High Resolution Auditory Brainstem Response System

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Abstract— **Auditory Brainstem Response (ABR) can be described as the early part of auditory Evoked Potential (EP). EP is an electrical response of the brain which is recorded from the scalp and obtained from acoustical stimuli. ABR signal often difficult to capture since it is small relative to the ambient noise. Electrodes placed on the scalp not only pick up ABR potential, but also any other physiological potential from multiple sources such as Electrooculogram (EOG), Electrocardiogram (ECG) and Electromyogram (EMG). The noise can be reduced by implementing high-resolution analogue to digital converter (ADC) into signal acquisition circuit. In this project, a high resolution ABR measurement circuit has been developed and evaluated with ABR signals. The signal acquisition circuit consists of AT91SAM3X8E in Arduino Due as microcontroller and ADS1299 as integrated amplifier and also ADC. The microcontroller is programmed to control the serial peripheral interface (SPI) connections and send the signal to computer through USB connection. The signal is displayed, processed and saved in MATLAB environment. With the used of high-resolution ADC, it gives advantage to higher signal to noise ratio of the prototype. Furthermore, the system has low input-referred noise which means it possess only small deviation from ideal ADC. The system is able to show the ABR signals with low number of trials which is less than 300. Thus, the prototype has high potential for further development to become a reliable device.**

Keywords— **ABR, High-resolution ADC, DAQ, EEG.**

I. INTRODUCTION

ABR can be described as the early portion (0-12ms) of auditory Evoked Potential (EP). EP is scalp-recorded electrical response of the brain obtained from acoustical stimuli. The ABR waveform consists of five to seven major peaks, label system using roman numerals, usually 1ms apart and have amplitudes of about 100-500 nanovolts. Each peak is considered to reflect a different portion of the auditory pathway [1]. The characteristics of measured signals (peaks V) which include the waveform morphology, major peak latency, inter-peak latency and amplitude are compared to the established normal values to identify hearing threshold, hearing loss, and damage to the auditory system [2].

Usually three electrodes are used to obtain ABR signal. ABR is recorded by measuring the difference in electrical activity with two electrodes. One of the electrodes (positive) is placed on vertex. Another electrode (negative) is placed on ipsilateral mastoid process of ear. The third electrode (ground) placed on contralateral mastoid process of ear [3].

Click stimulus is an ideal stimulus for ABR and has been employed traditionally in attempt to obtain ABR signal. It consists of short-term rectangular pulses ranging between 50-200μs with fast rise time. The advantage of click stimulus is that it provides good synchrony resulting clearly defined ABR [4][5].

In a previous study done by Kochanek, Sliwa, Zajac and Skarzynski, a portable device applicable for hearing screening known as Kuba Mikro As was developed. The audiometer system contains of probe control with amplifier, data processing module, pocket PC and printer. Kuba Mikro As is the first known device that provides 3 fundamental hearing testing methods which are Transient-Evoked Otoacoustic Emission (TEOAE), ABR measurement and hearing screening [6].

EEG-ITM03 EEG Data Acquisition which can be used to asses hearing capabilities under non-controlled condition (noise proof facilities) was developed by Gnecchi, Soriano and Garcia. The system used MSP430F149 as microcontroller and RS232 as interface port. The limitation of this equipment is that it cannot be used as hearing screening tool for newborns [7].

In different study, Beltran and Cornejo have introduced a technique and an instrumentation set up for a simultaneous TEOE and ABR test. They used ILO-96 test probe as acoustical stimuli, two channels of the Neuroscan's SynAmps as signal acquisition, Interacoustic AC-40 audiometer as stimuli amplifier delivered through TDH-39 earphone and Neuroscan's Scan to obtain ABR. By coupling these two test, cochlear microphonic information and ABR time synchrony can be obtained although it increases testing time and complexity of the instruments [8].

