NEWBORN HEARING SCREENER BASED ON AUTOMATIC AUDITORY BRAINSTEM RESPONSE DETECTION

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Abstract: Hearing loss is one of the pathologies with the highest prevalence in newborns. If it is not detected in time, it can affect the nervous system and cause problems in speech, language and cognitive development. The recommended methods for early detection are based on otoacoustic emissions (OAE) and/or auditory brainstem response (ABR). In this work, the design and implementation of an automated system based on ABR to detect hearing loss in newborns is presented. Preliminary evaluation in adults was satisfactory.

1 INTRODUCTION

According to the Health World Organization, 5 per 1,000 neonates are born with significant hearing loss. This pathology has a negative incidence on the nervous system, causing a delay in the development of speech and language, and consequently affecting cognitive and behavioral skills (Priesler, 1999; Jacobson, 1985).

Early detection of hearing impairment is therefore essential, in order to allow a more successful intervention and rehabilitation. Recommended practice begins with universal newborn hearing screening (UNHS) using objective physiological methods, preferably either before being discharged from the hospital or no later than at 2 or 3 months of age (Gracey, 2003).

All over the world, strategies used in UNHS are based on otoacoustic emissions (OAE) and auditory brainstem response (ABR). Particularly, methods based on ABR are well-considered due to their high specificity and sensitivity rates and their high correlation between impairment and alteration in the ABR pattern (American Academy of Pediatric, 1999; European Consensus Statement on Neonatal Hearing Screening, 1998).

However, traditional analysis is complex and time consuming, limiting its use to selective screening of a small percentage of newborns. With the development of Automatic ABR (AABR) analysis, results are obtained faster, facilitating its application on a larger population (Suppiej & Rizzardi, 2007).

In this context, the Facultad de Ingeniería de la Universidad Nacional de Entre Ríos (Argentina), in cooperation with the Hospital Materno Infantil San Roque (HMISR), Paraná, Argentina, and the Centro de Especialidades Médicas Ambulatorias (CEMA), Rosario, Argentina, have begun a technological development project, aiming at designing and building a universal hearing screening system based on AABR. This work presents the design and preliminary results obtained with an implemented prototype, named *AudioScreen*.

2 SYSTEM REQUIREMENTS

A universal hearing screener based on AABR should be able to evoke, record, store and process electroencephalographic (EEG) signals coming out from the brain (McAllister & McCullagh, 2000).
Therefore, suitable hardware and/or software for these purposes must be able to perform the following tasks:

- Stimulate the auditory system according with specific parameters (Mercuri et al., 2006).
- Record the EEG signals from the scalp, synchronizing the acquisition with the stimulation (Acevedo et al., 2006).

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- Perform a digital processing on the EEG signals, in order to detect whether the ABR is present or not (Acevedo et al. 2006).

The system has to be flexible enough to allow a range of stimulation and recording options. Tables 1 and 2 summarize specific requirements for this system.

Table 1: Stimulation parameters.

Parameter	Description
Stimulus type	Condensation click
Stimulus width	100 μs
Stimulus intensity	20 to 70 dB peSPL in 10 dB steps
Stimulation frequency	11 and 31 clicks/s
Audio output	Mono
Masking	None

Table 2: Recording parameters.

Parameter	Description
Gains	500 a 100.000 in 10 steps
Bandwidth	100 Hz – 2500 Hz
Input impedance	$> 10^6\ \Omega$
CMRR	> 80 dB
Isolation	> 3.000 V_{RMS}
Sampling frequency	200 Hz to 20 kHz
Sampling period	Up to 15 ms
Resolution	> 10 bits

3 SYSTEM DESIGN

The design of the hearing screener is based on four modules: auditory stimulation (AS), signal conditioning (SC), signal acquisition and digitalization (SAD) and signal processing and visualization (SPV). Figure 1 shows a block diagram of these modules.

As this is the first research prototype, it is planned to be used both in research and clinical environments. The former requires this system to be flexible at the digital processing stage, in order to allow testing and evaluation of different algorithms for automatic ABR detection. For this reason, the SPV module is implemented in software, and a personal computer is required in order to use the screener. Future versions of *AudioScreen* will implement this module in specific hardware, making the system independent from the computer.

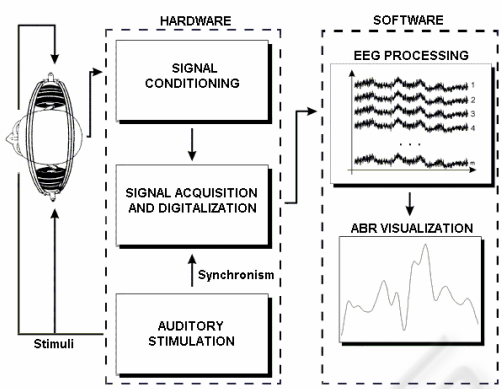

Figure 1: Block diagram of the *AudioScreen* hearing screener modules.

