Wireless EEG amplifier for brain-computer interface

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Many different disorders can disrupt the neuromuscular channels through which the brain communicates with and controls its external environment. A brain–computer interface (BCI) is a direct communication pathway between the brain and an external device which can be useful in case of restoring partial activity of patient with injury.

BCI separates into two categories: invasive (brain implant, electrocorticography) and non-invasive (electroencephalography, magnetic resonance imaging).

Invasive BCI research has targeted repairing damaged sight and providing new functionality to persons with paralysis. Invasive BCIs are implanted directly into the grey matter of the brain and produce the highest quality signals of BCI devices but are prone to scar-tissue build-up, causing the signal to become weaker or even lost as the body reacts to a foreign object in the brain. This technology remains very good biocompatibility of electrodes and has several difficulties with correct surgical placement of them.

In non-invasive BCI recorded signals have been used to power muscle implants and restore partial movement. Although they are easy to wear, non-invasive implants produce poor signal resolution because the skull dampens signals, dispersing and blurring the electromagnetic waves created by the neurons. Although the waves can still be detected it is more difficult to determine the area of the brain that created them or the actions of individual neuron.

The most popular non-invasive BCI based on electroencephalography (EEG) signals processing. EEG is the most studied potential non-invasive interface, mainly due to its fine temporal resolution, ease of use, portability and low set-up cost. But as well as the technology's susceptibility to noise, another substantial barrier to using EEG as a brain–computer interface is the extensive training required before users can work the technology.

In most EEG based BCI special software detects P300 brainwave response, also called event related potential. These waves are generated involuntarily when people see something they recognize and may allow BCIs to decode categories of thoughts without hard training patients first.

For example, this stimulus can be presented as a matrix of letters that flash one at a time, and the user selects a specific letter by producing a P300 evoked potential when that letter flashes. This type of BCI allows people with serious neuromuscular disabilities to communicate, to use PC keyboard and etc.

In basic design of any BCI system signals from the brain are acquired by electrodes on the scalp or in the head and processed to extract specific signal that reflect the user’s intent. These features are translated into commands that operate a device (e.g. a simple word processing program, a wheelchair, or a neuroprosthesis). Success depends on the interaction of two adaptive controllers, user and system. The user must develop and maintain good correlation between his or her intent and the signal features employed by the BCI; and the BCI must select and extract features that the user can control and must translate those features into device commands correctly and efficiently.

For most current BCIs, the output device is a computer screen and the output is the selection of targets, letters, or icons presented on it. Selection is indicated in various ways. Some BCIs also provide additional, interim output, such as cursor movement toward the item prior to its selection. In addition to being the intended product of BCI operation, this output is the feedback that the brain uses to maintain and improve the accuracy and speed of communication. Initial studies are also exploring BCI control of aneuroprosthesis or orthesis that provides hand closure to people with cervical spinal cord injuries. In this prospective BCI application, the output device is the user's own hand.

There aren't need a large number of EEG leads for event related potential's processing. Using 6 leads from standard scheme of electrode arrangement (10-20) can provide a good P300 brainwave processing. For example, it can be 4 differential channels based on next leads: F3-C3, C3-P3, F4-C4, C4-P4.

Using a small wireless amplifier can provide a great opportunities in area of EEG based BCI systems. Was developed wireless amplifier with miniature dimensions and low cost. Major parameters of this device are:

- 4 differential EEG channels;
- analog gain – 2080;
- pass band 1 – 50 Hz;
- sample rate - 122 Hz;
- working area up to 200 m^2;
- wireless protocol IEEE 802.15.4 / ZigBee;
- dimensions 55x35x15 mm;
- time in transmission mode up to 10 hours;
- charging by USB from PC.

Hardware design of amplifier based on microcontroller Texas Instruments CC2530. It's a system-on-chip solution tailored for IEEE 802.15.4, ZigBee applications. With its large flash memory of up to 256 KB, the CC2530 is ideal for ZigBee PRO applications. Additionally, the CC2530 combines a fully integrated, high-performance RF transceiver with an 8051 MCU, 8 KB of RAM, 32/64/128/256 KB of flash memory, and other powerful supporting features and peripherals. The CC2530 has various operating modes, making it highly suited for systems where ultralow power consumption is required. Short transition times between operating modes further ensure low energy consumption.

Signal goes through several operating amplifiers, low pass and high pass RC filters set frequency limitations (1 – 50 Hz for EEG), second low pass filter used for antialiasing. RF frontend based on discrete balun and chip antenna. Flash memory circuit used for stable transmitting in cause of signal loss. Device can charge from PC by USB, built in Li-Ion accumulator allows to work up to 10 hours in active transmitting mode. Wireless ZigBee technology allows working up to 10 amplifiers at one time.

Small dimensions allow attaching to the electrode cap. This fastening method is very comfortable for patient and reduces noise from cable displacement. Cheap and ergonomical wireless amplifiers can greatly improve research in area of EEG based BCI and provide wide possibilities in biofeedback system's application.