Study of ADS1299 for EEG Signals Acquisition

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1. Abstract

The Texas Instruments' ADS1299 belongs to a family of integrated circuits developed as analogue front ends for measuring electrocardiogram and electroencephalogram signals. This paper approaches the initial study of an EEG application using ADS1299 along with the Arduino Uno board.

2. Electroencephalogram

Electroencephalogram (EEG) as the measurement and record of brain electrical activities, provides a better understanding of the brain functioning. It consists in a non-invasive method of measuring biopotencials using electrodes on the human scalp. The method was first performed in the 1920s by the psychiatrist Hans Berger. Despite the high developments in technology since then, Berger's work is still a cornerstone for the EEG analysis [1].

The EEG signals, having a main frequency range between 0.5 Hz and 45 Hz, are split into minor frequency ranges that represent patterns of brain activity. These are the alpha, beta, gamma, delta and theta waves. By analysing the signals of determined pattern it is possible to know if a person is relaxed, in an alert state, asleep or drowsing [1]. It is also possible to detect pathologic states of the brain such as lesions or psychiatric disorders. Thus the importance of studying the brain activity.

As a biopotencial, the EEG is a naturally difficult signal to measure. Its complexity consists of having a very low amplitude, between 20µV and 100µV, opposite to noise and artefacts of much higher amplitude. The simple movement of a muscle in human face, such as eye blink, would generate a much higher signal. There are also difficulties in using a non-invasive electrode that might not adhere perfectly to skin or even the presence of the 60 Hz power line [2]. To work around these interfering signals, a hardware that performs a high common mode rejection ratio (CMRR) is required. The ADS1299 presents 120 dB of CMRR for typical conditions [3].

3. Front End ADS1299

The ADS1299 is a low power, low noise, 24-bit analogue front end (AFE). It has eight channels, programmable gain amplifiers, delta-sigma analogue-to-digital converters, internal reference and on-board oscillator. It integrates the main processes of a medical instrumentation front end system.

The programmable gain amplifier can be configured to have a gain of 1, 2, 4, 6, 8, 12 or 24. The higher the gain used, the less the input referred noise (IRN). In [4], a comparison with RHA2216, another AFE for biopotencials, ADS1299 presents less IRN and higher CMRR and signal to noise ratio than the RHA2216.

The delta-sigma converter is a high resolution analogue-to-digital converter that performs the conversion in two parts, oversampling modulation and digital decimation filtering. It samples analogue data multiple times, with a sampling rate much higher than the speed of digital data to be output. This process shapes low frequency noise into higher frequencies. Then, the digital decimation filter discards some of the samples, discarding the noise and reducing data rate. Ultimately, the output signal has the same informational content than the analogue signal before oversampling, only it is a manageable digital signal [5].

Another integrated circuit (IC) from the same family as ADS1299, is the ADS1292 that has the same features but with only two channels. It is an IC developed as an AFE for specifically measuring electrocardiogram (ECG) and ventilator frequencies, therefore it does not need many channels.

4. Development

This study of the ADS1299 involves a study of the ADS1292 as well, as it is a simpler IC to initiate the project.

The EEG signal is not characterised by a highly fixed pattern. It has its ranges in frequency and amplitude as characteristics, in which it is possible to fairly analyse patterns. However, the waveform may vary from one person to another. Therefore, it would be difficult to determine the effectiveness of the IC, in this first stage, using an EEG signal. The approach in this project is to use ECG for the initial studies of both ICs. The ECG signal has a very recognizable and fixed pattern of behaviour, known as the QRS complex shown in Fig. 1.

In this initial stage, ADS1292 was initialised and set up for tests using mostly the default configurations. Care with the hardware set up and datasheet details was taken to assure the well functioning of the IC. Arduino Uno was chosen to control the ICs and it has also been used to supply the circuit.

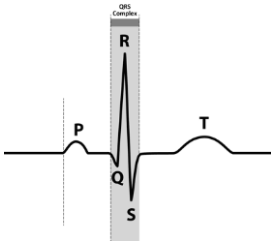

Fig.1. *Pattern for electrocardiogram signal indicating the QRS complex.*

A. Interface with Arduino

The Arduino Uno board was chosen for its easy access and programming language with several libraries and tutorials available. It is an easy approach in general.

The Arduino board communicates with the IC using the SPI system, as shown in Fig. 2. Both ADS1299 and ADS1292 have SPI as communication interface. Their datasheets dispose some command definitions such as START, RDATAC for reading data in continuous mode, STOP, RDATA for reading data by command or WREG and RREG to write and read the IC's registers.

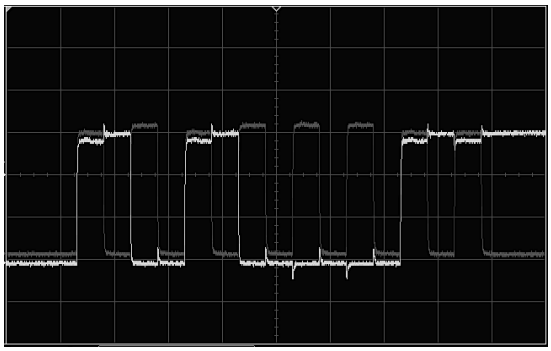

Fig.2*. SPI communication: sending A3h to write in register. The gray waveform is SCLK, while the white waveform is MOSI.*

An incompatibility between the voltages for the high level were a concern while assembling the circuit on breadboard. The Arduino Uno board is supplied with 5V and therefore, its high values for both input and output are around 5V as well. While ADS1292 works with a digital supply range between 1.7V to 3.6V. The IC's high values tend to be around the voltage used as the digital supply. At first, the IC would be supplied it the 3.3V from Arduino, but due to this incompatibility, a 3.6V zener diode is used along with the 5V from Arduino for supplying the circuit on breadboard. Also, the SPI and other pins connections are mostly interfaced with 3.3V zener diodes to limit the high values from Arduino. The assembled hardware can be seen in Fig. 3.

The next steps for this project is to implement the registers configuration as well as the circuit on breadboard for measuring ECG signals. With the ECG pattern it will be possible to analyse the IC's performance and evolve to the use of ADS1299, that is the main object of this study.

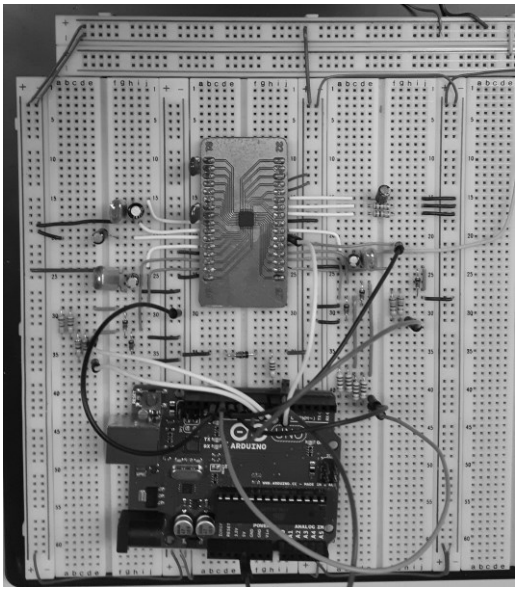

Fig.3*. Hardware for initialisation of ADS1292 using the Arduino Uno board.*

4. Conclusions

As still an initial study, it relies mostly on theory.

ADS1299's proposal is to provide an analogue front-end for EEG signals that results in a reduced use of space on printed circuit board, thus reduced size of hardware. As well as reduced power and overall cost. These are also main interests in this project.

Acknowledgments

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