# Using Multifunction DAQ and LabVIEW for the Development of a Single-Channel EEG for Multiple Sclerosis Detection

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*Abstract* – **In this paper is presented a single-channel EEG acquisition system using a multifunction DAQ. This is done in order to provide a presentation to students of the application of an EEG measurement setup for detecting symptomatic epilepsy-induced seizures in patients with multiple sclerosis.**

*Keywords* – **single channel EEG, multiple sclerosis, engineering education.**

## I. Introduction

Electroencephalography (EEG) is the recording of electrical activity of the human brain along the scalp. EEG measures voltage fluctuations resulting from ionic current flows within the neurons of the brain. In clinical contexts, EEG refers to the recording of the brain's spontaneous electrical activity over a period of time, as recorded from multiple electrodes placed on the scalp. Diagnostic applications generally focus on the spectral content of EEG, that is, the type of neural oscillations that can be observed in EEG signals.

EEG examination is a crucial precursor for the evaluation of a Multiple sclerosis (MS) patient. Diagnosing multiple sclerosis is a complicated task. There is no specific test for multiple sclerosis and, anyway, it is not even certain that it is only one disease. To an extent, getting an MS diagnosis is a process of eliminating all other causes of EEG abnormalities . Typically, people who have finally been diagnosed with definite MS have been passed through several diagnostic stages. This process is often drawn out over months or years.

As a chronic inflammatory disease of the immune system MS affects the brain central and central nervous system, spinal cord and optic nerves. More specific consequences subside to epilepsy seizures. Although not often manifested, they are more frequent than in the general population [1], with the average 2-2.5% [2]. Symptomatic seizures are the main differentiator when conducting EEG studies. EEG findings contribute to the multi-axial diagnosis of epilepsy [3], in terms of whether the seizure disorder is focal or generalised, idiopathic or symptomatic, or part of a specific epilepsy syndrome.

There are three main types of evoked potential test:

Visually Evoked Potential (VEP)-This test measures the speed of the optic nerve. The patient has to focus on the centre of a "TV" screen on which there is a black and white chequered pattern. Each square in the pattern alternates between black and white at measured intervals. The patient wears a patch on one eye for a while and then on the other, so that the speed of both optic nerves can be measured. 85-90% of people with definite MS and 58% of people with probable MS will have abnormal VEP test results [4,5].

Brainstem Auditory Evoked Response (BAER) test measures the speed of impulses along the auditory portion of Cranial Nerve VIII. This nerve arises in the Pons area of the Brainstem and therefore this test may be indicative of lesions in that area. The patient lies down in a darkened room to prevent visual signals from interfering with measurements. A series of clicks and beeps are played back to the patient. 67% of people with definite MS and 41% of people with probable MS will have abnormal BAER test results [6].

Somatosensory Evoked Potential (SSEP) test involves strapping an electrical stimulus around an arm or leg. The current is switched on for 5 seconds and electrodes on the back and skull measure the response at particular junctions. The current is very low indeed and completely painless. The speed of various nerves can be measured in this way and the points of slow-down (i.e. demyelinated lesions) approximated to because of the sampling at several places. 77% of people with definite MS and 67% of people with probable MS will have abnormal SSEP test results [7].

Slow nerve responses in any of these tests are not necessarily indicative of MS but can be used in conjunction with a neurological examination, medical history, an MRI and a spinal tap to deduce some kind of diagnosis.

A large variety of specialized EEG devices have been developed for all those different clinical approaches. But for experimenting with new methods for signal processing and to be able to reach a better educational effect it is feasible to utilize a Multifunction DAQ with a proper software [8]. National Instruments' LabView presents such a solution.

With recent bandwidth improvements and new innovations from NI, USB has evolved into a core bus of choice for measurement and automation applications. Devices for USB deliver high-performance data acquisition in an easy-to-use and portable form factor through USB ports on laptop computers and other portable computing platforms. National

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Instruments designed the new and innovative patent-pending NI signal streaming technology that enables sustained bidirectional high-speed data streams on USB. The new technology, combined with advanced external synchronization and isolation, helps engineers and scientists achieve high-performance applications on USB.

NI M Series bus-powered multifunction data acquisition devices for USB are optimized for superior accuracy in a small form factor. They provide an onboard NI-PGIA 2 amplifier designed for fast settling times at high scanning rates, ensuring 16-bit accuracy even when measuring all available channels at maximum speed.

All bus-powered devices have a minimum of 16 analog inputs, digital triggering, and two counter/timers. USB M Series devices are ideal for test, control, and design applications including portable data logging, field monitoring, embedded OEM, in-vehicle data acquisition and academic.

## II. Methodology

### A. EEG recording

EEG signals have highly non-Gaussian and nonstationary characteristics. In order to extract any beneficial information signal processing has to be employed. The postsynaptic potentials sum is the range of about 5uV to 100uV and frequency range 3Hz to 70Hz [4]. This narrows down to a few of the shelf solutions as the one chosen for the project – National Instruments USB-6211 data acquisition module along side the LabView graphical programming language. LabView allows a fast paced and low cost development of smart algorithms for signal processing.

