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Design of Numerically Controlled Oscillator for Neurofeedback Interface Machine

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Abstract

Till now we are able to do work only physically, either with the help of some instruments/machines or with the help of hand, but now it has become possible to complete any work with our brain signals. Whatever we want to do, it will be completed. Just think about a task to be done and it will be done. Suppose a handicapped is having an artificial hand, the hand will work as a natural hand. Or suppose we want to open/close the door while sitting on the chair or being on bed itself, the door will do so as we think about, no need to go to the door. This is all possible with neuro feedback interface machine. Recently there is development in brain computer interface, by which we can interact with computer. The brain machine interfacing facilitates interaction between human and machine with or without help of computer .first numerically controlled oscillator was designed and its linear characteristics analysis was successfully completed

Introduction

It is a means of communication between brain and machine, with the help of brain peripherals interfacing. Information of neural activities of brain can be exchanged with the machine. The computer can in turn use the information to control variety of devices or exchange the information with another BMI.

Thus BMI extracts *electrophysiological* signal from suitable components of brain (motor cortices) and process them to generate control signals for machine.

It involves neurology, mathematics, electronic engineering and material science with intelligent and (and emotional) devices all around us, it will become possible to just think about a task to be done and it will be done.

Block Diagram

Probes are implanted in the brain to tap neural signals. Depending upon the type of signals to be tapped and analyzed, probe location is decided. Probe will boost circuit to strengthen the weak neural signals and transfer them to neural processor. Processor will extract the different information from the signals.

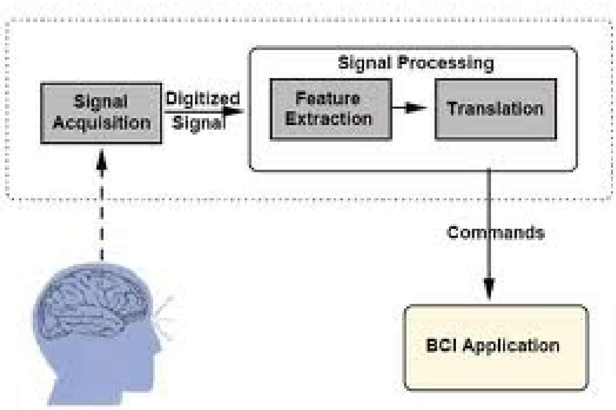

Figure 1: Block diagram of BCI applied for brain machine interface.

Components of BMI

Neural signal behaviour: There are 100 billion neurons in the brain. Identifying and understanding them is a tough job, like stars in universe. There are two ways of studying brain waves. The are**a.**

Invasive: Some of the techniques of this kind to read-out the brain are ElectroEncephaloGraphy (EEG), MEG .

Non-Invasive: ElectroCorticoGraphy (ECoG) Neural signals are essentially pulse steams. Artificial neural network programming using Mat lab is very popular in extracting the features of neural signals.

Neurons in the brain: This is the signal carriers in the brain that transfer information from sensory inputs of the body (eyes, ears, tongue, nose and skin) to the process The current version of the NIA uses carbon-fibers injected into soft plastic as substrate for the headband and for the sensors and achieves sensitivity much greater than the original silver chloride-based sensors using a clip-on interface to the wire harn. Processing unit of the brain (hippocampus).

Signal Extractor

The material chosen for the probe has to have suitable properties depending upon whether invasive or non-invasive technique is employed. In non-invasive technique the probes are directly implanted into the brain to connect to neurons. The non-invasive technique lets the probes to be fixed on the outer surface of the skull. Very sensitive probes are required for non-invasive technique, while tissue-friendly probes are more important for invasive techniques.

