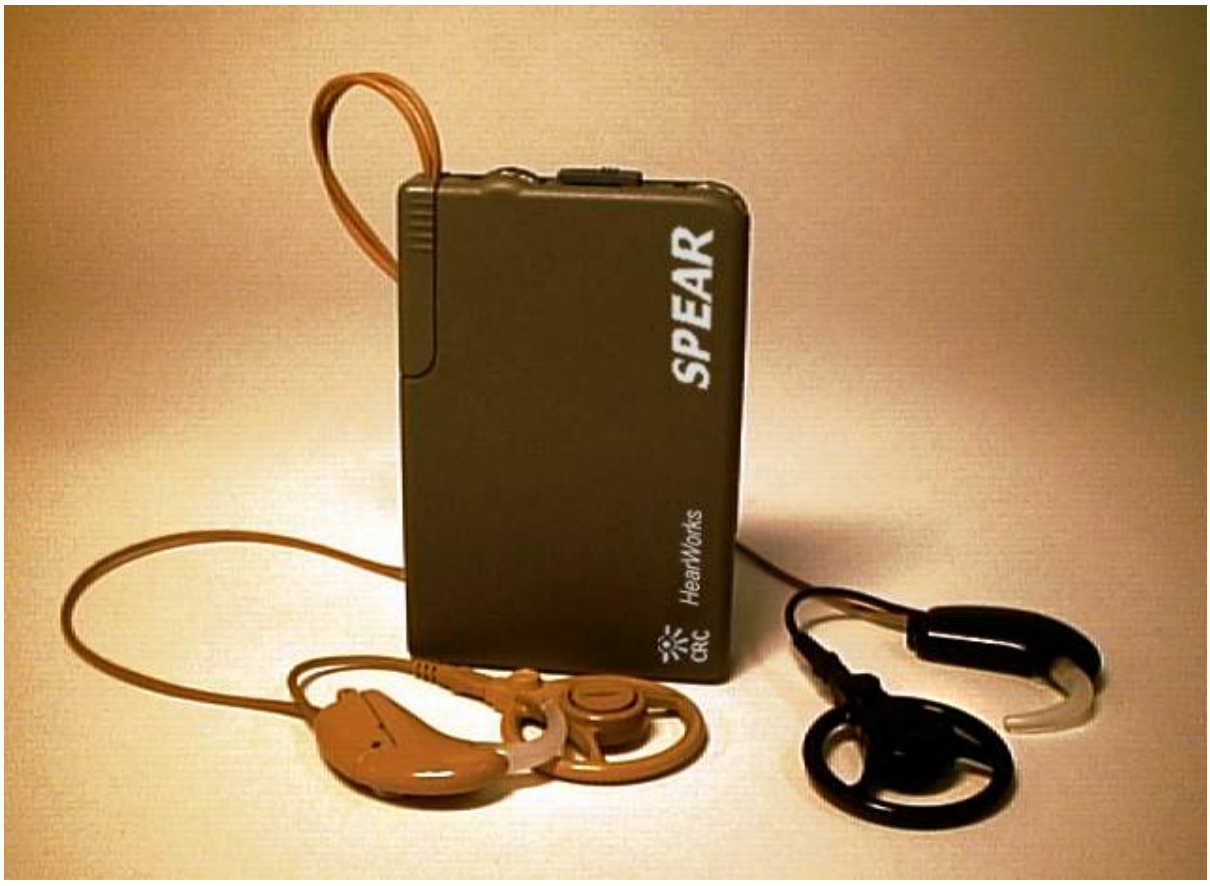
SPEAR3

Product Brief – 16/5/2003

SPEAR3 – 3rd generation "Speech Processor for Electrical and Acoustic Research"



SPEAR3 – 3rd generation "Speech Processor for Electrical and Acoustic Research"

SPEAR3 Processor Description

The SPEAR3 is a speech processor designed primarily for cochlear implant and hearing aid research. With 2 channels of audio I/O and twin implant drivers, the SPEAR3 embodies many of the features required for bilateral implant or hearing aid research in a portable device. Cochlear implants and hearing aids can also be combined to investigate electrical and acoustic stimulus in the same or opposite ears. The processor can be used where multiple microphones are required for directional arrays and noise reduction research.

