Implantable Muscle-Powered Piezoelectric Generator

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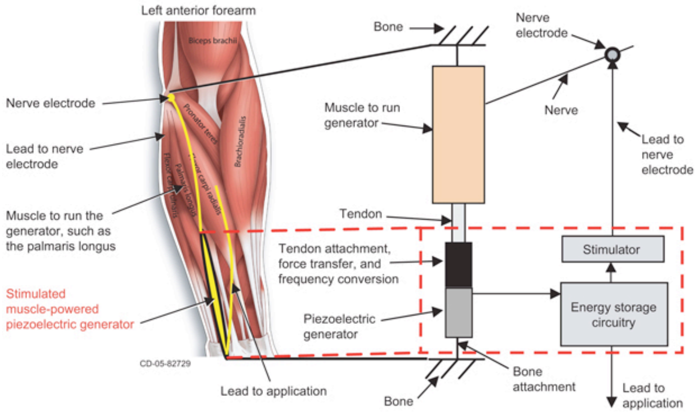
Many people use implantable functional electrical stimulation devices everyday to support their health conditions. The pacemaker or neuro-stimulators are two examples. In these devices there must be some sort of power source in order to function. They are either batteries implanted along with the device or some sort of transcutaneous power supply. The problem with implanted batteries is that they eventually deplete and require costly surgeries to replace. The transcutaneous source is an external unit that aligns with internal coils to charge the device. The external equipment itself is inconvenient and also misalignment of the coils can cause power interruptions. Fortunately, a possible solution to the issue is the Implantable Muscle-Powered Piezoelectric Generator.

The basic concept is a power system that is able to not only generate power for load applications but also be self-replenishing. The system is composed of a piezoelectric stack in series with a muscle tendon unit and a bone.



Piezoelectricity is a property of certain materials that have the ability to convert mechanical strain into electrical potential. Muscle itself acts like a power conversion system delivering an output power that is 5 orders of gain greater than the input. This output power increases as the cross-sectional area of the muscle increases. The idea is to stimulate the muscle to contract creating a compressive force or mechanical strain to alter the symmetry of the material, which generates an electrical potential. The output voltage is divided to power the device application as well as the generator.

To test this concept simulations as well as a physical experiment were performed. For the simulation a model circuit was tested using SPICE. The circuit consisted of a voltage source representing the piezoelectric material, a capacitor to hold the voltage, a diode bridge to convert to a DC voltage, a filter capacitor to filter any remaining AC Voltage, and a load resistor used to measure the DC output. The simulation tested the circuit using an applied force, representing the muscle contractions, of 25N, 50N, 100N, 200N, and 250 N.

A physical experiment was also performed to confirm the simulations. The experiment was set up using the same circuit as the simulation. Here the voltage source was replaced using the piezoelectric stack generator and the output voltage was measured. The results from the simulation and the experiment were compared and were in agreement.

The required input power necessary to drive the stimulator unit is estimated to be 40μW and power necessary to generate tetanic contractions in the muscle is 6μW for a total of 46μW. Three scenarios were analyzed. The first was using a 50N-applied force, which is comparable to the brachioradialis muscle. The output power generated was about 8μW, an insufficient amount to be self-replenishing. The second scenario was a 100N-applied force, which is comparable to the latissimus dorsi. The output power was about 54μW, a power output that would be self-sufficient but with little power left for the application device. The third scenario was a 250N-applied force. This is comparable to the gastrocnemius muscle. The output power was about 640μW, enough power to be self-sufficient and power an application device.

The results show that a self-replenishing muscle-powered piezoelectric generator can potentially replace currently used batteries and transcutaneous power sources. The next step is to perform *ex vivo* or *in vivo* testing on animals. Also the design of a prototype that entails a low power stimulator as well as circuitry to store excess power should be considered.