An EEG Front-End System Using ADS1299

Thanh Chau Nguyen, Tri-Quang Huynh, Tri-Thong Vo, Phuong Nam Nguyen, and Toi Vo Van

Abstract

The electrical nature of the human nervous system has been recognized for more than a century, up to now, the recording of different voltages in their distribution that is Electroencephalography (EEG) has well developed for diagnostic application in clinical and research serves many aspects in pathology, health care and entertainment. Meanwhile, most of the current EEG acquisition systems which are commercially available today are fastened to bulky signal processing machines, and subject with limit movement. The objective of this research are investigating, applying and integrating the ADS1299 EEG-FE for accomplishing a portable EEG system serving specific matter of EEG or BCI in the future. The fact that this work now successfully achieves a completed EEG front-end system with ADS1299_EEG sensor controlled by STM32F4 and an integrated real time interface, which is validated as well adapted for human mental activities, promises further development in the field.

Keywords

EEG • ADS1299 • Wearable system • STM32

1 Introduction

The electrical nature of the human nervous system has been recognized for more than a century since 1924 by German Hans Berger whereas its signal of animals is achieved in nearly fifty years sooner [1–3]. Up to now, the recording of different voltages in their distribution that is Electroencephalography (EEG) has well developed for diagnostic application in clinical and research use such as coma, encephalopathy and brain death, specially, epilepsy [4, 5]. In comparison with other method that study brain function such as Functional magnetic resonance (fMRI), Positron emission tomography (PET), Magneto encephalography (MEG), Near-infrared spectroscopy (NIRS), EEG possesses various advantages over. EEG hardware cost is remarkably lower and its requirement for installing is significantly easier [6, 7]. It is noninvasive cognition of neuroscience, possesses very high temporal resolution as milliseconds with sampling rates available from 250 to 20,000 Hz [8] and much more flexible as it allow subject movement, light and mobile equipment, friendly environment, un-invasive etc. Therefore, day by day, EEG method is more essential and needed to be advanced for better health application. Up to know, the trend of shifting from conventional system as gold reference device as Neuro Scan, BioSemi to ambulatory system for example Cadwell, and finally, wearable device in EEG implementation are clearly remarkable [8–10]. Besides, important marks of implementing wearable EEG system in research work can be used as comparison and resource for better approach as Chi et al. performed wireless non-contact cardiac and neuro monitoring served physiological monitoring; Kim et al. described a helmet EEG system serves application in cognitive states and military applications in 2009; in the same year, Tsai et al. reported great work of a

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portable device for real time drowsiness detection with embed cap; and, finally, in 2011, Wang et al. presented the development of a cell-phone based BCI as a headband daily life communication promotes a significant contribution in BCI application [11–14].

In July of 2012, Texas Instruments (TI) released an analog front end (AFE) ultra-low power integrated chips (ICs) thanks to the improvement in incorporates low power technology and component IC (instrumentation amplifiers, operational amplifiers, analog to digital convertors, …) that are ADS1299. Patrick J. Davies and his group published a successful portable wireless EEG system using ADS1299 with Arduino Pro Mini and Zigbee Radio, XBee series 2 in 2013 [15]. Especially, the Open BCI group is performing wearable EEG device with strong algorithms for translation from raw EEG signal to meaningful data, now serves their two ADS1299 EEG system hardware versions with Arduino UNO and DUE microcontroller. Their platform now is developed with fully available and accessible source to support and motivate a firm technical community in this field [16].

The objective of this research are approaching ADS1299 EEG-FE in a different, and more effectively and powerful way to accomplish an EEG front-end system whose quality is permissible for high frequency data collection, but wearable, compactible, wireless, cheap price and available for real time collection.

2 Methodology

2.1 Hardware System

2.1.1 Materials

The main EEG sensor is ADS1299 EEG-FE of TI, which is a specific product designed for EEG application with an eight-channel, low noise 24-bit data of channel, simultaneously sampling, low-power; integrated analog front-end (AFE), high frequency data collection (250–1k6 Hz).

The ADS1229 is controlled by ATM32 microcontroller through USART module FT232 wire or FT232RL Bluetooth module.