The SPEAR3 processor has evolved from a long line of portable DSP based speech processors over the past 18 years.

The SPEAR3's key features are:

- Full stereo operation: 2 microphone inputs & 2 acoustic outputs
- Two independent cochlear implant drivers for electrical stimulation
- Drives Cochlear's CI22 and CI24 implants
- Two independent hearing aid drivers for acoustic stimulation
- Easily reconfigured for any combination of microphones, hearing aids, and cochlear implants.
- Powerful 24-bit DSP for high speed and CD quality audio processing
- Small size
- Light weight
- Portable
- Battery driven (AA cell)
- Easy to use

It is envisaged that the SPEAR3 will be used to investigate:

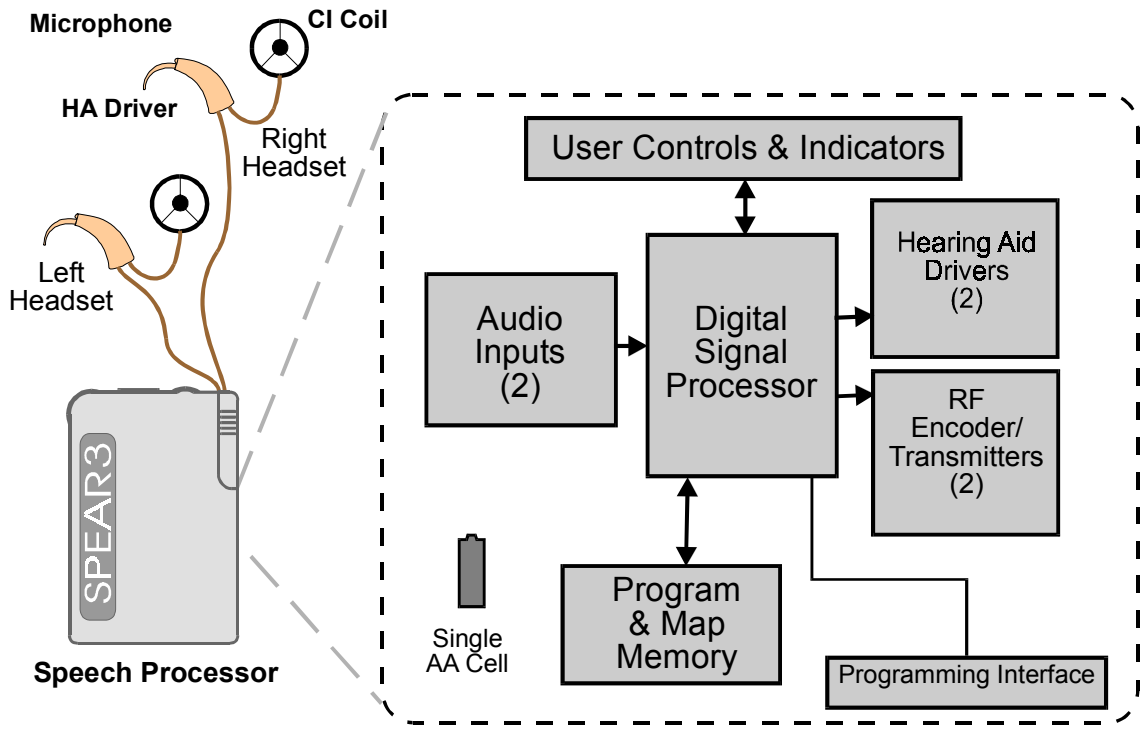
- Advanced speech processing schemes
- Bilateral implant and hearing aid schemes
- Multi-modal (Combionic) stimulus combining cochlear implant stimulation and residual hearing in one or both ears.
- Multiple Microphone applications for noise reduction and improved directionality
- Multi-channel electrical and acoustic psychophysics.