In another research, portable automated ABR screener was developed. The automated system consists of an amplifier, MSP430FG4619 microprocessor and Micro Control Pia LCD. The amplifier used is made up of differential

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amplifier, gain stage, 3kHz low pass filter and 100Hz high pass filter in cascaded form. This device works along EAR-3A earphones that act as channel to deliver acoustic stimuli. The system developed is simple to operate and has the ability in reducing time to implement the test. It also has the ability to review and edit screening results [9].

ABR signal is often difficult to capture since it is small relative to the ambient noise. Electrodes placed on the scalp not only pick up ABR potential, but also any other physiological potential from multiple sources such as Electrooculogram (EOG), Electrocardiogram (ECG) and Electromyogram (EMG). The noise can be reduced by implementing high-resolution analogue to digital converter (ADC) into signal acquisition circuit. The objective of this project is to develop high resolution ABR measurement circuit and to evaluate the circuit with ABR signal.

II. METHODOLOGY

Ten (10) normal subjects (average age of 21) were participated in the experiment. Each subject was given an auditory stimulation (click sound with 1kHz sine wave 60dB) to the right ear. Three EEG electrodes were placed on Mastoid and Frontal lobe (Reference and Ground). The signal was firstly captured by the prototype and followed by g.Tec EEG Data Acquisition System (DAQ) for comparison.

The main idea of this project can be illustrated as in Fig. 1 below:

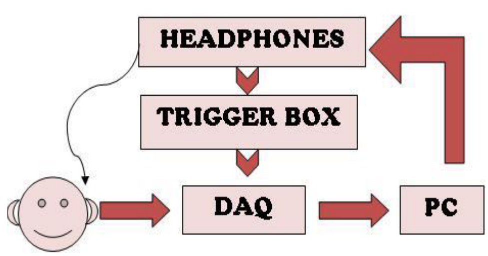


Fig. 1: Block diagram illustrates full system

The prototype DAQ system consists of AT91SAM3X8E in Arduino Due as microcontroller and ADS1299 as integrated amplifier and also ADC. The Due board which operates at 3.3V, supports SPI communication and board based on a 32-bit ARM core microcontroller. ADS1299 is an analogue front-end with 24-bit resolution. It is a low input-referred noise (1μ V_{pp}) and low power (5mW/channel) with an integrated gain amplifier (PGA).

The stimulus from Personal Computer (PC) is delivered to subject through a headphone. The headphone is connected to trigger box and the trigger box is connected to the DAQ. The signal from subject is then acquired by DAQ and sent to PC via USB.

Fig. 2 shows the block diagram of DAQ system for the prototype. Power supply in digital analog form is fed to the ADS1299 that featured with PGA, ADC and multiplexer. SPI communication connects ADS1299 and microcontroller. The functional block diagram of ADS1299 is shown in Fig. 3.