A brief description of the system operation would be as follows: initially, the computer sends a number of configuration parameters for the AS and the SAD modules. When a start signal is received, the stimulator generates acoustic stimuli, which are applied to the patient through headphones. At the same time, a synchronism signal is generated and sent to the SAD module to establish the beginning of the EEG recording which is amplified and filtered in the SC module. Finally, the EEG is digitalized and transmitted to the computer via USB 1.0, where the SPV module stores it for further processing and visualization.

4 SYSTEM IMPLEMENTATION

4.1 Auditory Stimulation Module (AS)

The auditory stimulator produces digital clicks (electrical stimuli) whose amplitude is set by a gain-controlled amplifier (PGA2310 Texas Instruments Inc). Then, the clicks are transduced to auditory stimuli by headphones (Telephonics® TDH39). Two stimulation parameters can be set: intensity, ranging from 20 to 70 dB peSPL in 10 dB steps, and frequency in two possible values, 11 or 33 clicks/s. The selected values are indicated by LEDs on the front panel. In this way, different configurations may be used for auditory stimulation.

The electronic circuit is implemented with an 8-bit RISC microcontroller. The microcontroller configures the gain-controlled amplifier through a serial port interface and it is linked up with the SAD module using two ports: one is used to generate the synchronism signal and the other is used to receive a start signal to begin the stimulation.

4.2 Signal Conditioning Module (SC)

Appropriate integrated circuits (IC) for medical instrumentation are used. This module consists of four parts:

- Instrumentation amplifier: INA128 (Burr-Brown Corp.). This IC has high input impedance (10^{10} Ω) and common-mode rejection (120dB at G ≥ 100), very low offset voltage (50μV) and drift (0.5μV/°C).
- Programmable gain amplifier: OP07 (Analog Devices Inc.). Gain can be set in the range of 500 and 100000 in 10 steps.
- Isolating amplifier: ISO121 (Burr-Brown Corp.). This IC has unitary gain and it is based on a 2 pF differential capacitive barrier, which results in a 3500 V_{RMS} isolation.
- Filter: a band pass filter is implemented using a cascade design of Sallen-Key cells with cutoff frequencies in 2500 Hz for low pass and 100 Hz for high pass. In order to reduce the electromagnetic induction produced by the power line, a Sallen-Key notch filter centered in 50 Hz is implemented. This notch filter can be enabled or disabled using onboard jumpers.

4.3 Signal Acquisition and Digitalization Module (SAD)

This module is based on another 8-bit RISC microcontroller which controls the AD module as well as the communication with the computer. The AD module includes a 12-bits, bipolar input range, analogical to digital converter and a low-noise, temperature-stabilized, precision reference. The sampling frequency can be set to a maximum of 20 kHz and the acquisition window is set to 15 ms.

4.4 Power Supply

The power supply has two stages: one of them is not isolated and the other is isolated according to the IEC 60610 standard. Isolation is achieved using PWR1303A (C&D Technologies Inc.). Table 3 summarizes its specifications.

Table 3: Power supply specifications.

Parameter	Description
Isolated stage	± 5 V, 150 mA, 4 kV DC
Non-isolated stage	± 5 V, ± 12 V, 1 A

Hardware-implemented modules are shown in Figure 2.

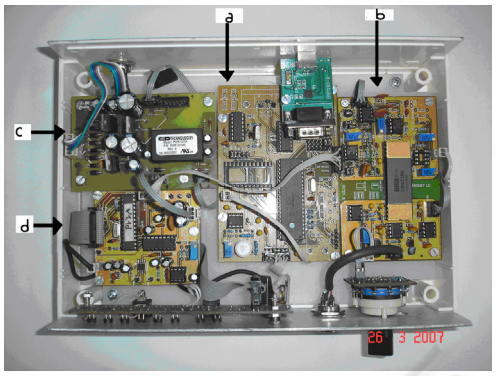

Figure 2: Inside view of the screener; (a) SAD module board, (b) SC module board, (c) power supply board, and (d) AS module board.

4.5 Signal Processing and Visualization Module (SPV)

SPV module block diagram is shown in Figure 3. This module was programmed using Borland® C++ Builder®, and the database was generated with Microsoft® Access® 2003. The user interface was designed taking into account pieces of advice from several professionals of the health centers mentioned above.

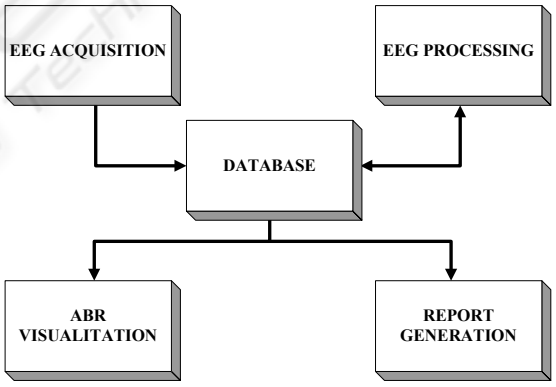

Figure 3: Block diagram of the SPV module.