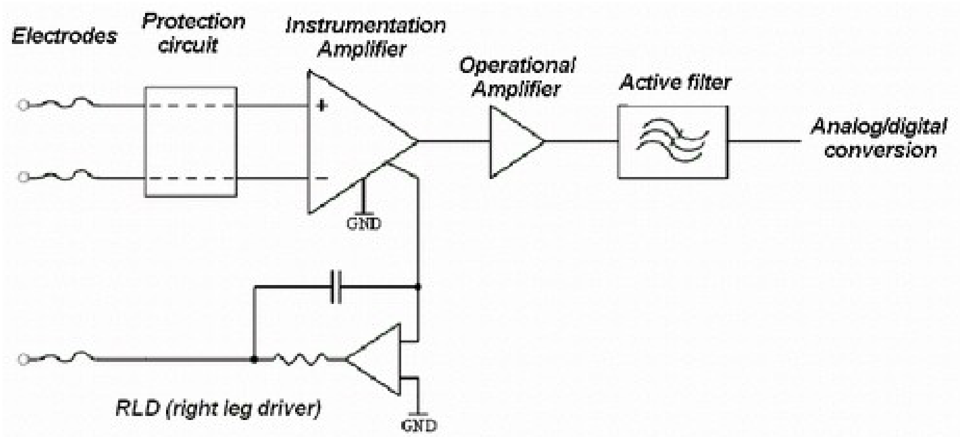

Figure 2: Probes for connecting signals

Neural Signal Actuator

The Neural Impulse Actuator (NIA) is a Brain-computer interface (BMI) device, which attempt to move away from the classic input devices like keyboard and mouse and instead read electrical activity from the head, preferably the EEG. The name Neural Impulse Actuator implies that the signals originate from some neuronal activity, including sympathetic and parasympathetic components that have to be summarized as biopotentials rather than pure Neural signals. The biopotentials are decompiled into different frequency spectra to allow the separation into different groups of electrical Signals. Individuals signals that are isolated comprise alpha and beta brain waves, electromyograms and electro oculograms.

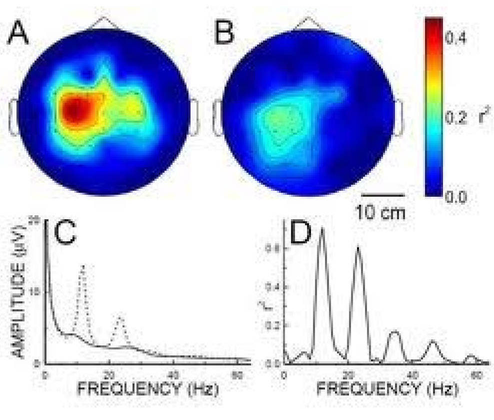

Figure 3: Areas of research for development of right probes

Biocompatibility

Various techniques to convert bio-inert material into biomimetic material are under research. Surface fictionalization and plasma processing are some of the techniques employed to covert substrate materials like silicon into bio-metric material by introducing a functional group chemically into structure. Chemical reactions due to various fluids and environmental factors of the brain can corrode the material. Therefore careful search is essential. Mismatch in size can damage a neuron during penetration of probes into brain. Therefore smaller size of probe is preferable.

High sensitivity and high selectivity material development for probes

Neural signals are captured through biochemical, optical or electromagnetic means. Because of high density of neurons placing of probes is difficult. This also introduce high noise immunity at the probes input and increases the chance of error in identifying the correct signal. Therefore the probes need to have high noise immunity and selectivity so that only the neural signals of interest are selected.

Reliability

Following are the fundamental problems of implantable microelectrode arrays, which can be removed so that probes can capture signals reliably overtime

a. The brain often encapsulates the device with a scar tissue.
b. Normal brain movement may cause micromotion at the tissue electrode interface
c. Proteins absorb onto the device surface

Neural processor

Signal extractor collects electrical signal from neural probes and process them to extract the signal information to be used to control the various devices interfaced to BCI system. Preamplifier refines the neural signals detected by probes. Its output has high signal to noise ratio and can be feed to a high speed analog to digital converter (ADC), so that signal can be processed using neural processor. Neural processor is a DSP tuned for neuron computing. The processor has to process the neural signals to classify, characterize and identify them. It needs to analyze the operations of neural process of several neurons simultaneously. A highly parallel architecture is required to process such a large number of inputs.

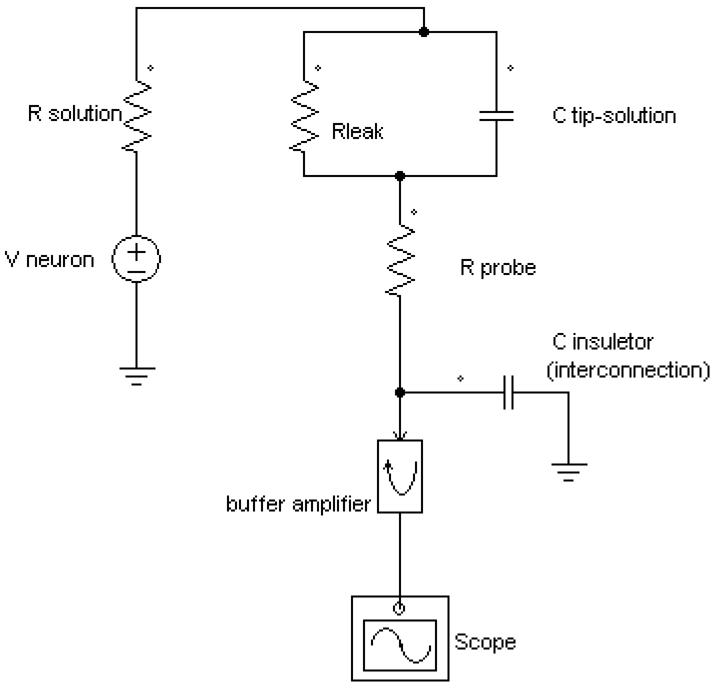

Figure 4: Probes for Neural Processor

Neural signals

Neurons undergo continuous interactions in the brain. This has a prehensile structure with finger like projections at both the ends that serve as antenna (receiver and transmitter). There is space between neurons called *Synapse*.

