Implant Biocompatibility: Creating an Automated System to Determine the Optical Degradation of Genetically Enhanced Bionic Pacemaker for Epilepsy

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Abstract

CANDO (www.cando.ac.uk) is a £10 million project to develop a new type of pacemaker to treat epilepsy. It involves genetically engineering light sensitivity into the target brain tissue and then inserting optoelectronic probes to perform closed loop control methodologies. The biological aspects of the project are being developed in the Newcastle medical school, whereas the engineering is a collaboration between Newcastle EEE, Imperial and UCL.

The aim of this internship is to develop both software and hardware aspects of a new degradation test rig to verify the long term durability of the probes in aqueous (brain-like) conditions. This will support and speed-up ongoing efforts considerably – allowing automation of the key aspects of the study.

Introduction

CANDO (Controlling Abnormal Network Dynamics using Optogenetics) is a world class, cross-disciplinary project to develop cortical implants to control neurons through optogenetics. In healthy individuals, nerve cells generate rhythmic activity. However, these patterns are disrupted when examining those with various neurological diseases. Epileptic individuals usually have localised abnormal brain behaviour or 'focus', which then continues to spread, causing a seizure. For the 600,000 people in the UK with this disorder, treatment is typically limited to conventional drugs or failing this, surgical removal of the focus. CANDO looks to instead genetically alter cells within the focus using a safe virus, making them sensitive to light. A small, implantable device can then be used to monitor brain waves, to enable modulation of abnormal activity and provide precisely timed stimulation via implanted light sources.[1]

This projects main aims and objectives are pertinent to providing automation of key parts of the studies outlined above. Hardware consisting of various analogue components and microcontroller architecture, alongside software aspects are proposed, designed, developed, and integrated to provide a degradation test rig that can perform a particular function and testing and analysis on collated data regarding the performance of the implantable devices and allowing future improvements to be made, with the penultimate goal of the project of creating successful first-in-human trials in patients suffering from epilepsy.

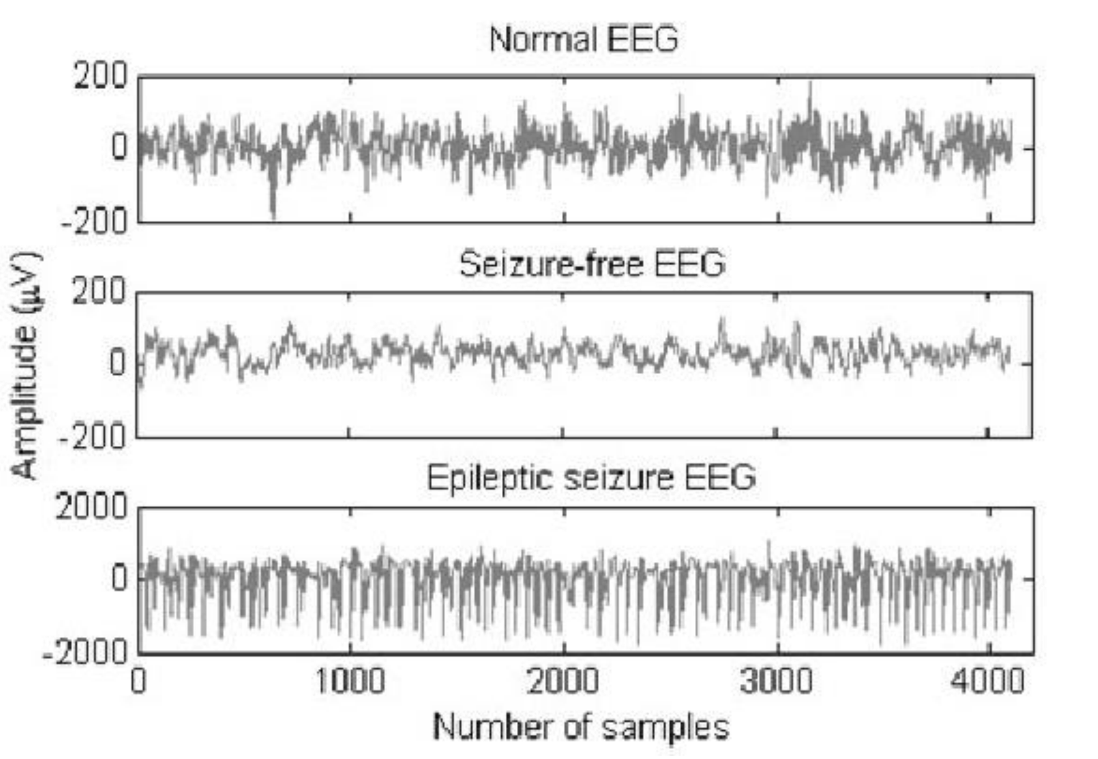

Fig.1 – Comparisons between the amplitudes of EEG readings in µV between normal, seizure-free and epileptic seizure conditions over a range of 4000 samples. [2]

Methods and Materials

The initial stages of the project involved large amounts of research and conceptual circuit design, relating to selection of analogue components, review of different microcontroller architectures, their capabilities, and integration between them. The finalized circuit design was then developed for a large proportion of the project in PCB design software Altium Designer. The PCB is to be enclosed by a small aluminum box, with a high-powered light emitting diode (LED) mounted to it. This LED emits light on to the implantable devices, the intensity of which is varied continuously, allowing important parameters to be monitored regarding the efficacy of the implantable optogenetics. Through this process, various different designs were produced, culminating in one final design sent for manufacture.