The Electrode Adapter is implemented with Standard (0.060) 1.5 mm DIN safety plug and Standard Gold Cup (0.060) or 1.5 mm DIN EEG Electrodes connector with a 48″ leads and gold cup. In addition, the adapter is implemented with 8 plugs correspond to 8 different colors for easy identification and test preparation and nice design (Fig. 1).

2.2 Firmware System

Basing on the huge advantage of available support firmware library of STM32, which are very basic and fundamental for us to avoid too deep approaching to the source code, the firmware system is developed with 6 main parts, as in order, are: Analog & Digital Power Up, Ready State Announcement, ADS1229 Configuration, Data Recording, Data Conversion & Packing, Data Transmit. In order to attain the coherence in real timing, all firmware steps are performed following SysTick timing interrupt at 1 μs unit (Fig. 2).

Data transmitting package between ADS1299 sensor and microcontroller is prepared in 8-bit blocks, in which sending 24 bits for Electrical signal data and 32 bits for counting variables. Besides, an SPI packet at 42 MHz working is defined, thanks for that, the desired frequency value which is 2.625 MHz with Prescaler = 16 is permissible.

Commanding to sensor is strictly performed following the Command definition table of ADS manual, which uses both RDATAC and RDATA mode.

2.3 User Interface and Real-Time Data Processing

Interface and Real-time data processing software is designed to catch data from EEG devices, process and display data in real-time, store and process offline. More than that, a filter box with FIR/IIR types of lowpass, highpass,bandpass and bandstop filter is embed in the interface with adjustable threshold and order, available for both online or offline. Besides, spectrogram for offline processing is permissible.

2.4 Validation Setting

The validation of EEG system is included EOG task and EEG task. The electrode adapter with gold standard EEG cup and condensed Elecfix gel is applied to subject. Data recorded with gain G = 1, sampling frequency Fs = 250 and 500 Hz.

In EOG task, the signal is collected from 2 positions above and below subject's right eye (±) and the bias is located at his right temple. In EEG test, the EEG signal is picked up only 1 channel at Cz and O2 position and bias at right mastoid in EEG. The subject data is recoded at following state: open eyes, close eyes and close eyes with mental calculation. The protocol is recording open eyes 3 min and then closes eye 3 min then start recording 0–25 s, mental task (25–45 s), at rest again (45–∼).

3 Results

3.1 EOG Testing

The recorded EOG signal is very good to recognize not only the blink detection, but also the eye tracking. This good data

