Passive Inductively-Powered Dual-channel Implantable Pulse Generator System for Rodent Sciatic Nerve Stimulation

Sachit Kshatriya, Derrick Liu, David Valencia, Kyle Golobish, Emily Szabo, Stephan Nieuwoudt, Manfred Franke
Neuronoff, Inc., Cleveland, Ohio, USA

Introduction

- The use of implantable pulse generators (IPGs) for long term neurostim therapies is limited by the longevity of implanted batteries.
- Functionally dynamic, remotely powered and controlled IPGs address these challenges by adopting battery-less, wireless power transfer (WPT) technologies.
- We demonstrate an IPG system utilizing helical wire structure electrodes (HWSEs) with a transcutaneous driver, before connecting HWSEs to an IPG.

Materials & Methods

- Helical wire structure electrodes (PtIr,polyolefin) were manufactured (Neuronoff,Cleveland,Ohio) for attachment to custom IPGs.
- Printed circuit boards for the IPG system were manufactured and assembled (JLCPCB,Shenzhen,China), dip-coated in thermoplastic polyurethane (TPU), and embedded in silicone for a hermetic seal.
- Rodents (CD-1,Sprague-Dawley,Charles-River,Durham,NC) were implanted with HWSEs on each sciatic nerve under IACUC approved protocols.
- HWSE placement was validated by measuring joint angles and off-target contractions 0 - 8 weeks post-implant before the IPG placement..

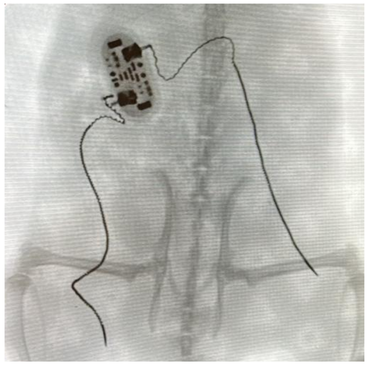


Figure 1: Fluoroscopy of two HWSEs (previously placed on the left and right sciatic nerves) surgically connected to the anodic and cathodic channels respectively of the IPG. Specifically, the biphasic variant of the IPG is implanted here.

Electronic Design

Highly efficient, handheld, implant-agnostic external driver hardware to address multiple implant types: single-channel, dual-channel, triple-channel, and biphasic.

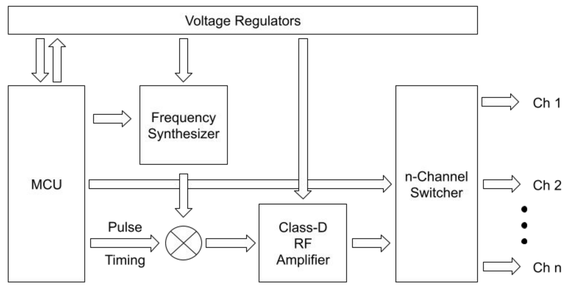


Figure 2: Functional diagram of the remote controller. The MCU controls transmitted power, frequency, and series LC channel by enabling/addressing the voltage regulators, the frequency synthesizer, and the channel switcher respectively. Frequency is mixed with control pulses before being fed to the class-D amplifier. The amplified signal, hence referred to as RFout, is wirelessly-coupled to the passive analog circuitry of the implant to generate waveforms in **Figure 3**.

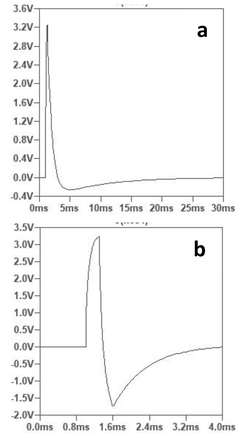


Figure 3: Example output waveforms for **(a)** single phase and **(b)** biphasic implant types across a 1kΩ parallel with 1µF tissue model. Pulse widths and stimulation frequency is determined by programming the remote controller.

