

Introduction

Herein we report the design and fabrication of an electroencephalograph (EEG) system for use as a real time MIDI controller. This effectively outputs music based on the patient's brainwaves. The process was partitioned into three parts: First, analog circuitry was designed to amplify and filter the signal from the electrodes. Second, an Arduino microcontroller was used for analog to digital conversion and to process the signal. Lastly, Arduino code was written to map characteristics of the EEG data to specific musical aspects and output both an analog tone through a speaker as well as a MIDI signal capable of controlling external synthesizers. We show this device is a novel musical instrument also having applications in the medical industry.

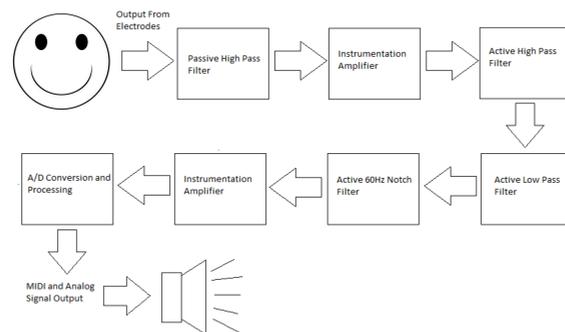
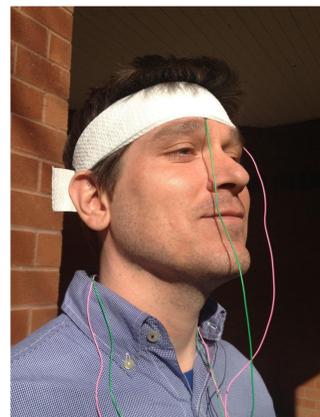


Figure 1: Circuit Block diagram.

Music Synthesis

Melody in its most simplistic form is characterized by both pitch and note duration.

Methodology:

- Amplitude of the current sampled value was mapped to a pitch.
- Note duration was specified by the difference in amplitude from the current and previously sampled values.
- The chromatic scale (12 notes per an octave) was used, resulting in one of 24 possible notes spanning the range of two octaves.
- Four different note durations were used: 150ms, 300ms, 450ms, and 600ms.

Interactive features:

- Potentiometer capable of sweeping the analog output through five octaves and the MIDI output through two.
- Ability to choose only the MIDI output or both the analog and MIDI outputs via push button.

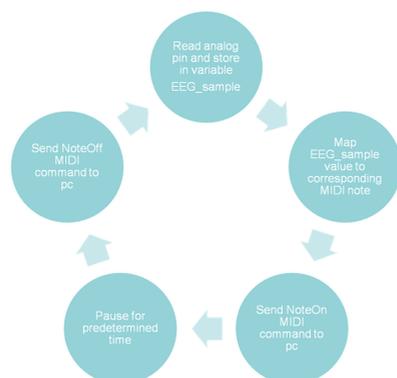


Figure 6: Polling strategy

Analog Design

The purpose of the analog circuit is to amplify signals in the μV range to a useable signal, and to filter unwanted frequencies.

Design Parameters:

- Signal gain of 100dB
- Bandwidth of 55Hz, and frequency response of 2Hz- 57Hz.
- Notch filter at 60Hz to remove noise.
- Output between 0V-3.3V, required by the Arduino's ADC.

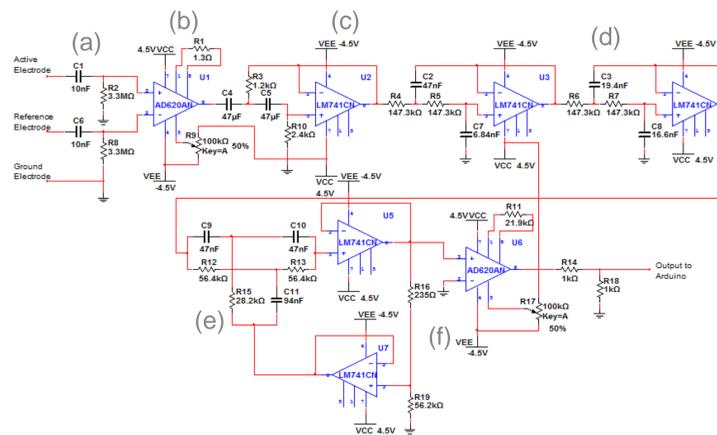


Figure 2: Complete analog circuit. (a) High-pass RC filter. (b) Low noise signal amplifier utilizing an AD620. (c) Active high-pass filter. (d) Fourth order Butterworth low-pass filter. (e) High Q Twin T notch filter (f) Final amplification stage with DC.