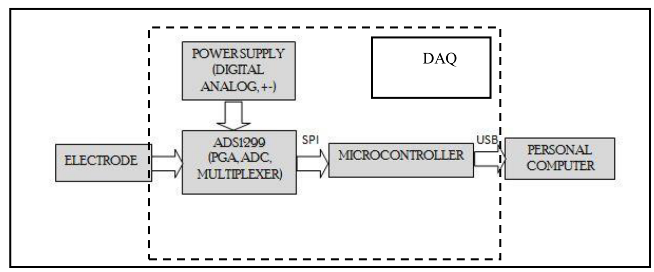


Fig. 2: Block diagram of DAQ

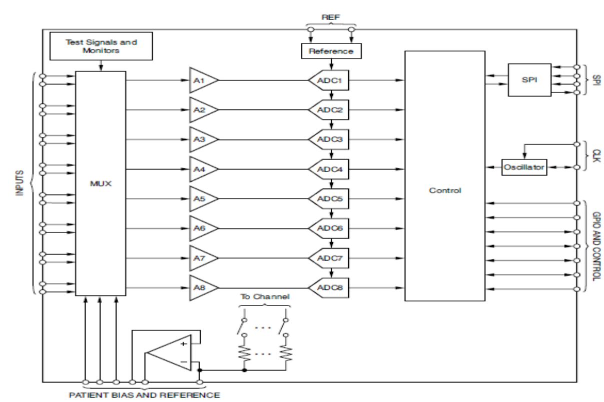


Fig. 3: Functional block diagram of ADS1299

Data is displayed and saved on computer through the serial interface that is designed using Simulink. Then, the data acquired is processed by a program developed using MATLAB. Processes which are contained in the program are DC component removal, trigger signal normalization, time frame setting for 20ms, signal filtering using band pass (100-2000Hz) and averaging.

In summary, the whole study contains six stages. The first stage is circuit design which is followed by hardware development. The third stage is hardware programming which is the process to set up the SPI communication between ADS1299 and Arduino Due. The next stage is interfacing the hardware with MATLAB. The fifth and the last stage include collecting and analysis data.

III. RESULTS AND DISCUSSION

The signal obtained from developed circuit shown in Fig. 4 is compared with a commercialize Electroencephalogram (EEG) DAQ system, g.Tec. Wave V detection was done based on wave physical appearance without involvement of professional audiologist.

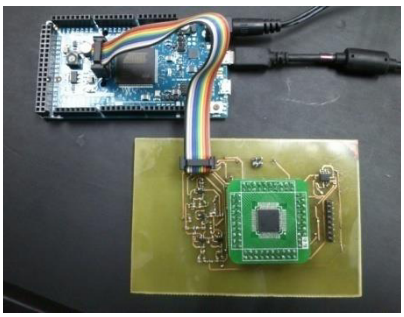


Fig. 4: Prototype of ABR measurement circuit

An ideal ABR signal as illustrated in Fig. 5 is used as reference in wave V detection for signal obtained from the prototype and g.Tec.

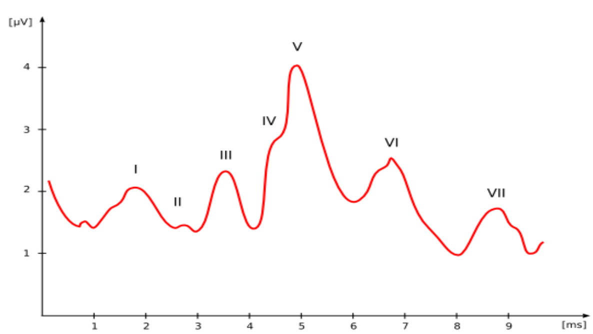
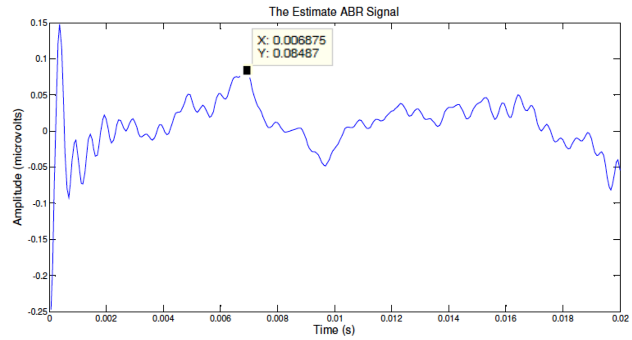
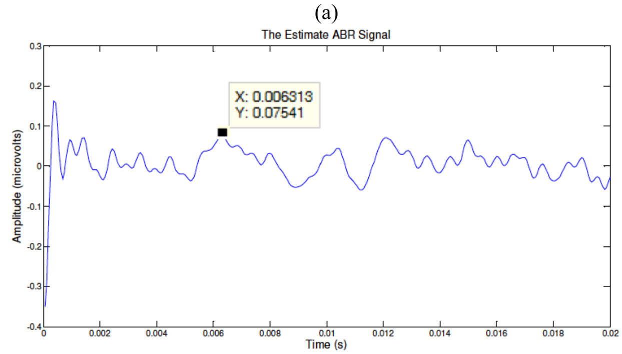


Fig. 5: An ideal ABR signal [8].