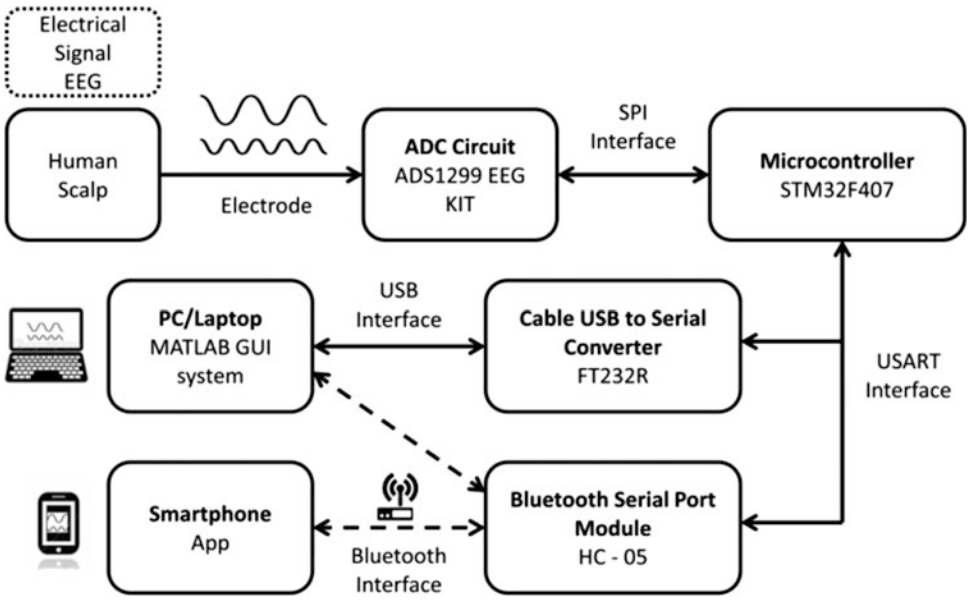

Fig. 1 System working process

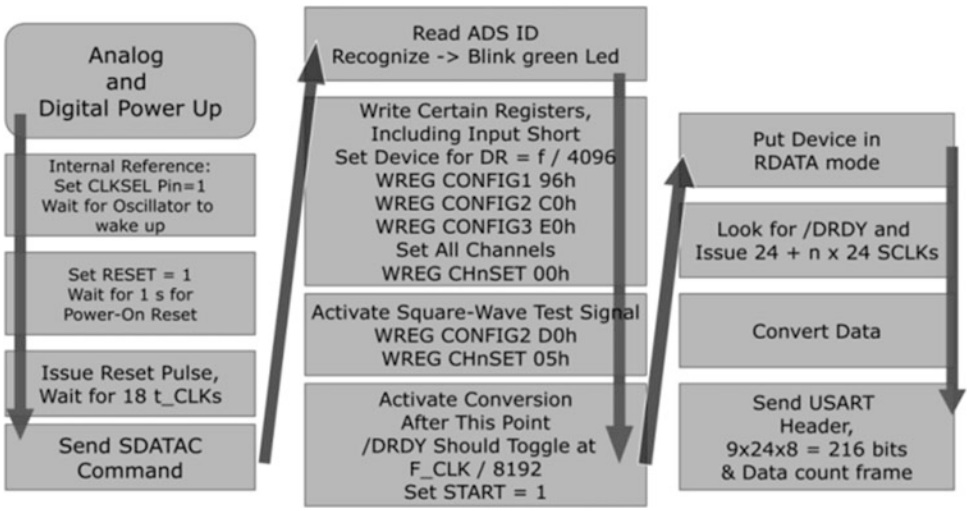

Fig. 2 Firmware process

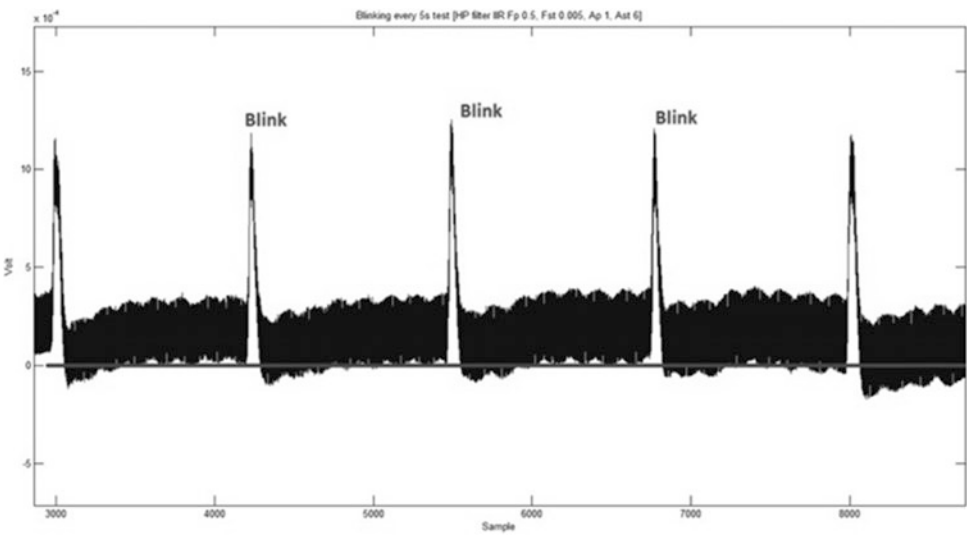

Fig. 3 Result of EOG recording —Blink task

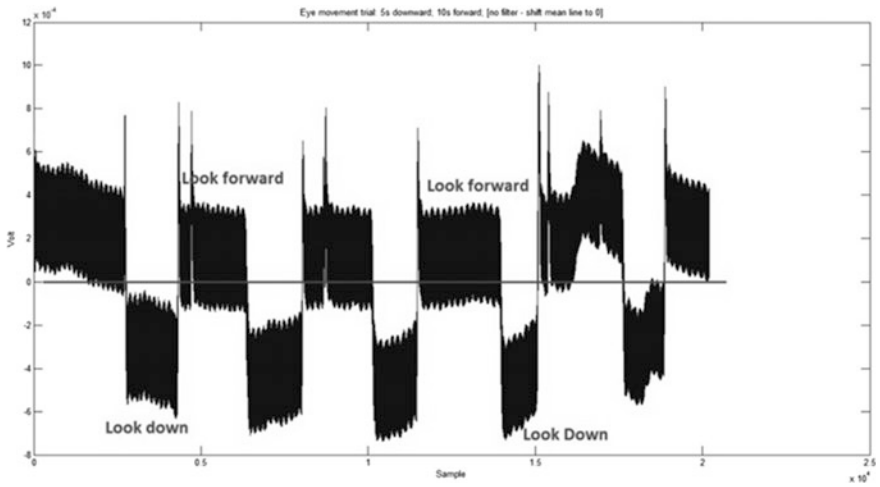

Fig. 4 Result of EOG recording —Eye tracking task

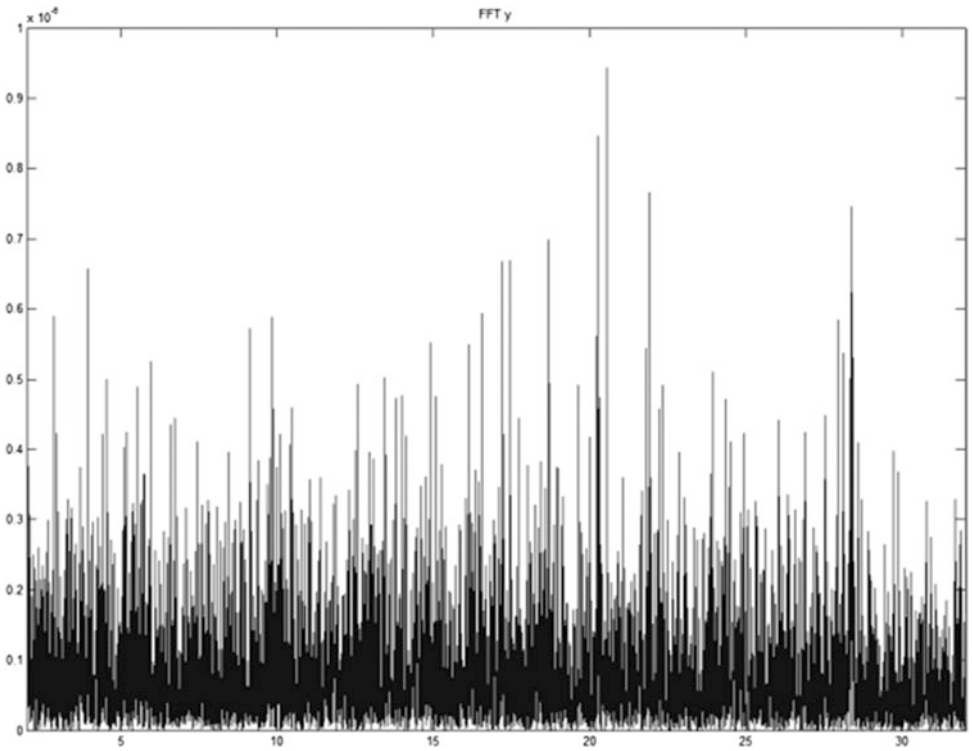

Fig. 5 FFT of corresponding EEG results—eyes closed with mental tasks

states the success of the device in EOG recording and promise further EOG application that associates with EEG application (Figs. 3 and 4).

3.2 EEG Testing

The result of EEG testing has huge different changing in the magnitude of waves between 2 stages. In the close eyes task, the first stage of close eyes and be at rest, results with high peaks around 10–14 Hz supposed as alpha waves frequency range (~8–14 Hz) (Figs. 5 and 6).

