國立陽明交通大學

電子研究所

碩 士 論 文

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National Yang Ming Chiao Tung University

Master Thesis

應用於神經調節技術之八通道
單端雙相電流電壓雙模式高壓刺激器

Dual-Mode Monopolar Biphasic
8-Channel Stimulator for Neuromodulation
Realized in High-Voltage CMOS Process

研 究 生：劉子齊 (Liu, Tzu-Chi)

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應用於神經調節技術之八通道

單端雙相電流電壓雙模式高壓刺激器

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摘要

神經調節是一種將電訊號或藥劑直接送至目標區域的神經，以達到改變或調節神經活動的技術。近年來，使用功能性電刺激對神經進行刺激的神經調節療法已被廣泛應用在如帕金森氏症、癲癇、聽力喪失、失明、慢性疼痛等各種疾病或病症的治療中。而隨著積體電路以及生醫電子技術的進步，逐漸有能夠應用於各種疾病臨床治療的系統單晶片被開發出來，例如應用於癲癇或帕金森氏症治療的神經失調控制系統單晶片。

本篇論文提出了一個八通道單端雙相位定電流-定電壓雙模式電刺激器。為了能夠有更大的刺激強度，因此使用了 0.18μm 的高壓製程進行實現。本刺激器利用固定轉導偏壓電路(constant gm bias circuit)搭配數位-類比轉換器(DAC)來產生不同大小的參考電壓、電流，接著使用電流鏡(current mirror)以及運算放大器(operational amplifier)將其放大至所需的刺激脈衝強度，最後透過刺激驅動電路(stimulus driver)將刺激訊號送至指定的輸出通道。結合放電電路(discharge circuit)的功能，此刺激器能夠在符合安全規範的情況下對神經進行刺激。在定電流刺激模式中，此刺激器能產生±0.2mA~±10mA 的大範圍輸出刺激電流，而在定電壓模式的輸出則可達±0.2V~±10V。因此本刺激器能夠根據不同的應用來使用適當的

刺激強度。並且受益於高彈性的輸入控制訊號設計，刺激的各種參數如刺激頻率、脈衝寬度等，皆可以進行調整。

本刺激器已透過電性量測的方式在電極與人體組織介面的等效電路模型上進行驗證，若與適當的電荷幫浦電路搭配，本刺激器能夠順利進行高電壓以及負電壓的操作，並且不會產生過壓問題以及 p-n 接面的順向導通問題，因此能夠與其他電路進行系統單晶片整合。

關鍵詞/字 — 神經調節、高壓電刺激器、單端雙相刺激、深腦刺激、植入式生醫裝置

Dual-Mode Monopolar Biphasic 8-Channel Stimulator for Neuromodulation Realized in High-Voltage CMOS Process

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Abstract

Neuromodulation is a technology that modulates nerve activity by delivering electrical pulse or pharmaceutical agents to the nerves directly. In recent years, neuromodulation therapy with functional electrical stimulation has been widely used to treat various diseases or symptoms such as Parkinson's disease, epilepsy, hearing loss, profound hearing loss, blindness, chronic pain, etc. With the advancement of integrated circuit processes and bioelectronics technology, system-on-chip (SoC) devices that can be applied to the clinical treatment of various diseases have been developed, such as neurological disorders control SoC for treating epilepsy or Parkinson's disease.

In this thesis, an 8-channel monopolar biphasic stimulator with constant current and constant voltage dual-mode is proposed. The stimulator is fabricated in a 0.18μm high-voltage process for a higher stimulation intensity. In the stimulator, the constant gm bias circuit and the digital-to-analog converter (DAC) are combined to generate the reference voltage and current in different values. The reference voltage and current are amplified to the required output stimulus level by the current mirrors and the operational amplifiers. The stimulus signal is delivered to the selected output channel by the stimulus driver. With the discharge circuit, the stimulator can stimulate nerves without violating safety standards. A wide output range is designed for the stimulator that the output current can be adjusted from ±0.2mA to ±10mA, and the output voltage can be adjusted from ±0.2V to ±10V. Therefore, the appropriate intensity of stimulus pulse can be determined according to the applications. Besides, the stimulation parameters, such as frequency, pulse width, etc., can be modified with the flexible input control signal.

The proposed stimulator has been verified by measurement with an equivalent impedance model of electrode-tissue interface. Combining with a charge pump circuit, the stimulator can work without device overstress and p-n junction forward biasing problem under high voltage and negative voltage operation, and it can be integrated into a SoC device.

Keywords – neuromodulation, high-voltage electrical stimulator, monopolar biphasic stimulation, deep brain stimulation, implantable biomedical devices.