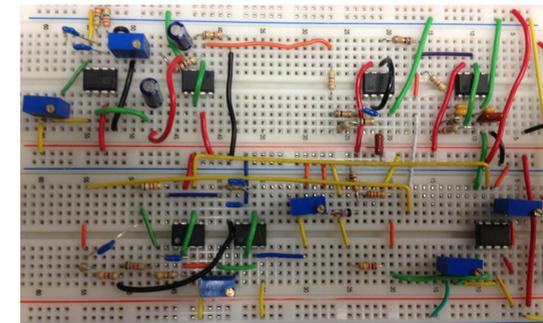


Figure 3: Prototype circuit on a solderless breadboard.

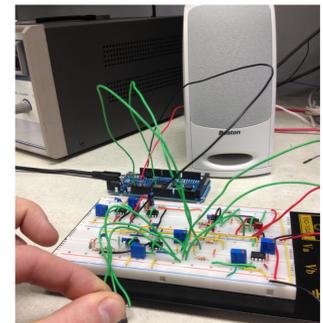


Figure 4: Prototype circuit with Arduino and speaker.

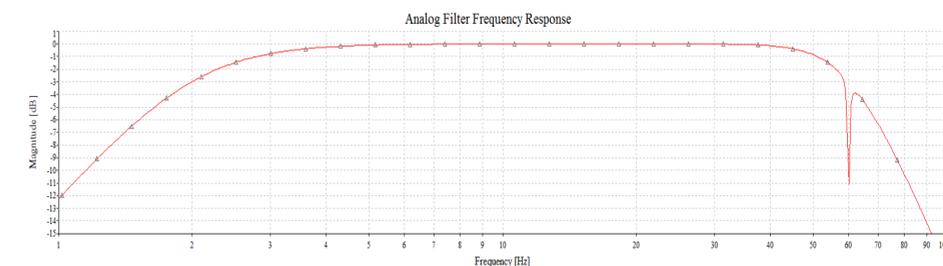


Figure 5: Simulated frequency response of filter network. This is a band-passed signal between 2Hz and 60Hz, with a notch filter centered at 60Hz.

Data and Results

Accomplishments:

- Portable, low-cost device powered by 6 AAA batteries.
- Generates unique music based on EEG data.
- Novel creative tool for music production.

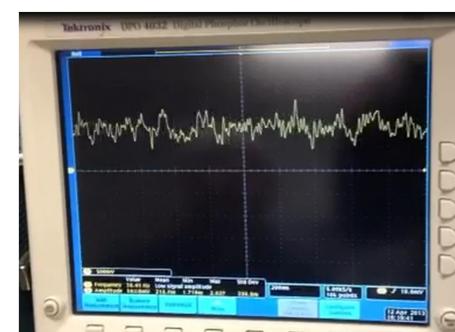


Figure 7: Sample EEG data.

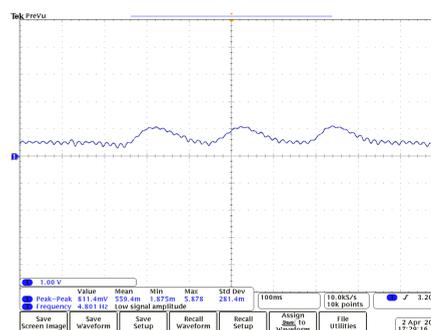


Figure 8: EEG data displaying three blinks.

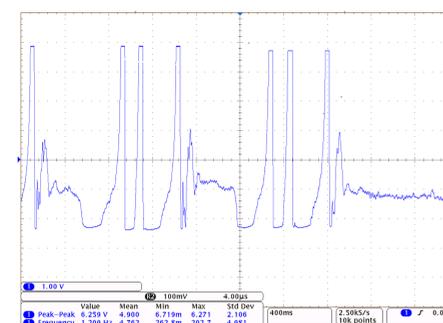


Figure 9: Motion artifacts due to patient activity (foot tapping, turning of head, etc.)

Conclusions and Future Work

Potential medical applications:

- Early warning system for the onset of seizures in epilepsy patients.
- Alert system for surgeons to indicate if the patient is in pain.
- Positive feedback system such that the music created by a coma patient further stimulates their brain activity.

Future work:

- Adding a Fast Fourier Transform to the Arduino code, so that the frequency component of the EEG signal can be mapped to additional musical attributes of the output.
- Experimenting with adding multiple electrodes, each mapping to a different MIDI instrument to create a virtual musical ensemble.

Acknowledgements:

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