The 2nd stage of closed eyes and do mental calculation results in EEG signal as an increasing trend from 12 to around 20 Hz as Beta waves in alert state (as doing math). Finally, the last stage of close eyes remarks a decreasing trend in frequency. The system is successfully catch difference alert stages of the protocol.

In the open eyes and rest in stage 1, to comparison with the more extremely large of stage 2, the EEG just very

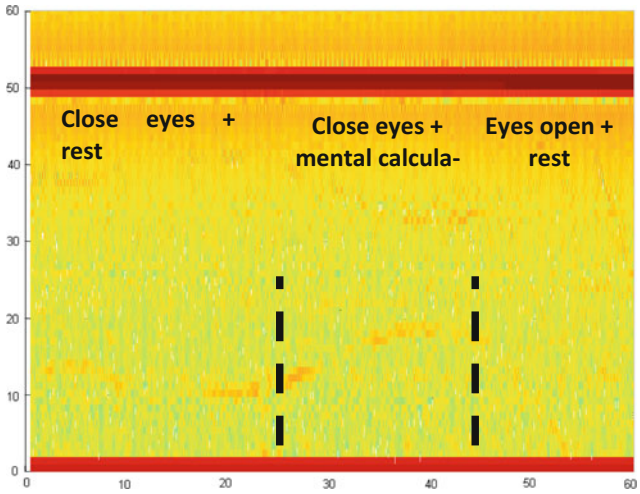

Fig. 6 Spectrogram of corresponding EEG results—eyes closed with mental tasks

serene with low frequency magnitude. The obviously difference between 2 stage and corresponding 2 results confirm the success of the system (Figs. 7 and 8).

4 Discussion and Implementaion

First of all, the implemented system with ADS1299 EEG ADC and STM32F4 Microcontroller has tested with good result in recording and recognizing both subject's biological signal of EOG and EEG. For more details, as ADS1299 is a front-end device, data is just raw then, has analyzed by basic filter such as Lowpass, Bandpass and Notch without using patient bias drive, this result has confirmed the normal function ability and promised for further application in our EEG system. However, the existing problem is the amount of noise in the testing task of EEG signal due to small gain of amplification needs to be considered carefully.

Secondly, the GUI interface has successfully operated with 1 ~ 8 channel, the program now is stable and work beautifully. For further work, the number of channels can be increased for EEG fully recording, other embed buffer with advance frame transmit technique as TCP/IP for data missed retrieving is important to improve also. Last but not least, the various desultory code need to be connected to build as coherence GUI Matlab program for EEG amplitude signal displaying in real time with source code and analysis tab for software filters, FFT, histogram and spectrogram.

5 Conclusion

In conclusion, though the research work now still has such matters to fulfill as totally perfect in the further future's work, such as improving noise removal, implement Active electrode, GUI real-time system with embed application for controlling as BCI… However, the achievements in this work as a first step for further research of investigating and implementing a portable EEG device for BCI and other EEG applications with

