

Low Noise EEG Amplifier Board for Low Cost Wearable BCI Devices

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ABSTRACT

Designing a real-time BCI device requires an Electroencephalogram (EEG) acquisition system and a signal processing system to process that acquired data. EEG acquisition boards available in market are expensive and they are required to be connected to computer for any processing work. Various low cost Digital Signal Processor (DSP) boards available in market come with internal Analog to Digital converters and peripheral interfaces. The idea is to design a low cost EEG amplifier board that can be used with these commercially available DSP boards. The analog data from EEG amplifier can be converted to digital data by DSP board and sent to computer via an interface for algorithm development and further control operations. EEG amplifiers are highly affected by noise from environment. Proper noise reduction techniques are implemented and simulated in circuit design. Each filter stage and noise reduction circuit is evaluated for a low noise design.

KEYWORDS

Decoupling, EEG Amplifier, Filter Design, RFI/EMI (Radio Frequency Interference/Electro Magnetic Interference) Noise, Right Leg Drive (RLD)

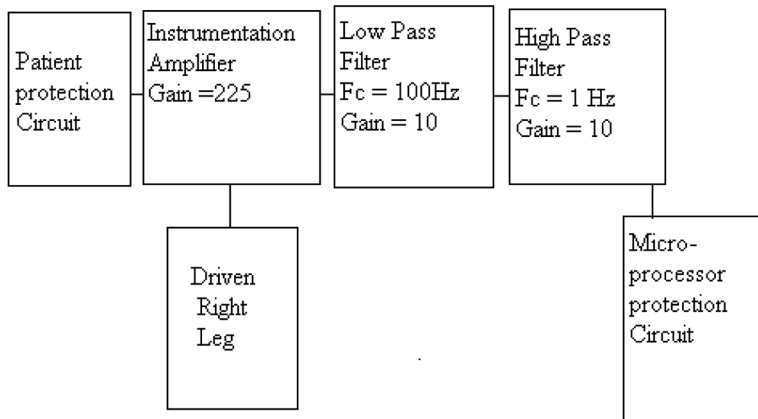
INTRODUCTION

Brain-computer interface makes use of wearable modules for acquiring the signals, process it and further, control the peripherals. There are many low cost DSP processor boards available in market with inbuilt Analog-to-Digital converters (ADC) but compatible EEG amplifier boards are not available in market. Here we propose to design an amplifier board that can be used with these boards for acquiring of EEG signals and real time processing of data.

EEG is the measurement of time-varying magnitude of electric field generated by the brain. For the acquisition purpose, proper electrode placement based on 10:20 system is followed and electrodes are placed on scalp. The purpose of the amplifier board design is to amplify these acquired EEG signals up to a level from which it can be converted to readable data and also to remove the noise signals that come at the electrode surface. Filter design is implemented to reduce coupling effect, low frequency noise and to remove RFI/EMI noise (R S Khandpur, 2014). Proper grounding techniques are employed in PCB Layout Design to minimize the RFI/EMI noise. Protection circuits for patient and the microcontroller board are also implemented and tested. A battery Circuit for power supply is designed and verified (Figure 1).

R S Khandpur (2014), Charles Kitchin and Lew Counts (2004) are referred to understand the basic concepts for designing an acquisition board for making proper modifications in available designs. They give elaboration on the proper placement of each stage and their design considerations. Nitin Agarwal et al (2011) have designed different stages in acquisition board and their simulations are

Figure 1. EEG board system diagram



done. Labview is used in this paper for analysis of filter stages and noise analysis is performed for calculation of signal-to-noise-ratio (SNR). They make use of the concept of virtual ground for DC offset reduction. Hank Zumbahlen (2010) has worked on multi feedback (MFB) filter design and explains equations for easy calculation of component values. The MFB is used for its high tolerance on component value changes. The Sallen Key filter is highly affected by component value changes due to heating effects and different tolerance of used components thus this topology is not suitable for biomedical instrumentation. A low pass filter for cut off frequency 100HZ is designed using the described formula and components available. B B Winter and John G Webster (1983) Matthew W Hann (2013) Venkatesh Acharya (2011) provide techniques for calculation of different parameters for designing of RLD circuit. Calculation of filter stage and proper implementation of inverting stage with high enough gain is necessary for better CMRR. The paper provides application of RLD and the circuit simulation techniques. Proper designed RLD can help in suppression of 50HZ noise hum and improves CMRR of final design. It is a negative feedback common mode signal amplified and fed back to body for cancelation. R. Mark Stitt (1997) Charles Kitchin (2007) Paul Brokaw (2010) Hank Zumbahlen (2010) give the concepts of ac coupling and decoupling and these concepts in PCB design are explained in these literatures. Implementation of amplifier stages and calculation of component values are explained. It provides concepts of reducing the other noise sources like power line noise and coupling noise. The issues arise due to improper placement of coupling and decoupling capacitors are explained. It helped in proper designing of stages to reduce the effects of coupling and power line noise that are the main sources of noise introduced in analog circuits. The PCB fabrication requires signal line isolation, proper grounding and RFI suppression techniques for better noise performance. The concept of two-layer PCB design using EAGLE™ is used for the final PCB board design.

Design and Testing of Circuits

EEG signals are very low amplitude (10μV to 150μV) random signals easily affected by noise from different sources (Table 1).

Patient Protection Circuit

This circuit is designed to protect patient from any back current from the board. It is designed as per the standard norm of “IEC 60601-1-2” for designing of medical equipment (Figure 2).

This circuit is designed using 1N4148 SMD diodes having a maximum reverse current of 50microAmps will pass 1vpp ac voltage. Since EEG signal comes in the range of few microvolts thus it will pass while not allowing any reverse voltage of more than 1Vpp.

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