An important matter is the ability for denoising the acquired signal. A common drawback in evaluating patients with MS is that the measurements are conducted in intensive care units which have the disadvantage of the low preparation time and exposure to a variety of electrical equipment [2]. In this case there are many sources of noise, to most of which the available EEG equipment is highly susceptible to. EMI artefacts are seen more frequently. An important matter is to obtain the main characteristics of the measurement device in these conditions. Recording methodology and is crucial for minimizing noise.

Instead of doing a single conversion, the ADC performs the conversions ("samples" the input) periodically. Resulting in a sequence of digital values that have converted a continuous-time and continuous-amplitude analog signal to a discrete-time and discrete-amplitude digital signal. This greatly reduces and simplifies the medical and engineering analysis. The estimated levels of the signals in such a small range (±0.2 to ±10 V per channel) as specified previously can be calculated from the main characteristics of the DAQ. Most important being the Minimum Voltage Range (from -200 mV to - 200 mV) and Minimum Voltage Range Sensitivity - 4.8 μV, well in the limits of normal EEG signals. Input impedance for the analog input is >10 GΩ in parallel with 100 pF. Analog input are 16-bits and sampling rate 250kS/s, so within the range the best resolution will be about 6uV. In order to improve the resolution we perform a suitable amplification of the EEG signal with gain of 100. Also, the sampling rate is reduced down to 250S/s.

### C. Amplification

The EEG Amplifier plays a vital role in the field of education and research. The EEG amplifier has served many different uses in a variety of different fields, and even with more recent advancements in high-tech machines. EEG Amplifier system may combine data acquisition hardware and software to allow researchers and educators to perform unipolar and bipolar measurements. Output can be switched between normal EEG output and Alpha wave detection, and software can then automatically filter the raw EEG signals for Alpha, Beta, Theta, and Gamma wave activity, providing a full frequency analysis of the data.

### D. Single channel EEG

One of the holy grails of EEG, along with dry electrodes, is the idea of single-channel EEG. System solely dependent . Or rather, useful single-channel EEG. It’s very easy to record EEG from a single channel but making sense of the data and building a useful application around it is not. The reason that single-channel EEG is so attractive is not just ease-of-use but the relationship between ease-of-use and the amount of data that can be reasonably recorded.

When it comes to EEG, more channels (electrodes) are always better, having a dense network of electrodes allows us to create spatial maps of activity which brings EEG into the realm of brain imaging. See Michel and Murray for a nice overview of this topic. As we know EEG (along with MEG) has far and above the best temporal resolution of all techniques used to study the brain. If we add full-head dense electrode arrays we also have decent spatial resolution.

This is an extremely powerful and as yet underexploited tool in neuroscience but it has a major drawback, by increasing spatial resolution we decrease ease-of-use and comfort while increasing the cost. The beauty of EEG is that, of all possibilities for measuring brain activity, it is currently the only one that can conceivably be packaged in a miniaturised, light, comfortable and low cost package. This directly addresses one of the major obstacles in neuroscience today, lack of data. We typically only have data for patients who have already presented with serious symptoms (because brain imaging is expensive and difficult). We don’t know very well what “normal” brains look like and how they evolve over the life time.

The solution for us is obvious, cheap, medical grade EEG on a massive scale but to make this happen we need to reduce the number of electrodes to make the process user friendly and robust. The end point of this is single channel EEG.

Consumer grade products already exist such as Neurosky and iBrain. With these devices the emphasis is on making it easy to use and cheap enough for consumer apps.

*E. Multiple sclerosis detection*

Three main types of evoked potential tests are used in the diagnosis of MS. Each of these tests requires that electrodes are attached to the scalp and connected to an electroencephalograph (EEG) to record brainwaves in response to different stimuli. The different tests are:

Brainstem Auditory Evoked Potentials (BAEP): A series of clicks are played in each ear through headphones.

Visual Evoked Potentials (VEP): A series of checkerboard patterns are displayed on a screen.

Sensory Evoked Potentials (SEP): Mild electrical shocks are administered to an arm or leg.

The doctor is looking for both the size of the response and the speed in which the brain receives the signal. Weaker or slow signals may indicate that demyelination has occurred and that MS is a possibility. However, this test is also not specific to MS; abnormalities could indicate another problem. A series of all three tests could take up to two hours to complete.

## III. EXPERIMENTS

*A. Setup*

A setup was prepared to closely resemble and EEG acquisition room – away from active electronics and with reduced electromagnetic interference. Signal recordings were made with differentiation in the electrode to electrode comparison. NRSE (detect the ground voltage provided by the signal for all EEG leads) and differential voltage between the electrodes. 3 leads are chosen for the measurement – Z (for ground - ear), Cz, C4, T4. All are placed on the EEG cap and linked to bridge electrodes.

*B. Real recorded data*

In Fig. 1 two notable noise components are observed. One is a low frequency component ”pushing” the whole envelope bellow the zero and the second is dominant 50 Hz mains one. Fig.2 on the other hand exhibits a steady low frequency amplitude change due to heart rate/ pulse interference. In Fig.3 a multiple electrode NRSE measurement was set up graphically depicting the 50 Hz induced component from the power supply.