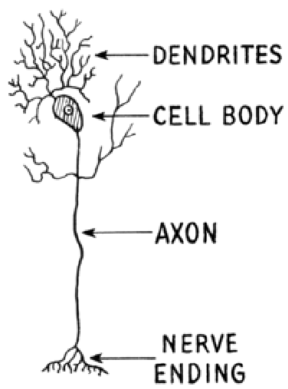

Figure 5: Structure of neurons

Understanding the synaptic processes that gather, store and retrieve information through the brain is cutting edge of modern neuron science.

The vast amount of data associated with neural signal processing necessitates development of encoding of neural data for lesser bandwidth requirement. First it reduces the large memory requirement in chip which directly impacts the chip size.

Processing speed improves because for the same operating frequency, the processor can process faster on a large amount of data if the data size is smaller. Neural signals are assembles of spike trains. These give data which depend upon the frequency, amplitude components and source of channels from which spikes trains has been recorded.

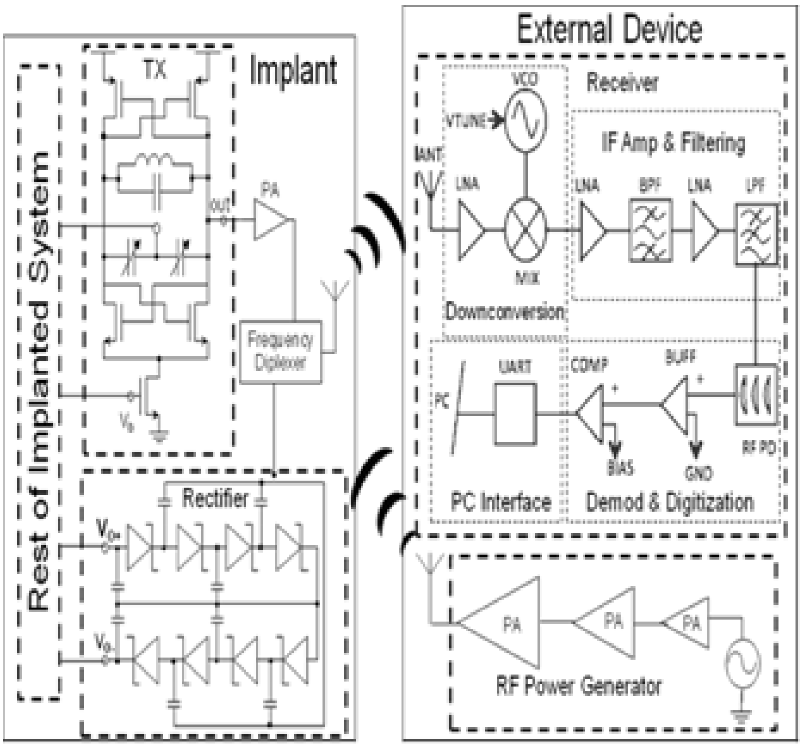

Figure 6: block diagram-neuro feedback machine

Basic theory

The MOS M1 acts as control switch to gain control over the switching of the circuit such that the switching is done by controlling the gate voltage given to it turns on the MOS which grounds the entire circuit voltage from the tank circuit to prepare for full cycle of operation.

The tank circuit F2 enables the selective grounding and control of the oscillations of a particular frequency to pass through the M1 transistor so that the selective tuning is made possible.

The transistors M2 and M3 are the cross – coupled giving rise to a perfect matching of the isolation provided by M4 and M5. MOS transistors offer high input impedance that makes its usage as a much preferred input stage of many devices and circuits to avoid direct grounding of the actual resonance circuits.

The resonance circuits provide the energy sustenance to provide oscillations of the desired frequency, which is passed to the load through a ground noise filtering circuit so as to eliminate ground noise, which is much prevalent in circuit when implemented in the printed circuit boards... The ground traces offer a certain amount of resistance to the signals which need to be protected against the noise to maintain signal quality and strength.

