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Work In Progress: Adapting Inexpensive Game Technology to Teach Principles of Neural Interface Technology and Device Control

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Abstract

An inexpensive commercially available game that detects the brain's beta wave activity to control game function was analyzed by biomedical engineering students to teach principles of electrical engineering, device control and neural interface technology. Students disassembled the game and identified major systems and components. They analyzed inputs and output signals to determine how the game could be used for device control. A low cost housing was designed and built for the game components with integrated front panel switches and connectors for signal inputs and outputs. Prototyping breadboards were integrated into the housing to allow flexibility to build various signal conditioning circuits. Students were able to use the device to mentally create musical notes of various pitches and design a frequency filter to create TTL signals for device control. The game served as a low-cost and fun teaching tool to facilitate student interest for learning about circuits and neural interface technology.

Introduction

Neural interface research has become a popular topic, opening the possibilities of creating man-machine interfaces that have the potential to allow electro-mechanical augmentations of the human body.[1] This is especially impactful for people who suffer from particular disabilities for which artificial body parts could restore some or all functionality.[2,3] Ideally, mechanical prosthetics would be directly controlled by the thoughts of the user.[4]

Training the next generation of engineers and scientists who aspire to work in this field can be challenging due to the cost and risk associated with invasive neural interface experiments with human subjects. The basic principles needed to inspire students to pursue graduate studies in neural interface technology can be taught at any undergraduate school with a rudimentary electronics laboratory using commercially available game technology.[5]

In this project, undergraduate students analyzed the game "The Force ™ Trainer" from Star Wars ™ Science which contains a biosensor device for measuring neural activity and functions as a basic electroencephalogram (EEG).[6] This game was developed by the game company Uncle Milton in conjunction with NeuroSky Inc., which pioneered the low cost biosensor that allows forms of neural activity to be monitored and used for game play and research endeavors.[7,8] By specifically examining "The Force ™ Trainer" game and its components through a reverse engineering process, the students were able to observe its ability to detect brainwaves and measure a correlating signal. The beta waves measured through the game's biosensors control the variable fan speed in the game that levitates a ball, but also produce a measureable sinusoidal wave that can easily be sampled to control other systems. One simple method of applying this control is generating standard TTL logic states (5V and 0V DC) to turn on and off devices.

Materials and Methods

Based on Electroencephalograph technology, Neurosky Inc. has successfully commercialized an inexpensive method of detecting beta wave brain activity. This technology is available in several third party games or direct from the company in a research development kit.[9,10,11] The games sell for much less than the full hardware development kit. Students disassembled the game to adapt it into a research platform for neural interface demonstrations.

The game's headset is worn by the user and three sensors maintain contact with the scalp. The sensors are able to detect changes in beta waves, which are generated when a person is deep in thought, specifically when in a state of mental concentration. The game generates an electrical signal representative of concentration level and uses it to drive the speed of the fan and blow air to levitate a ball at a particular height in the plastic tower. A sinusoidal signal can be probed across the encoder.

The first task for students with this project was to actually play the game. After students have obtained a reasonable amount of success with neural control, they disassembled one of the devices, or studied one of the deconstructed games to learn each component's function and how they are connected. The students are then shown where the drive circuitry is for the fan and the leads on the encoder that produce a clean alternating current signal. They are also shown how to operate an oscilloscope and measure the range of frequencies produced by the game. The encoder's waveforms were measured for analysis. The ranges of frequency vary based on user, but for one test subject a signal of 3 Volts peak to peak was generated that ranged from 530 Hz to 1750 Hz. At a complete loss of concentration the sinusoid can drop to a flat line of zero voltage. To reach the extreme frequencies measured, the calibration wheel for the fan had to be adjusted. The range achievable at the low end setting was approximately 530-1,145Hz, and on its highest setting 1,200-1750 Hz. Knowing the output of the encoder allows for the design of circuitry to condition the signal for various applications, either using the frequency of the wave to drive a device, or convert it to a particular value based on the frequency range. Band pass frequency filters can be designed to create standard TTL signals when the signal falls into a specific range, or at the least a high or low pass filter could trigger an on/off event. This can be achieved by combining the band pass filter with an AC-DC converter and a comparator that drives the signal to a low or high voltage for TTL control.

Results

The output signal from the encoder can easily be connected directly to a speaker to listen to pitches created by the frequencies generated in correlation with mental activity. These pitches can be mapped onto the music scale to show the range of notes possible. It is difficult to have enough mental control to lock on to any single pitch in tune, but a sliding scale of sound can be generated. Since the game's adjustment dial changes the frequency range, two ranges of musical notes were measured at the extreme settings. At the low end, a 530-1,145Hz range approximately covers $C_5 – C_6^{\#}$, and the high end from 1.2-1.75 kHz, spans $D_6 – A_6$. Addition circuitry can be added to amplify the signal or clean it up the quality of the tone. Students used circuit design software and basic design principles to adapt and combine circuit diagrams found online to condition the output of the game. A circuit was designed that could drive the variable frequency output to a TTL signal so that the game could convert thought to on-off triggers for device control. Students developed skills in reverse engineering, circuit analysis, and device control using electronics tools such as multimeters, oscilloscopes, function generators, circuit design software, and breadboards for circuit prototyping. Many of the students learned these skills prior to a college circuits class and

Conclusions

The Force ™ Trainer from Star Wars ™ Science has proven to be an inexpensive and viable platform to teach engineering students about the fundamentals of reverse engineering and adaptation of devices, while introducing concepts of neural interface technology. The toy has been used to demonstrate its functionality as a research platform. Students successfully used it to generate music notes using only the mind. It was also shown with some rudimentary circuits using design software models that the output signal could be converted to TTL levels for device control. For engineering programs that lack resources for extensive neural interface research, this game offer a less expensive, but no less educational, laboratory experience for undergraduates. The possibility for adaptation of these toys to control various devices for neural interface demonstrations is limited only by the imagination of an engineer.

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