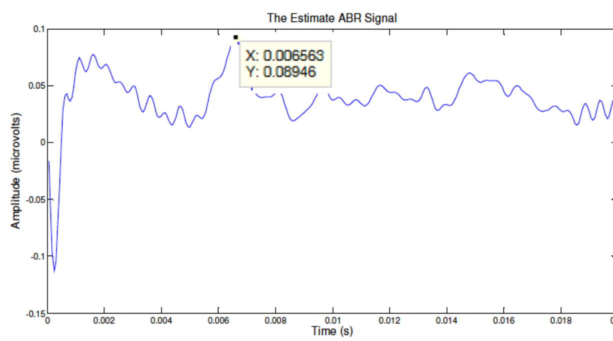
Fig. 6 shows the samples of ABR signals obtained from three subjects using the prototype at 1200 sweeps. The wave V of ABR can be clearly estimated it happens around 6ms after the auditory stimulus. The sample of ABR signal obtained from g.Tec DAQ system is shown in Fig. 7.



(a)



(b)



(c)

Fig. 6: (a), (b) and (c) The ABR signals from three subjects using the prototype.

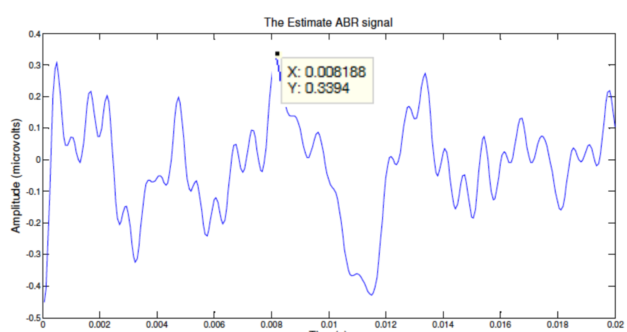


Fig. 7: The ABR signal from g.Tec.

For further analysis, time at which wave V is identified is recorded for 10 adult subjects. Data is recoded at 300, 700 and 1200 sweeps.

Table 1: Wave V detection using prototype

Subject	Time (ms)		
	300 sweeps	700 sweeps	1200 sweeps
01	-	6.625	6.875
02	-	-	6.313
03	-	6.563	6.563
04	-	-	6.875
05	-	-	-
06	6.813	-	-
07	-	-	4.938
08	-	-	-
09	6.875	6.25	6.25
10	5.938	6.063	6.063

Table 2: Wave V detection using g.Tec

Subject	Time (ms)		
	300 sweeps	700 sweeps	1200 sweeps
01	-	8.5	8.5
02	8.125	8.125	8.188
03	-	7.625	7.687
04	-	7.125	-
05	-	-	8.5
06	-	7.938	7.813
07	-	7.938	7.938
08	-	-	-
09	7.625	7.625	7.875
10	-	-	7.188

Based on the results obtained, both prototype and g.Tec are able to identify the wave V and have high consistency at which the wave V is determined. Although in overall the performance of g.Tec is better than the developed circuit, the results obtained show that the developed circuit has a higher detection of the wave V at 300 sweeps than the g.Tec. This proves that the prototype has higher signal-to-noise ratio. However, the performance of the prototype can be improved by providing proper shielding to the device.

IV. CONCLUSION

In conclusion, the low noise ABR measurement circuit was developed using 24-bit analogue front-end (ADS1299) and Arduino Due microcontroller board based on the Atmel SAM3X8EARM Cortex-M3 CPU. The developed circuit is capable in measuring the ABR signal with high resolution and low noise interference.

As for recommendation, the overall system can be improved by providing proper shielding to the developed circuit. In addition, the used of active electrode is highly recommend to enhance the signal obtained and wireless approach also can be used to eliminate power line noise.

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