Experimental Set and Result Analysis

Arbitrary selection of components and their values need to be done based on the small signal analysis of the circuit and the time domain transient analysis results.

Basically, the two tank circuits that are used in the circuit involve small values of inductors and capacitors which can be tuned or changed depending upon the range of oscillations required. The oscillation frequency can be found from the above mentioned analysis using small signal model of the circuit.

The ac component part of the equation (1), when let to zero, yields the value of ω, which is a function of the passive components such as L and C (including R, which is a damping component in the oscillations generated)

This ω, is taken as reference radians that would give the value of the exact frequency of oscillations to which the circuit need to be retuned and redesigned for every simulation run done.

The permutation and combination possibility of the number of instances of change in the LC is given as 24. However, since two of the tank circuits are LC for producing sustained oscillations, the values have to be chosen based on the small signal analysis. Thus approximately 10 combinations of L and C can be tried for various settings.

The capacitors C4 and C5 are to be replaced using the values as given by the equation of frequency of oscillations. These capacitors would be replaced by the varactor diodes and lumped distributed elements of the same value available in the market.

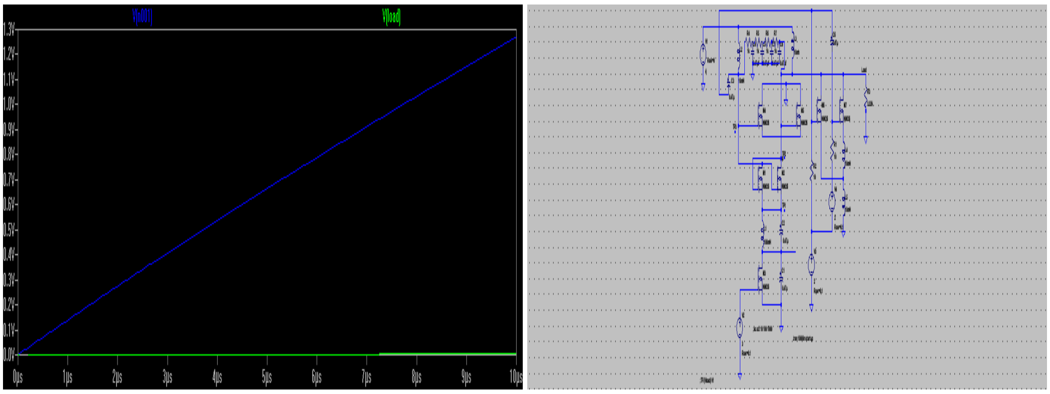

Figure 7*:* The probe for one setting of the L and C and the excitation voltage for lumped element equivalent circuit

Table 1: Linear Analysis

Time	Excitation Voltage
	Fig 6
0.00 µs	0.00v
0.5 µs	0.065v
1.00 µs	0.130v
2.00 µs	0.283v
3.00 µs	0.401v
4.00 µs	0.537v
5.00 µs	0.661v
6.00 µs	0.755v

Shown above in fig (6) is the voltage observed through the probe for one setting of the L and C and the excitation voltage.

Simulation can be done for various values of L and C by change in the settings and the diode. The different values are tabulated in Table1.

Variation in Gating Signal means variation in the output. As we have seen, passing an input function in response to a CONTROL signal applied to the transistor, thereby to generate an output function related to the input function. In this project the focus is to utilize this quality of the pass transistor in the design of my NCO by having a gating signal which will help to provide the required output.

The resonance circuits provide the energy sustenance to provide oscillations of the desired frequency, which is passed to load through a ground noise filtering circuit so as to eliminate ground noise, which is prevalent in circuit when implemented in the printed circuit boards.

The ground traces offer a certain amount of resistance to the signals which need to be protected against the noise to maintain signal quality and strength.

Neural signal classification

Critical thinking is required for right match of the correct signal source, its generated neural signal and intended psychological behavior. Cross-correlation analysis is used to reveal temporal and spatial relationships between multiple spike trains in neuronal circuit, in which two neurons are synaptically connected or two neurons are independent but receive a common input.

Different mathematical techniques of pattern matching has to be applied to classify neural signals and associated them with the particular physiological phenomena.

Signal transmission

Antenna design

The wireless features of neuro feedback machine are enabled by an antenna, a 2.4-

GHz transmitter for wireless data transfer, and a radio-frequency (RF) rectifier for remote powering and recharging. The antenna is a monopole-like structure. This antenna is modelled using High Frequency Structural Simulator (HFSS) in free space and implanted in tissue. HFSS is used to simulate the input impedance of the antenna and roughly model the antenna pattern, when accounting for tissue effects on electromagnetic wave propagation. The final antenna topology is a curved monopole/whip antenna whose length is approximately a quarter wavelength at 2.4 GHz and the simulated gain for this structure is about 6dBi.

