國立陽明交通大學

電子研究所

博士論文

Institute of Electronics

National Yang Ming Chiao Tung University

Doctoral Dissertation

互補式金氧半無線電源管理次系統及其在植入式人工耳蝸微系統之應用

The Design of CMOS High Efficiency Wireless Power Management Subsystems and Their Applications on the Design of Cochlear Implant Microsystem

研　究　生：王嵩皓 (Wang , Sung-Hao)

指導教授：吳重雨 (Wu, Chung-Yu)

　　　　　柯明道 (Ker, Ming-Dou)

中華民國一一 O 年七月

July 2021

互補式金氧半無線電源管理次系統及其在植入式人工耳蝸微系統之應用

The Design of CMOS High Efficiency Wireless Power Management Subsystems and Their Applications on the Design of Cochlear Implant Microsystem

研　究　生：王嵩皓　　　Student：Wang , Sung-Hao

指導教授：吳重雨 博士　　　Advisor：Dr. Wu, Chung-Yu

柯明道 博士　　　Dr. Ker, Ming-Dou

國立陽明交通大學

電子研究所

博士論文

A Dissertation
Submitted to Institute of Electronics
College of Electrical and Computer Engineering
National Yang Ming Chiao Tung University
in Partial Fulfillment of the Requirements
for the Doctor of Philosophy
in
Electronics Engineering

July 2021
Hsinchu, Taiwan
中華民國一一０年七月

互補式金氧半無線電源管理次系統及其在植入式人工耳蝸微系統之應用

學生: 王嵩皓　　　　指導教授: 吳重雨/柯明道 博士

國立陽明交通大學 電子研究所

摘要

關鍵詞: 人工耳蝸微系統、植入式生醫裝置、無線電源與資料傳輸、活體動物實驗。

隨著植入式醫療元件的快速發展，生理訊號擷取放大系統結合無線能量與資料傳輸系統在健康監控、腦機介面以及閉迴路神經調控的應用上已被大量的運用。其大致上可以分為含有電池的植入式生醫裝置與不包含電池的植入式生醫裝置。本論文中提出的無線能量及資料傳輸與電源管理次系統扮演了提供植入式生醫裝置能量以及與外界溝通的媒介。此外，所設計的無線充電電路則可針對含有鋰電池的植入式生醫裝置進行充電。本論文中採用了新的設計概念分別實現了兩個晶片。第一個晶片實現了一個無線充電與電池電源管理的電路，透過電池電壓偵測以及資料回傳電路以及可調式功率發射器，輸出的功率可以隨著電池電壓的增加而改變，進而降低體內接收端充電電路的功率消耗。實驗結果顯示，在電池電壓範圍 3.3 V 至 4.2 V 的範圍之內，接收端主動式全波整流器的輸出電壓可以保持在比電池電壓稍大一些的電壓準位，且平均功率轉換效率為 90.9%。因此，所提出之高效率無線充電電路適用於由鋰電池供電之植入式生醫裝置。第二個晶片將無線功率與雙向資料傳輸電路整合進一個植入式人工耳蝸微系統。在此晶片中，採用近場無線傳輸能量並同時傳收資料的的方式去提供無線電源給植入的生醫元件使用並傳收資料與外界溝通，體外控制器傳到體內的部分採用二進制相位鍵移調變技術，而體內傳到體外的部分採用改良式負載鍵移調變技術。經由實驗驗證，可以量測到的傳輸資料率為每秒 211 千位元之資料率。通過 13.56 MHz 無線電源和雙向數據傳輸，產生的刺激模式和命令可傳送至植入晶片進行控制。所實現出的改良型植入式人工耳蝸微系統除了功能驗證外，也經過天竺鼠的體內動物試驗，在電誘發腦幹聽性反應波形顯示出誘發的第三波，代表其確實能成功引發聽覺神經的反應。本論文中的骨導式人工耳蝸微系統展示了一個安全且有效的聽力治療方式。在未來，將可成為感音神經性聽力損失患者的一個新臨床治療選擇。

The Design of CMOS High Efficiency Wireless Power Management Subsystems and Their Applications on the Design of Cochlear Implant Microsystem

Student: Sung-Hao Wang Advisor: Dr. Chung-Yu Wu / Dr. Ming-Dou Ker

Institute of Electronics
National Yang Ming Chiao-Tung University

ABSTRACT

Keywords: cochlear implant, implantable medical device, wireless power and bilateral data telemetry, in vivo animal test.

Implantable medical devices (IMDs) are widely used in human body to perform various functions of prostheses, monitoring, and modulation. Recently, rechargeable Lithium-ion (Li-ion) batteries have been used in IMDs with battery because of safety requirement, rechargeability in long-term implantation. In this thesis, new concepts have been applied to the two fabricated ICs. In the first work, a high-efficiency CMOS wireless battery charging system with battery voltage tracking and global power control through the proposed pulsed load-shift keying (PLSK) backward data telemetry technique is designed. The power transmitted from the adaptively controlled power transmitter (ACPT) for battery charging is automatically adjusted with the battery voltage tracking through the PLSK backward data telemetry. Therefore, the generated rectifier output voltage is only slightly larger than battery voltage and tracks with battery voltage during the charging time of linear battery charger. Experimental result shows that the average receiver efficiency with battery voltage tracking from 3.3 V to 4.2 V and global power control is 90.9% which is 14.9% higher than that without these techniques. In the second work, an improved design of implantable SoC with monopolar biphasic constant current stimulation (CCS), double-electrode multiple stimulation, and the evoked compound action potential (ECAP) acquisition is proposed for the BGCI microsystem. The implanted SoC is powered wirelessly and the stimulation patterns are sent from the external unit. The improved BGCI microsystem enables ECAP and electrode-tissue impedance acquisition. The acquired ECAP signal and impedance data can provide additional help to estimate the effectiveness of stimulation during clinical diagnosis. In vivo animal tests on guinea pigs have shown that the Wave III of electrically evoked auditory brainstem (EABR) response is successfully evoked by the stimulation of the improved BGCI microsystem.