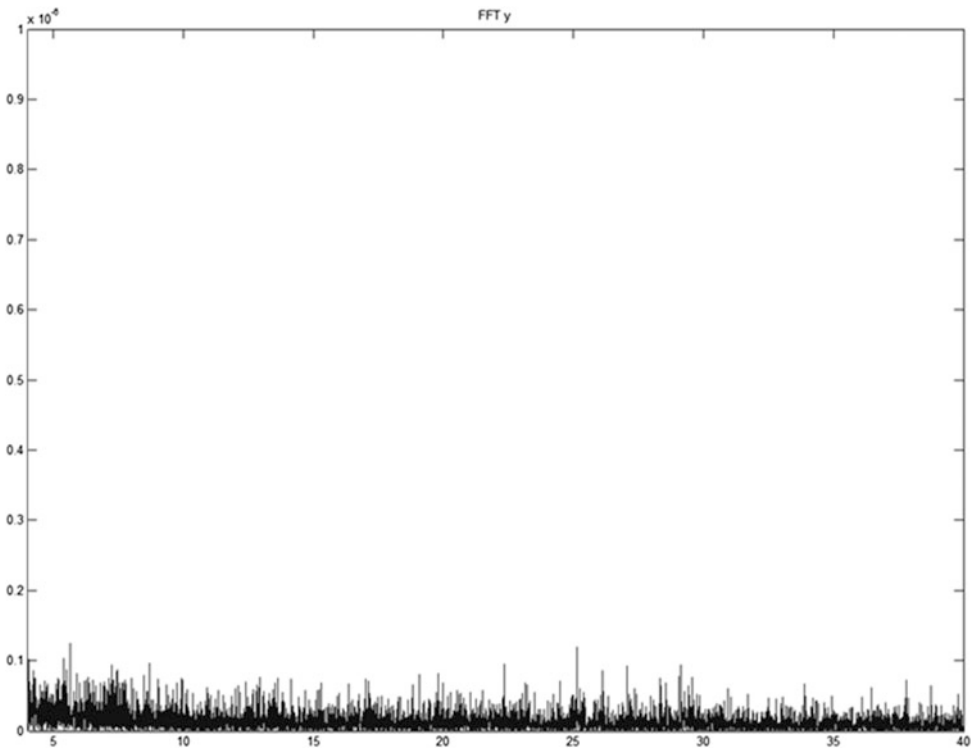

Fig. 7 Spectrogram illustration of corresponding EEG results—eyes opened

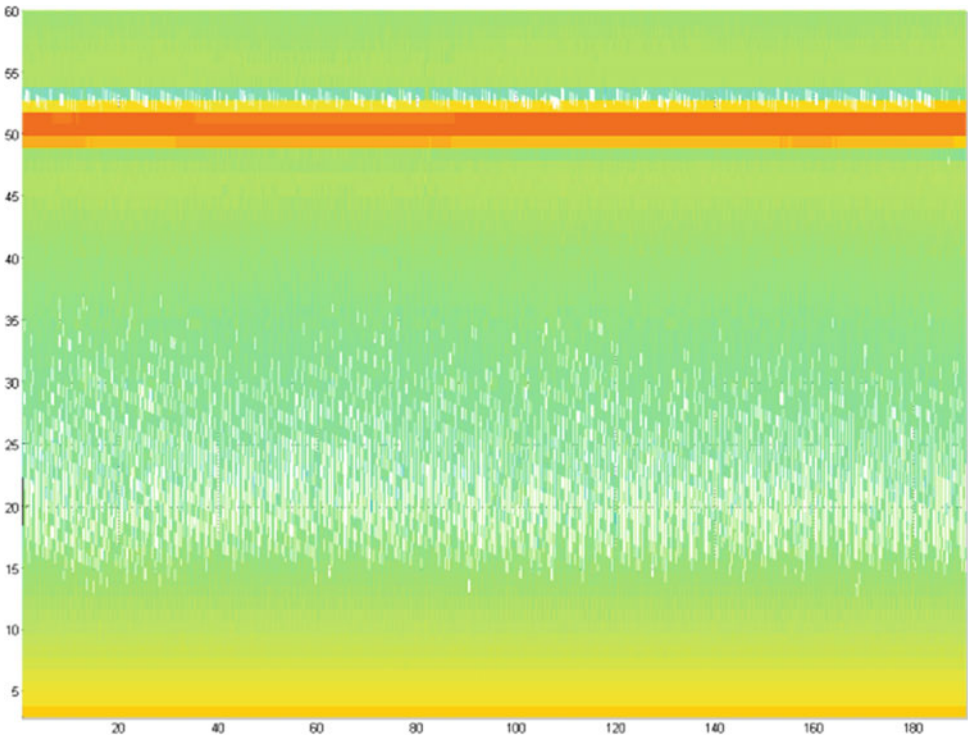

Fig. 8 Spectrogram illustration of corresponding EEG results—eyes opened

high precision, small size, low cost and wearable is obviously significant. In fact, the implemented EEG front-end system using ADS1299 is successfully developed with acknowledgement of biological signals testing result. More than that, it qualified and promises great contribution of ADS1299 in the future.

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