## IV. RESULTS

A working setup was created for testing.

Due to the high susceptibility of the set up to noise a good step would be the inclusion of a better pre-amplifier, post processing, low and notch filters, as well.

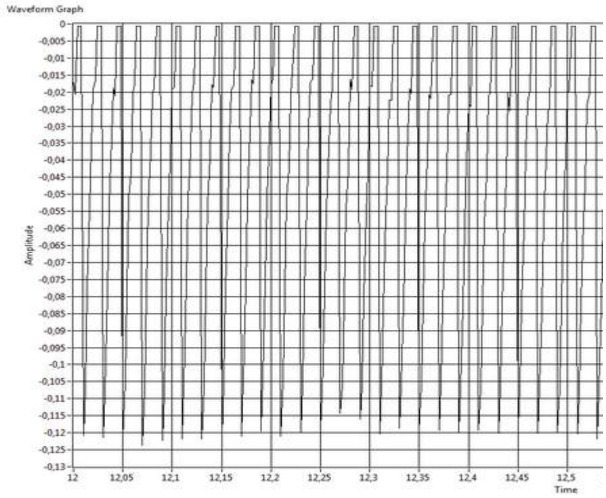


Fig. 1. Sample measurement Cz-Z. Amplitude is mV [Y axis], Time is in seconds [X axis]

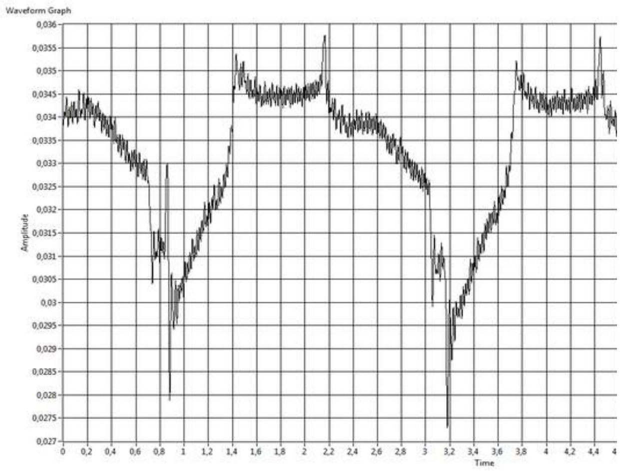


Fig. 2. Sample measurement C4-Z. Amplitude is mV [Y axis], Time is in seconds [X axis]

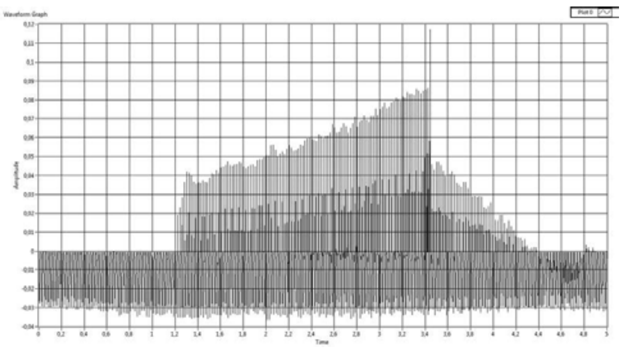

Fig. 3. Sample measurement Cz, C4, T4-Z. NRSE Measurement. Amplitude is mV [Y axis], Time is in seconds [X axis]

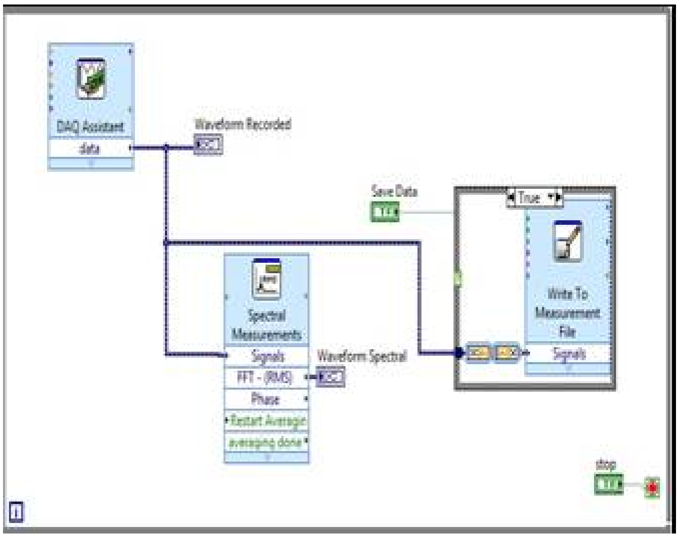


Fig. 4. An overview of the LabView measurement recording without any post signal processing. All data is recorded to a TDMS file format

## V. Conclusion

It is convenient to use Multifunction DAQ and LabVIEW when it comes to experimentation. It is also suitable for students training. In real task is better to think for specialized FPGA solution.

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