Wireless transmitter

A 2.4-GHz wireless transmitter has been designed on the Texas Instruments 130-nm CMOS process and custom made to feed the skull antenna, provide enough power to ensure successful data reception when implanted. To allow for wireless signal transfer, the signal has to be modulated onto a 2.4-GHz carrier through an on-off keying modulation scheme. The oscillator has to be turned off during the off cycles by controlling the NMOS current source bias voltage. A buffer is necessary to isolate the oscillator from the external connection to the antenna. Although other power-amplifier types can achieve greater efficiencies, a self-biased class AB power amplifier can be chosen for this work because it provides a good compromise between efficiency, low phase noise, and minimization of die area.

External receiver

For this application, the implant has much more stringent requirements than the external device, especially in terms of complexity and power consumption. The transceiver link therefore has to be optimized as an asymmetric link where the minimal power draw of the implanted transmitter is priority and the complexity can be pushed over to the external receiver side. A custom-designed receiver architecture can be used to decode the unlocked-carrier, non-coherent, 2.4 GHz On-Of Key-modulated transmission from the implant. The receiver consists of an antenna, low-noise amplifier, down-converter, intermediate-frequency (IF) amplifiers and filters, a demodulation and digitization block, and a computer interface circuit. After reception from the antenna, passing through the L-match network, and RF amplification through the LNA, the signal will be down-converted through a non-coherent, single-conversion, low-IF architecture. After down-conversion, IF amplification and filtering /isolation will be performed.

Experiment analysis and report

The simulation on the above circuit [figure.7] for nco synchronization for up conversion and down conversion has been performed using spice tool. neuron voltage has been performed in reference with different brain waves like alpha, beta, gamma and delta in PSIM SIMULATION software.

Result

The result analysis is estimated by using simulation tool PSIM.

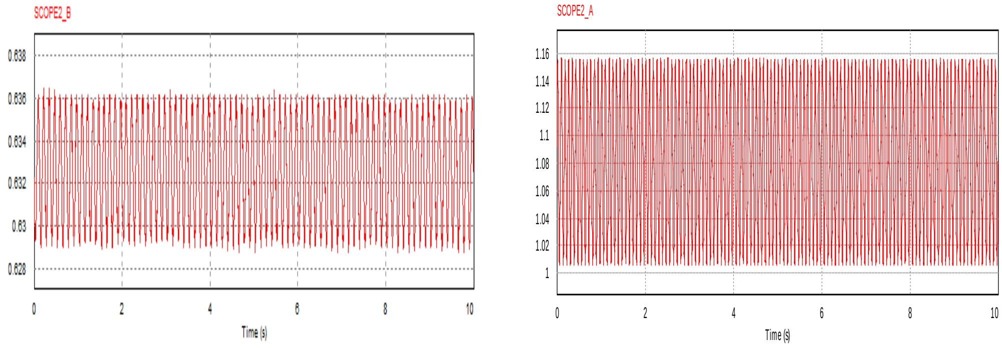

Figure 7: Independant Parameter

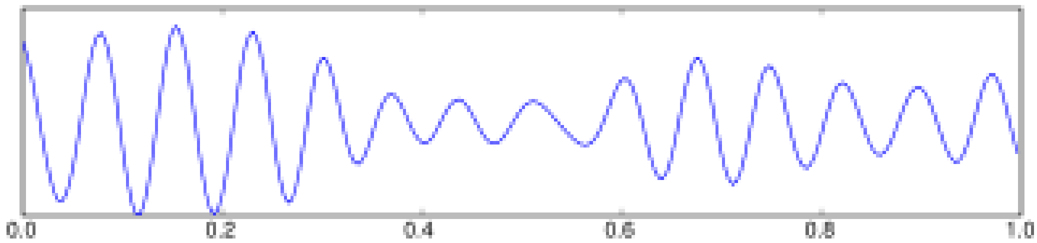

Figure 8: Graph of the Alpha waveform taken from EEG.

Conclusion

Thus we have seen this is applicable in our daily life especially for handicapped, those who have lost their organs. Apart from these this can be used for making our day to day work easy and fast. In this paper, a BCI system was developed that allows the control of a neuroprosthesis. The resulting system is robust. No direct dependency of the BCI accuracy or detection time on the stimulation intensity could be detected. This approach could be used with other neuroprosthesis where accuracy of user interaction is important without the need for instantaneous control action. In following work, the working system described here can be tested in subjects with neurological impairment

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