The SPEAR3 has some limitations compared to commercial speech processors:

- Short battery life
- No Implant Telemetry facilities
- Limited availability, service support, and application. (Not intended as a long term replacement of commercial devices)
- SPEAR3 hardware is supplied without warranties (other than statutory warranties). It is designed for use as a speech processing research tool and is not suitable for use as a therapeutic device for sale or issue to patients.

Functional Description

The speech processor consists of a number of main sections as shown in the diagram below. Each section is described below.



--- SPEAR3 functional diagram ---

Audio Section

The SPEAR3 accepts low-level audio from two headset microphones. Alternatively an external mono microphone can be plugged into a standard 3.5mm socket. This socket will also accept stereo signals of up to 1Vpk (line level).

The audio input signal is amplified by an adjustable gain preamplifier. The gain is controlled digitally by the DSP. The preamplifier and input circuits also contain filters to remove out of band audio and radio interference. Additional audio pre-emphasis can be performed by the DSP. The DSP receives a status signal from the external socket indicating the presence of external microphones requiring special pre-emphasis characteristics.

A stereo CODEC converts the audio input to linear 16-bit words for processing by the DSP. The CODEC uses 16-bit Sigma-Delta conversion after performing anti-alias filtering. Data from the DSP can be converted by the CODEC back to an analog audio signal and amplified by a power amplifier capable of driving two low impedance hearing aid drivers. It may also drive stereo headphones to aid software debugging. The power amplifier also filters quantisation noise and distortion from the CODEC signals.

DSP Section

The Motorola DSP56309 24-bit digital signal processor is at the core of the speech processor. It performs all signal processing tasks, such as filtering, spectral analysis and coding functions. The DSP also performs house keeping functions such as monitoring front panel controls, measuring battery states, and communicating with a host PC during configuration.

A Flash RAM provides non-volatile storage for program storage and data such as patient maps. This device can also be used for storing user settings when the processor is turned off.

A serial data link is used to program the speech processor from a PC and perform limited diagnostic tasks. The SPEAR3 Programming System Interface (SPS) connects the SPEAR3 to a standard PC serial port. The SPEAR3's DSP also has a OnCE port that can be connected to a host system for more advanced program development and debugging using standard DSP56300 development tools.

Implant Transmitter & Hearing Aid Driver Section

The SPEAR3 contain two identical but independent transmitter sections that can be used to drive Cochlear's 22 and 24 channel cochlear implant devices. These sections receive stimulus data from the DSP and encode the data into a serial data stream which modulates a radio frequency driver which in turn drives the coil of the implant headset.

The SPEAR3 may be used with a single implant but is also capable of being used by bilaterally implanted users. A combination of 22 and 24 channel implants can be accommodated. Since the transmitter is independent of the Audio Output section, it is also possible to use the SPEAR3 with combinations of implants and hearing aids, in either "combionic" configurations, or residual hearing configurations.

The transmitter section has a degree of "future proofing" in-built because it is implemented with a re-programmable gate array. Encoding schemes for future implants may be possible by simply re-configuring the gate array by software.

Power Supply Section

The SPEAR3 is powered by a single AA cell. A switched mode power supply (SMPS) efficiently converts battery voltages between 0.8 and 3.6 volts to a constant voltage, which is further filtered and regulated to run each of the main sections in the processor. The input voltage range is wide enough to get maximum use from all currently available battery technologies, including Alkaline, NiCd, NiMH, Li-Ion, and single use Lithium cells.

The power supply section also contains a slow speed analogue to digital converter that is capable of monitoring the battery voltage. This can be used to indicate battery state to the user, or to cut-off batteries that may require low voltage discharge protection.

