Functional Electrical Stimulation: BIONs ™

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Since the time of the first experiments of Luigi Galvani two centuries ago, it has been known that electrical currents can be used to stimulate muscle contraction. Yet, only in the past thirty years have engineers and neurophysiologists recognized the demands that movement places on sensors and control systems. Technological advances in the past decade have made it possible to create BIONs. BIONs reanimate useful function in paralyzed or atrophied limbs by acting like a bionic neuron and strengthening and retraining muscles by mimicking the nerve impulses from the brain. They are individually addressable, single channel electrical interfaces. Being roughly the size of two grains of salt, they are modular and micro miniature devices that are implanted via a needle directly into the "motor spot." The basic idea behind the BIONs is that they provide a long-term wireless interface between an electronic controller and a neural function in the body. This is achieved by having a magnetic transmitter coil (RF transmission coil) placed over the region of the body that contains the implanted BION. This coil receives power and command signals via inductive coupling to generate stimulation pulses to activate motor units. As the BION contains no battery, the electrical power is derived from the externally generated RF field in the transmitting coil.

There are three different designs of BIONs; the BION1 provides stimulation only and operates only when powered and controlled by an external transmission coil in the vicinity of the implant(s). The BION2 provides stimulation and sensing via bi-directional telemetry but only when powered and controlled by an external transmission coil. The BION3 is programmed and charged by an external coil but it can generate stimulation programs autonomously while drawing energy from an internal, rechargeable battery.

The BION1 is a cylindrical glass capsule with two rigidly mounted electrodes on each end. The internal package is dominated by the antenna coil that has 200 turns of 1mil-insulated coil wrapped around a cylindrical ferrite form, which maximizes the capture of magnetic energy. The most important quality of the BION other than its size is that the package protects the electric circuitry for the damaging effects of water, especially the data receiver and the digitally controlled stimulus pulse generator. The aspect of the design that encompasses this are the hermetic glass to metal seals.

The way that the BION works is that myoelectic signals will be detected by existing electrodes and amplified, digitalized and processed within the BION2 implant prior to outward transmission. Data will be used as command signals from voluntarily activated muscles and as feedback to quantify muscle recruitment by functional electrical stimulation. Within the BION there are accelerometers based on capacitive charge detection that provide limb orientation with respect to gravity and translational acceleration, these provide kinesthesia. The Electrical currents in the metallic conductors are carried by free electrons and passed by way of two methods, a capacitive "double layer" charging and electrochemical reactions. The command transmission is a method of modulation of the closed loop class-E transmitter that allows for extremely high data rates with no extra power requirements.

BIONS are being used is ongoing clinical trials in three classes of treatment that are based on the nature of the interaction between the patient and the technology. There is the therapeutic Electrical stimulation, functional electrical stimulation and neuromodulatory stimulation. They all study the effects of using electrical currents to produce muscle stimulation. Two in specific were run to 1) prevent chronic shoulder subluxation and 2) strengthening the quadriceps muscles. After a six to twelve week period of two to three stimulation sessions ten to thirty minutes each day there was a 87% to 111% reduction of subluxation and improved knee function, decreased pain and a 15% on average muscle thickness increase. With these positive results and ongoing trials and improvements the BION will soon take over the current practices of painful electrical shocks as stimulators on the surface of the skin.