國立陽明交通大學

前瞻半導體研究所

碩士論文

Institute of Pioneer Semiconductor Innovation

National Yang Ming Chiao Tung University

Master's Thesis

應用於植入式生醫系統單晶片具強化穩定性與可靠度之 13.56 百萬赫茲無線功率與雙向數據傳輸電路設計

The Design of a 13.56-MHz Wireless Power and Bidirectional Data Telemetry Circuit with Enhanced Stability and Reliability for Implantable Biomedical System-on-Chips (SoCs)

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摘要

隨著植入式生醫元件需求的增加，無線功率和數據傳輸技術變得至關重要，體內晶片需要使用近場線圈傳輸資料，並使用無線充電解決更換電池與晶片功率限制的問題。本論文使用 TSMC 0.18-μm CMOS 製程，設計並實現了一種具備強化穩定性與可靠度之 13.56 MHz 無線功率與雙向數據傳輸電路。在功率傳輸方面，提出了一種改良型的 E 類功率放大器，使其耐壓能力提升至 9.9 V，以提升輸出功率能力。此外，將自適應功率控制器由 3 位元提升至 4 位元，以更精細的控制體內晶片整流器的輸出電壓。針對脈衝式負載鍵移反向遙測，本論文提出了一種自動設定電路，能在每個資料封包結束時自動重置解調器，將潛在的數據反轉錯誤限制在單一封包內，確保後續數據的正確性。另外，改進後的比較器顯著降低了誤碼率，量測結果顯示，本系統的二進制相位鍵移與脈衝式負載鍵移數據傳輸在 115.2 kbps 的速率下，誤碼率皆小於 3×10^{-8}，且最高傳輸速率可達 500 kbps。

關鍵詞：無線功率傳輸、雙向數據遙測、E 類功率放大器、二進位相移鍵控、脈衝負載移位鍵控、自動設定電路、植入式醫療裝置。

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Abstract

With the increasing demand for Implantable Medical Devices (IMDs), wireless power and data transmission technologies have become crucial. The internal chip requires near-field coils to transmit data and uses wireless charging to address the issues of battery replacement and power limitations. This thesis presents a 13.56 MHz wireless power and bilateral data telemetry circuit with enhanced stability and reliability, implemented using the TSMC 0.18-μm CMOS process. In terms of power transmission, an improved Class-E power amplifier is proposed, improving its voltage tolerance to 9.9 V to enhance output power capability. Furthermore, the resolution of the Adaptive Power Controller (APC) is increased from 3 bits to 4 bits to provide finer control over the output voltage of the internal chip's rectifier. For PLSK backward telemetry, this thesis proposes an Auto-Set circuit that automatically sets the demodulator at the end of each data packet. This mechanism confines potential data inversion errors to a single packet, ensuring the correctness of subsequent data. Additionally, the improved comparator significantly reduces the Bit Error Rate (BER). Measurement results show

that the BER for both BPSK and PLSK data transmission is less than 3×10^{-8} at a data rate of 115.2 kbps, with a maximum transmission rate of up to 500 kbps.

Keywords: Wireless power transfer, bilateral data telemetry, Class-E power amplifier, Binary Phase-Shift Keying (BPSK), Pulsed Load-Shift Keying (PLSK), Auto-Set circuit, Implantable Medical Devices (IMDs).