Front Panel Section

The front panel of the SPEAR3 has two controls. The first is a four position switch with the positions normally being: OFF, ON-Normal, ON-Special, ON-Test,. The three "ON" positions may be assigned any task by the software.

The second control is a continuously variable edge-adjusted "dial". An ADC measures the position of this dial, which may be used by the DSP to adjust microphone sensitivity, loudness, stereo balance, or other user adjustments.

Two high efficiency LEDs on the front panel indicate the status of the speech processor. Normally one LED indicates warnings such as low battery voltage. The other may be used to indicate the presence of speech signals, special modes. Both are under software control so that their tasks can be reassigned as required.

Headsets

The standard HS-8 headset microphone and CI24 transmitter coil (manufactured by Cochlear) is suitable for use with the SPEAR3 processor. Processor can be configured to use either a single (unilateral) headset or dual (bilateral) headsets. For bilateral processors, special headset cables are provided (which have a miniature 4-pin connector at the processor end) to connect the headset to the SPEAR3 processor. SPEAR3 processors can be converted from unilateral to bilateral (or vice-versa) by CRC/HearWorks at any time. A special CI22 transmitter coil is also available for driving the Nucleus CI22 receiver/stimulator.

Hearing aid microphones and receivers can be connected to the acoustic inputs and outputs respectively of the SPEAR3 processor via the same connectors used for the Cochlear Implant headsets. The CRC/HearWorks does not provide a specific hearing aid headset for the SPEAR3 system, but can provide assistance in interfacing custom headsets or hearing aids to the SPEAR3 processor.

Physical Construction

The SPEAR3 uses Cochlear's familiar SPECTRA-22 (or MSP) plastic case components. This case is small and light and has ergonomically designed controls and good access to batteries and cable connectors. The smaller SPRINT style HS-8 headset and cables are used for superior performance.

A special adaptor socket replaces the standard Cochlear 3 pin connector. Adaptors are available for either a single headset cable using the large SPRINT 4 pin connector, or an adaptor for dual headsets using two of the miniature 4 pin connectors.

This case however cannot accommodate more than one AA sized battery cell at present. An external battery pack could be used to provide longer running time for extremely intensive speech processing and stimulus schemes.

SPEAR3 Programming System (SPS) Interface

The SPEAR3 Programming System (SPS) Interface is used to connect the SPEAR3 processor to a computer (MS-Windows PC) via its serial communication port. The package includes the SPS Interface box, a DC-power pack, a SPS interface-to-processor programming cable and a SPS-to-PC serial cable. SPEAR3 Windows applications such as Seed-Speak and Woomera use this interface to communicate with the SPEAR3 processor.

SPEAR3 Software Packages

Two software packages will be available under licence for the SPEAR3 processor. The Speech Processing System will be available for researchers who wish to conduct cochlear implant speech perception studies without the need to develop their own speech coding software. Alternatively, Software Development Tools will be available for researchers who wish to develop their own applications.