The software aspect of the design was handled through various different positions. The microcontroller was programmed using C++ language, however LabView was also incorporated to create an environment for communication over Ethernet and integration between all aspects of the overall design. Additional software was also used, such as terminal emulators and Ethernet hosts, to provide methods of testing and validation at numerous points throughout the project.

Results

A significant proportion of the testing was conducted in regards to the software implementation. The C++ program was composed through the writing and verification of individual pieces of code relating to each component, which was then assembled once proper operation was achieved.

Performance of the microcontroller and each individual analogue components used within the hardware design were validated thoroughly. The light intensity radiated by LED devices was varied between minima and maxima through the use of the incorporated current limiting device programmed accordingly. Further, high-grade engineering equipment such as oscilloscopes and digital multi-meters were used to perform testing on hardware, ensuring the correct output waveforms are achieved at varying stages of the system software.

Finally, the microcontroller also successfully handled communication between all the devices included within the design. This was verified using a Transmission Control Protocol (TCP) emulator, which is able to act as both a transmitter and receiver of information over a network. It was found that the microcontroller could connect successfully to a network, and transmit numerous samples of data, such as temperature, to the host computer.

Discussion and Future Work

The results presented in the previous section indicate a significant body of work has been conducted in regards to software and individual hardware test and validation. The software within the project has been shown to be operating correctly, with efficient programming measures put in place to ensure fast computations. However, due to time constraints within the project, hardware validation of the overall, first-pass PCB design does need to be conducted in the future, to ensure integration between the two aspects.

The project was carried out in the interest of designing a singular degradation test system to investigate the efficacy of implantable devices for epilepsy. However, future work could also be conducted to allow parallelization of multiple test systems over a single Ethernet network (fig.2). In this case, the transmitting station can communicate with multiple devices at once, further improving the automation aspects of the study, allowing amplified realizations of the outlined aims and objectives.

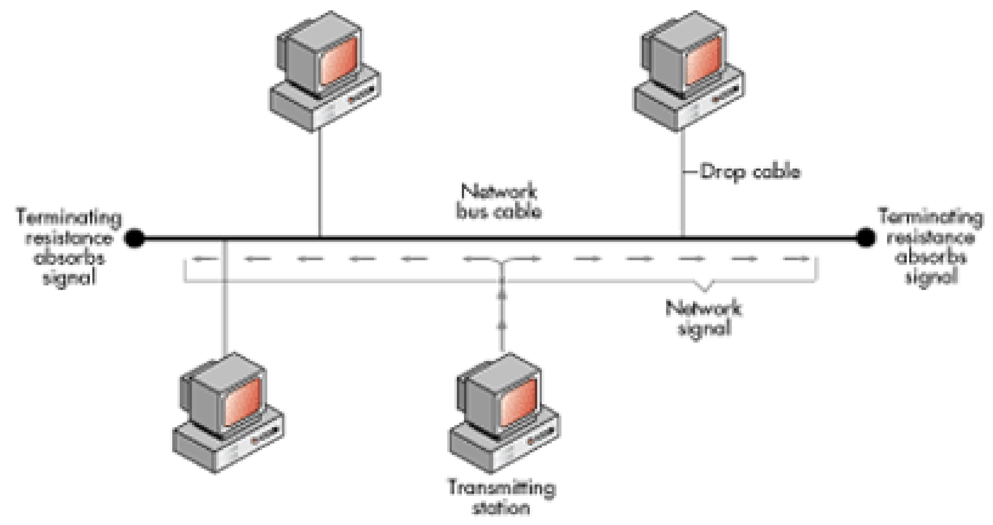

Fig.2 – Typical Ethernet bus topology illustrating how numerous degradation test rigs can be incorporated into the design to achieve parallel computations.[3]

Conclusions

Significant contributions have been made to the overall project effort, however some more suggested work does need to be performed in the future to bring together the produced hardware and software aspects proposed within this project. Once this is complete, testing on the overall system should be indicative of necessary improvements needed to create a fully integrated, operating system in the coming years.

Characterization of the system and collection of relevant practical data pertinent to the probes in aqueous, brain like conditions can then be performed, allowing analysis of their various important characteristics in parallel in a significantly smaller time-frame than is currently possible in the laboratory.

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