國立交通大學

電子研究所

碩士論文

應用於植入式人工耳蝸之
四通道單端雙相電流刺激器系統設計

Design of Four-Channel Monopolar Biphasic
Current Stimulator System
for Cochlear Implant Application

研　究　生　：黃昱凱　　Yu-Kai Huang
指 導 教 授　：柯明道　教授　Prof. Ming-Dou Ker

中華民國　一〇八 年　八 月

國立交通大學

電子研究所

碩士論文

應用於植入式人工耳蝸之
四通道單端雙相電流刺激器系統設計

Design of Four-Channel Monopolar Biphasic
Current Stimulator System
for Cochlear Implant Application

研 究 生 ：黃昱凱 Yu-Kai Huang
指導教授 ：柯明道 教授 Prof. Ming-Dou Ker

中華民國 一〇八 年 八 月

應用於植入式人工耳蝸之
四通道單端雙相電流刺激器系統設計

Design of Four-Channel Monopolar Biphasic Current Stimulator System for Cochlear Implant Application

研究生　：黃昱凱　　Student　：Yu-Kai Huang

指導教授　：柯明道　　Advisor　：Ming-Dou Ker

國立交通大學

電子研究所

碩士論文

A Thesis
Submitted to
Institute of Electronics
College of Electrical and Computer Engineering
National Chiao Tung University
in Partial Fulfillment of the Requirements
for the Degree of
Master of science
in
Electronics Engineering
August 2019
Hsinchu, Taiwan, Republic of China

中華民國　一〇八 年　八 月

應用於植入式人工耳蝸之
四通道單端雙相電流刺激器系統設計

學生　：黃昱凱
指導教授　：柯明道　教授

國立交通大學

電子研究所

摘　　要

近年來，隨著生醫科學及半導體領域的迅速發展，整合智慧型仿生系統於系統單晶片可行性大幅提高，其中人工耳蝸為一種植入式的聽覺輔助裝置，人工耳蝸對於尚未受損之聽覺神經進行脈衝式電刺激，藉此使失聰的患者恢復一定的聽語知覺。本論文提出一個應用於人工耳蝸之電刺激器系統的電路設計，此電刺激器系統使用了四個電極放置於耳蝸骨表面以及一個電極放置於圓窗，達到非侵入式的電極植入方式，保留患者部分的聽覺感知。電刺激器電路提供單端雙相位電流刺激，並且支援雙通道同時刺激的功能，電刺激之波型與電流大小皆可藉由數位控制訊號彈性調整，電流大小的設計範圍為 10 微安培至 1.2 毫安培，解析度為 10 微安培，正負極性的輸出電流之匹配程度符合植入式醫療裝置之一般安全規範。此外，考量到輸出負載之高阻抗，刺激器驅動電路之工作電壓必須高於正常工作電壓 (1.8V/3.3V)，由於單端刺激的方式，同時也需要負的高電壓，以產生雙相位的刺激電流。此電刺激器電路實現於 TSMC 0.18 微米低壓工藝，透過電設計的技巧使其具有高電壓之耐受能力，並且能正常操作在正負高電壓同時存在之電源域。電刺激器所需之正負高電壓源由多電荷幫浦穩壓系統所提供，該系統具有同時提供 ± 6 伏特以及 -3 伏特之功能，並且能透過變頻之回授系統成功耐受驅動電路抽載高達 2.5 毫安培的電流，其中正負高壓產生器之電荷幫浦以電路的手法利用四相位之時鐘控制電荷轉移開關的導通與否，達到壓抑逆電流的產生，進而提高功率轉換效率，同時亦確保實現於低壓工藝之電荷幫浦免於電晶體閘極過壓問題。此電刺激系統已成功於低壓工藝中下線，也完成了電性量測驗證。

關鍵字：生醫晶片、人工耳蝸、電刺激器、高壓產生器、電荷幫浦

Design of Four-Channel Monopolar Biphasic Current Stimulator System for Cochlear Implant Application

Student : Yu-Kai Huang
Advisor : Prof. Ming-Dou Ker

Institute of Electronics
National Chiao Tung University

ABSTRACT

With rapid development of biomedical science and semiconductor, SoC for biomimicry is becoming feasible. Cochlear implant is an implanted hearing-aid device which provides senses of sound by electrical stimulation. In this work, the stimulator system employs four electrodes placed on the surface of bone and one electrode on the round window to preserve partial hearing. The proposed circuit is capable of providing monopolar biphasic current stimulation with single-output or dual-output mode. The pulse shape and magnitude of current can be flexibly controlled by digital signals, and the tuning range of the magnitude is from 10μA to 1.2mA with resolution of 10μA. The matching between cathodic and anodic current is within the safety regulation of implantable devices. Besides, positive and negative high voltages are required due to the high impedance of load and monopolar configuration. The proposed design is realized in low voltage process with the ability to tolerant high voltage and operate in complex power domains. The positive and negative high voltages are provided by multiple-charge-pump which is able to provide $\pm$6V and $-$3V simultaneously. With pulse-frequency-modulation feedback control, the voltages can be regulated within 2.5mA loading current. Also, the four-phase clock scheme is utilized to suppress the generation of reverse current; hence, the power efficiency can be improved. The proposed stimulator system has been taped out in TSMC 0.18μm low voltage CMOS process and the functions are verified by electrical measurement.

Keywords : biochip, cochlear implant, stimulator, high voltage generator, charge pump