SPEAR3 Speech Processing System

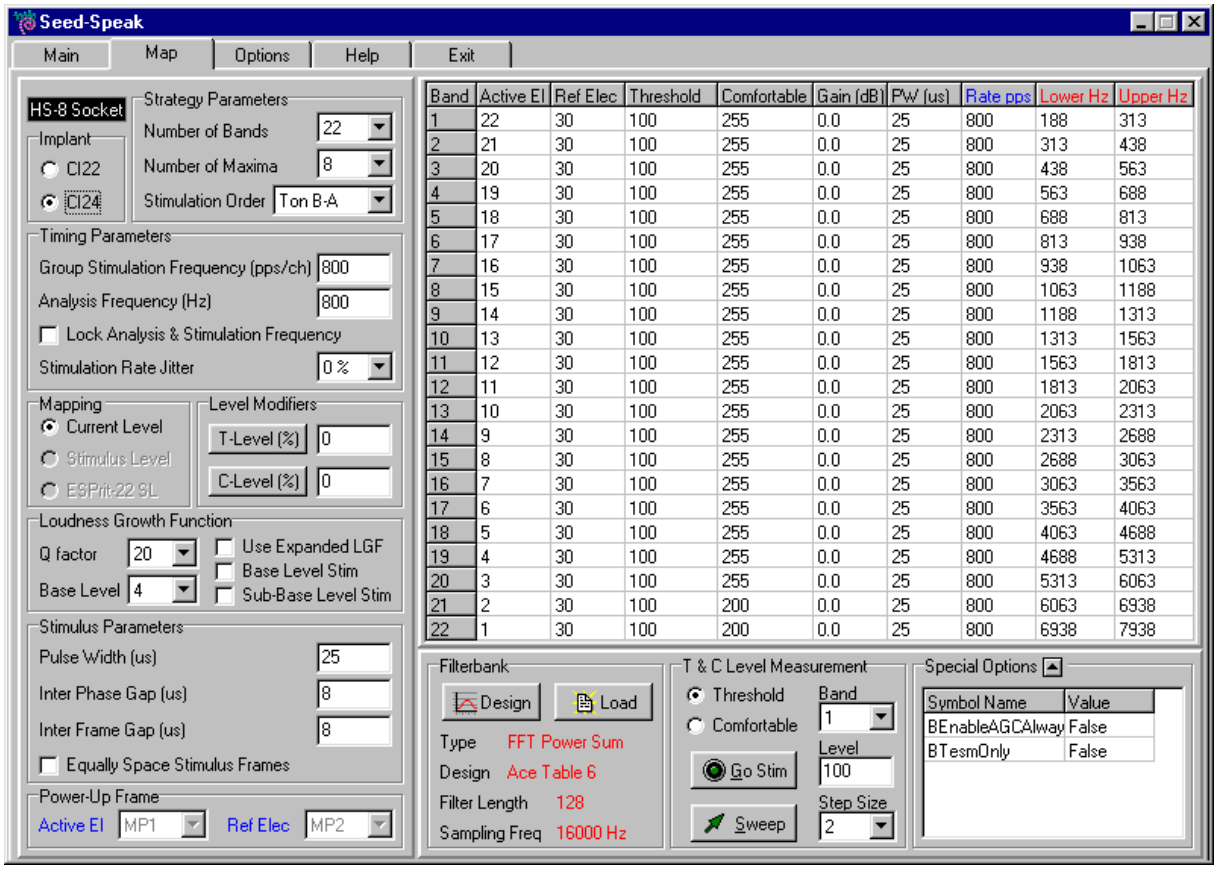
The Speech Processing System provides a means for programming the SPEAR3 processor for speech coding research with cochlear implants. The system comprises two components: (1) CSPEAK (Configurable SPEAK) a core speech coding program for the SPEAR3 processor and (2) Seed-Speak, a GUI application that runs under MS-Windows, which configures/seeds parameters of CSPEAK, and programs the SPEAR3 processor.

The Speech Processing System drives unilateral and bilateral implant configurations and both the Nucleus CI22 (mini) and/or CI24 (micro) implants are supported. Many program and client parameters, such as rate of stimulation, analysis (update) rate, number of bands (channels), number of maxima, loudness growth mapping parameters, and subjective threshold and comfortable stimulation levels can be configured by the system.

CSPEAK, the core speech coding program is a configurable version of the SPEAK strategy that can be configured to emulate the SPEAK, ACE or CIS strategies. New speech coding strategies that are developed for the SPEAR3 processor can be easily interfaced to the Seed-Speak. For instance both the ADRO (Adaptive Dynamic Range Optimisation) and TESM (Transient Emphasis Spectral Maxima) strategies have been implemented as SPEAR3 core programs and their functionality can be accessed via the Seed-Speak interface.