The database stores all the information about the screening, which basically consists of newborn's and mother's personal information, along with the signals recorded with the EEG acquisition block and the parameters used in the study, e.g. stimulation frequency and intensity.

The EEG processing block performs two main tasks: signal averaging to enhance signal-to-noise ratio, and automatic ABR detection using the FSP algorithm (Gentiletti et al., 2003). The results of the study are visualized in the computer monitor (Figure

4), and can be printed along with a full report of the study.

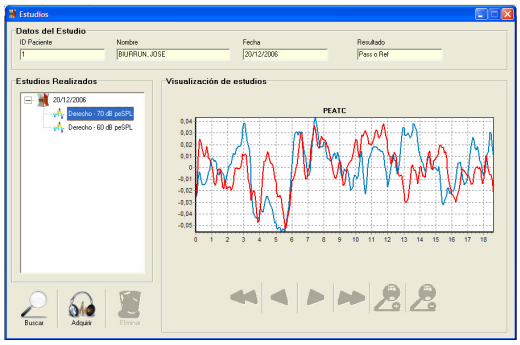

Figure 4: ABR visualization window.

5 EXPERIMENTS AND RESULTS

Figure 5 shows the complete system, which complies with the IEC 60610 standard for medical equipment.

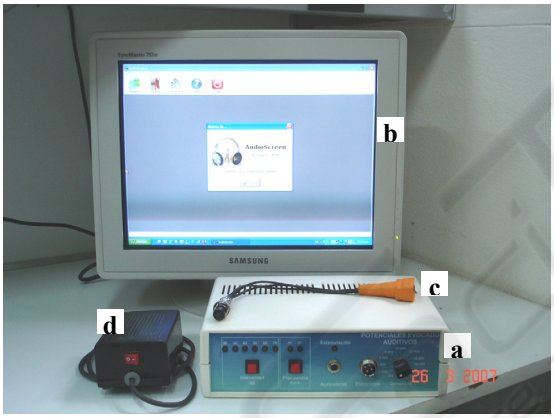

Figure 5: *AudioScreen* system with the software running on the computer; (a) screener; (b) software interface; (c) electrode cable; (d) power supply.

The user interface was assessed by HMISR and CEMA personnel, and the resulting evaluation was satisfactory. Finally, a full set of tests were carried out with healthy patients, which verified the correct performance of the system.

6 CONCLUSIONS

A first prototype of the *AudioScreen* system was designed, built and it's has been tested. It was done using adequate off the shelf electronic components, which met the standard for medical equipment and were fully operational. The following step is to perform system validation at the HMISR as well as the CEMA. In addition, an algorithm of ABR signal detection based on support vector machines is being developed, which will be validated and contrasted against the *Fsp* method.

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REFERENCES

Priesler G., 1999. *The Development of Communication and Language in Deaf and Severely Hard of Hearing Children: Implications For The Future.* Int J Pediatr Otorhinolaryngol; 49(Suppl 1):S39-43.

T. Jacobson. 1985**.** *The Auditory Brainstem Response, Boston, Editorial Collage-Hill Press.*

Gracey K. 2003.*Current Concepts in Universal Newborn Hearing Screening and Early Hearing Detection And Intervention Programs*. Advances in Neonatal Care, Vol. 3, No. 6 (December): pp 308-317

American Academy of Pediatric, 1999. *Newborn and Infant Hearing Loss: Detection and Intervention.* Pediatrics; 103: 527-30.

European Consensus Statement on Neonatal Hearing Screening. Milan. May 1998.

Suppiej A, Rizzardi E, Zanardo V, Franzoi M, Ermani M, Orzan E, 2007**.** *Reliability of Hearing Screening in High-Risk Neonates: Comparative study of automated OEA, and conventional ABR. Clin Neurophysiol. 2007 Apr; 118(4):869-76. Epub Feb 20.*

McAllister H. and McCullagh P, 2000. *Objective methods of hearing assessment.* Computing and Control Enginnerging Journal. April, 53-64

Mercuri C., Escobar S., Cadirola F., Astiasaran P., Gerardo G., Aldonate J., Bonell C., Acevedo R., 2006. *Estimulador auditivo para audiometría tonal y potenciales evocados auditivos*, Revista Argentina de Bioingeniería, vol 12, nro 2, pp. 13-19.

Acevedo R., Bonell C., Gentiletti G., Aldonate J., Mercuri C., Escobar S., Biurrun J., 2006. *Potenciales Evocados Auditivos De Tronco Cerebral: Aspectos tecnológicos del Registro,* Revista Argentina de Bioingeniería, vol. 12 No. 1, pp. 10-17.

Gentiletti G., Yañez O., Cornejo J, 2003. *Evaluation of Automatic Identification Algorithms for Auditory Brainstem Response used in Universal Hearing Loss Screening.* Proceedings of 25 th Annual International Conference of the IEEE EMBS.