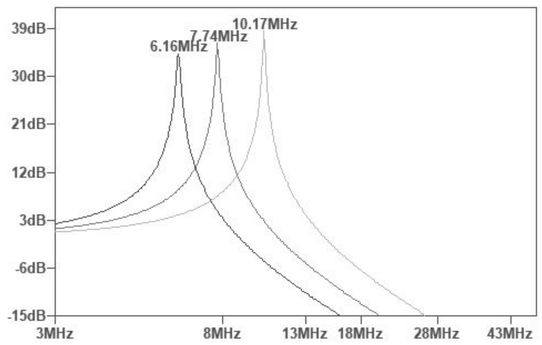


Figure 4: Resonant series LC transmission tank frequency response for each addressable channel. Each transmission tank has an unloaded Q ~ 50.

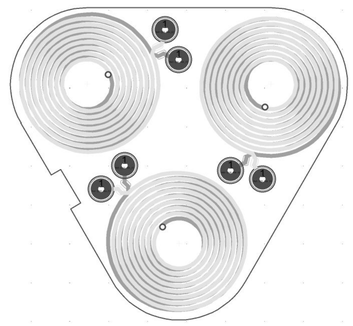


Figure 5: Example IPG receiver coil arrangement. High-Q PCB coils allow for tight spacing without cross coupling between independent control channels.

Results

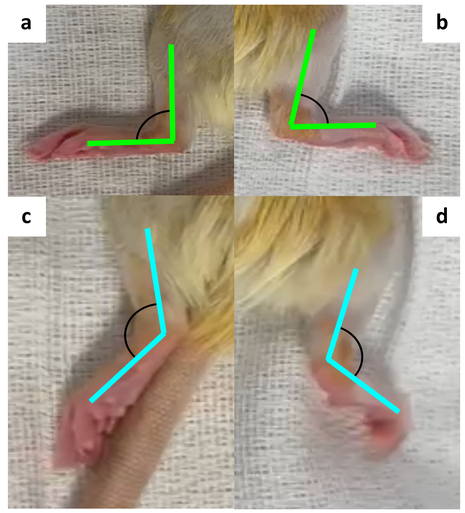
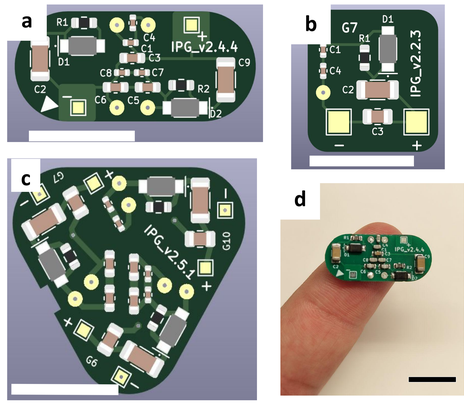


Figure 6: (a, b) Hind limb joint angles formed by the knee joint, ankle joint, and metatarsal head at rest **(c, d)** change in joint angles in response to 100Hz, 3.1V RFout, 300µs per phase biphasic stimulation of the IPG shown in **Figure 1**. Joint angles did not change in a different transmission coils orientation with respect to the IPG coils.

Figure 7: Renders of the different functional implants under the IPG system. Each scale bar represents 10mm.
(a) biphasic IPG (as used in the aforementioned preclinical implementation in rodents)
(b) single-channel IPG (monophasic only)
(c) triple-channel IPG capable of independent single phase stimulation for three targets – representing circuit topology (**Figure 5**) for the receiver coils
(d) biphasic IPG on a finger tip to demonstrate relative scale of this prototype circuit prior to attachment of connectors, hermetic sealing, and encasement.



Conclusions and Future Directions

We have developed a wirelessly powered and controlled, customizable IPG system that is power efficient and offers fully addressable stimulation parameters with only passive implanted components. The biphasic IPG variant is effective in triggering changes in hind limb join angles as a response to stimulation in rodent models.

Acknowledgements and Disclosures

Supported by Neuronoff Inc. SK, DL, DV, KG, ES, SN, MF hold shares or options in Neuronoff, Inc. SK, DL, DV, KG, ES, SN, MF are employees of Neuronoff, Inc.

Contact Us: info@neuronoff.com | (216) 505-1818 | www.neuronoff.com