Seed-Speak is used to configure parameters of the core program, such as those described above, as well as to provide a mechanism for maintaining client (patient) maps and to load these maps into the SPEAR3 processor. Seed-Speak can also be used to configure the filter bank used by the core program. The filter bank can be matched to that used by the ACE or SPEAK (SPrint) speech coding strategies or designed to some other specification. In addition, Seed-Speak provides some psychophysics functions for measurement of subjective threshold and comfortable loudness levels, sweeping of electrodes, tasks for estimation and ranking of loudness or electrode-pitch, and a task for loudness balancing electrodes.

SPEAR3



--- Seed-Speak Client Map Settings window ---

Software Development Tools

For researchers who want to develop their own applications (speech processing or psychophysics), software development tools will be available under licence. For these researchers, no collaborative agreements are required apart from the terms stipulated in the SPEAR3 licence agreement.

The software development tools include: (1) Woomera/ShaLo, a monitor/loader program used to communicate, program and control the SPEAR3 processor via a PC; (2) SPEAR3 Development Library, a library of DSP563xx source code which enables programmers to configure and access peripherals in the SPEAR3 processor; (3) SPS Interface DLL, a MS-Windows DLL (Dynamic Link Library) for the SPS interface that allows developers to write Windows applications that communicate with the SPEAR3 processor via the SPS interface. SPEAR3 hardware and programming documentation is also provided.

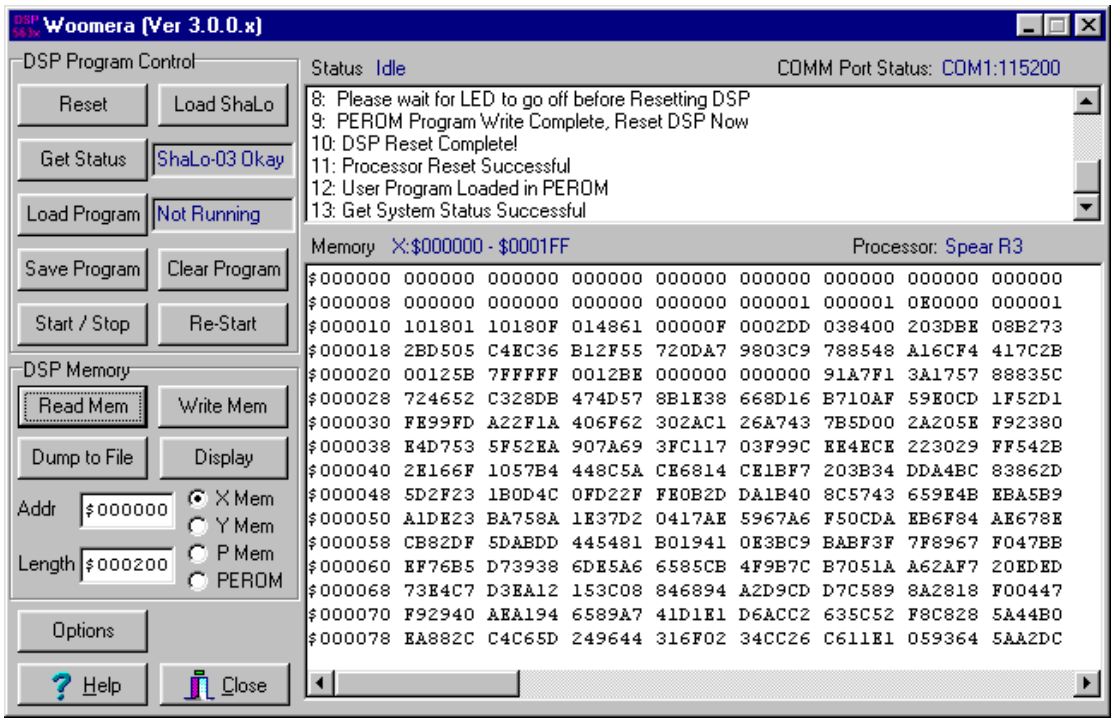
Woomera/ShaLo - Monitor/Loader program

Woomera is a MS-Windows GUI program used to communicate with the SPEAR3 processor via a PC (*Note, the SPS serial interface is used to connect the processor to a PC's serial communication port).* Woomera, together with ShaLo (which is a resident monitor program in the SPEAR3 processor), provide a mechanism for down-loading programs to the processor; saving programs in the processors non-volatile Flash RAM; controlling program execution and examining and modifying memory contents.

SPEAR3 Development Library

The SPEAR3 Development Library contains source code (Motorola DSP563xx assembly language)which enables programmers to configure and access all peripherals in the SPEAR3 processor. Routines are provided for initialising and accessing the CODEC (ADC and DAC), adjusting the audio input gain, configuring and

programming the encoders (CI22 or CI24), and accessing the front panel controls (i.e., the LEDs, rotary knob, 4 position switch and external microphone jack input). The Motorola DSP563xx assembler tools are also provided as well as some Motorola DSP563xx application source code. Documentation for SPEAR3 hardware, the SPS interface box, and programming of the SPEAR3 processor will also be provided under licence. This will include data sheets for the components used in the SPEAR3 processor (e.g. DSP563xx, CODEC, Digital POT, etc) and Motorola DSP563xx application notes.



--- Woomera Monitor/Loader program ---

SPS DLL for Development of SPEAR3 MS-Windows Applications

The SPS DLL is a MS-Windows (flat C) DLL (Dynamic-Link Library) which enables programmers to develop Windows applications that can communicate and control the SPEAR3 processor via the SPS interface. DLL functions are provided for assigning and configuring a Windows Serial Communication Port (Comm Port) to the SPS interface and for communicating with the SPEAR3 processor via its monitor/loader program (ShaLo). Specific functions are provided for: resetting the SPEAR processor; installing the monitor/loader program known as ShaLo in the SPEAR processor; sending messages to ShaLo; testing the connection and getting the status of the SPEAR/ShaLo; reading and writing to/from the SPEAR processor memory; downloading application programs (in the form of Motorola DSP56K lod files) to the SPEAR processor; starting and stopping execution of application programs; storing specified memory areas and/or DSP application programs in the non-volatile flash memory; and clearing the flash memory.

History

Digital Signal Processing was first used in the department of Otolaryngology at The University of Melbourne more than 20 years ago. Early systems were minicomputer bound until the advent of early DSP chips. In the 1980's these chips provided more signal processing capabilities, but still required hefty power supplies and remained in the laboratory. Late in the 1980's the Motorola 24-bit DSP's appeared with respectable specifications for portable devices. This processor evolved into the Portable Digital Speech Processor (PDSP) and was used for many years of successful research on such developments as the SMSP scheme – later commercialised by Cochlear as the SPEAK scheme in the SPECTRA-22. During the late 1990's Motorola expanded their DSP range with more capable DSP chips that ran more efficiently at low battery voltages. These chips were used by researchers at the Bionic Ear Institute for hearing aid research in the MIPSY and SHARP speech processors. The SHARP was modified to drive a single implant and became the SPEAR (and later the SPEAR2). The SPEAR3 followed with the addition of dual channel audio inputs and outputs, as well as two implant drivers.

Specifications

Materials:
Polycarbonate case. Internal Polyimide and Epoxy-Glass printed circuit boards with electronic components. Lead-Tin solder.

Dimensions:
94mm x 62mm x 19mm maximum (without pocket clip).

Weight:
100 grams (including Alkaline battery)

Circuitry:
Analog and digital CMOS intergrated circuits for signal processing.

Battery:
1 x AA-sized disposable Alkaline or Lithium cell, or
1 x AA sized rechargable nickle cadmium, or nickle hydride cell.

Operating Characteristics:

Power consumption: 150 mW to 750 mW depending on application

Allowable battery DC voltage: 0.8 V to 3.6 V.

Audio Inputs: 59 mV_{PP} (@ max Gain = 30dB) to 935 mV_{PP} (@ min Gain = 6dB)

External Audio Outputs: Max 2.8 V_{PP} (990 mV_{RMS}) into 8 Ω load (120 mW_{RMS})

Controls:
4-position function switch. (Off, Normal, Test, Special)
Continuously variable edge-type control knob, numbered 1 to 8, sets microphone sensitivity and other uses adjustments. A Hinged cover conceals all connectors.

Audio Input Response:
Gain range: 6 dB to 30 dB adjustable via front panel sensitivity knob
External Audio Input -
- Input Range: Typically 3.5 uV_{RMS} to 21 mV_{RMS} @ 1 kHz $^1/_3$ octave band
- Dynamic Range: Typically 80 dB (100Hz to 10kHz) or ≥ 90 dB in any $^1/_3$ octave band
- Frequency Response: Flat from 30Hz to 20kHz (-3dB at 15 Hz & 50 kHz)

Acoustic Input (via HS-8 microphone) -
- Input Range: Max 90 dB_{SPL} @ 1 kHz for max Gain (or 114 dB_{SPL} @ 1 kHz for min Gain)
- Dynamic Range: Typically 70 dB (100Hz to 10kHz) or ≥ 80 dB in any $^1/_3$ octave band
- Frequency Response: 80Hz - 8kHz, +6dB/Octave up to 4.5 kHz, -18dB/Octave after 4.5 kHz

Audio Output Response:
Output Level: Max 990 mV_{RMS}
Frequency Response: ~30Hz to 20kHz into 330 Ω load
~50Hz to 20kHz into 32 Ω load
~150Hz to 20kHz into 8 Ω load
Noise Level: < -100dBV_{RMS} in any $^1/_3$ octave band

Microphone Headset:

Transmitting coil Frequencies:
5.0 MHz for CI-24M coil; 2.5 MHz for CI-22M coil

Microphone:
HS-8 Knowles EL7189 Directional Element
Directional response: Cardioid
Frequency response 80Hz - 8kHz , +6dB/Octave up to 4.5 kHz, -18dB/Octave after 4.5 kHz
Power: Typically 180uW

Firmware:

Resident monitor/loader program (ShaLo) for initialisation of processor and communication via the PC serial port.

Signal Processing:

DSP:
Motorola DSP56309 24-bit low voltage digital signal processor capable of 80 MIPS.
34 K Words of RAM
1 MB non-volatile RAM
Clock speed: 7.4 MHz to 80 MHz

Strategies:
SMSP, SPEAK, ACE, CIS, etc can be implemented in software.

Programming:
From a PC serial port via the SPS interface box.
Window GUI Seed-Speak programming system allows the processor to implement several standard implant strategies such as SPEAK, ACE and CIS-like schemes.

Diagnostics and program development:
Via the PC serial port using the Window GUI monitor/loader program Woomera.
Via the DSP's OnCE port (high speed serial port) using various 3rd party host computer interfaces (Serial, Parallel, PCI card, Ethernet)

Patents and trade marks:

The Nucleus Cochlear Implant System is covered by one or more patents registered to Cochlear Limited (Australia), Cochlear Corporation (USA), Nihon Cochlear Co Limited (Japan), Cochlear AG (Switzerland), Cochlear (UK) Ltd, Cochlear GmbH (Germany).

CI22, CI22M, CI24M, SPECTRA, SPRINT, SPEAK and ACE are trademarks of Cochlear Limited.

CIS is a speech processing scheme developed by Research Triangle Institute of the USA.

DSP56309 is a component manufactured by Motorola, Inc.
Motorola and OnCE are trademarks of Motorola, Inc.

CRC is the Cooperative Research Centre for Cochlear Implant and Hearing Aid Innovation, Australia.

HearWorks is the company name of HearWorks Pty Ltd, 384-388 Albert Street East Melbourne, Victoria, 3002, Australia. (ACN 089 900 676).