國立交通大學

電子研究所

碩士論文

應用於細胞組織研究之十六通道
雙端單-雙向電流刺激器系統設計

Design of 16-Channel Bipolar Biphasic or Monophasic Current Stimulator System for Cell Tissue Research

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摘要

醫生常利用生醫晶片給入脈衝式電刺激的方式刺激神經來達到緩解症狀的效果，本論文提出一應用於神經細胞組織生長研究的電路設計，於神經細胞輸入一電流脈衝，觀測神經元軸突的生長情形以及突觸在主皮質神經元之變化，並實際以生物膠實驗驗證功能。此電刺激器系統根據實驗需求提供 16 通道的雙端輸出，可細區分為小電流端輸出與大電流端輸出，並且支援同時刺激的功能，單、雙向位波型與電流大小可由數位控制訊號彈性調整，小電流端輸出電流大小的設計範圍為 100 微安培至 1.5 毫安培，解析度為 100 微安培；大電流端輸出電流大小的設計範圍為 1 毫安培至 4 毫安培，解析度為 1 毫安培。另外，雙向電流的匹配程度滿足植入式醫療裝置的一般性規範，並設有兩種主動放電電路以滿足各種放電機制的需求與考量，並能夠根據需求開啟或關閉已降低額外功耗。另外，系統電路中有一正電荷幫浦系統，能夠在快速電流抽載下提供穩定的+6 伏特給刺激器使用。此系統透過變頻回授的機制成功耐受 4 毫安培的電流抽載，並採用四相位時鐘控制電荷轉移開關，確保電晶體閘極免於過壓的同時，免於逆向電流的產生並提升轉換效率，含有電源管理系統使整個電刺激器系統在工作時，僅需 1.8V 與 3.3V 的直流工作電源。此系統電路實現於 tsmc 0.18 微米的高壓工藝，並考量植入系統所需要的高整合性與面積限制無使用外接元件，於 PCB 版設計下完成了電性量測並在生物膠中進行實驗驗證。

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Abstract

Doctors often use biomedical chips to inject pulsed electrical stimulation to stimulate nerves to relieve symptoms. This thesis proposes a circuit design applied to the study of nerve cell tissue growth. A current pulse input to nerve cells to observe the growth of neuron axons situation and changes in synapses in the main cortical neurons. It is verified with agar gum experiment. This electric stimulator system provides 16 channels of double-ended stimulator, which can be divided into the small current lead and large current lead. The biphasic or monophasic waveform and current levels can be digitally controlled for flexible adjustment. The design range of the output current of the one lead is 100 μA to 1.5 mA, and the resolution is 100 μA, and another is 1 mA to 4 mA for 1 mA resolution. In addition, there is a positive charge pump system in the system circuit, which can provide about stable +6 volts to the stimulator under fast current pumping. This system successfully withstands 4 mA current pumping through the pulse frequency modulation mechanism. Besides, it uses a four-phase clock to control the charge transfer switch to ensure that the transistor gate is free from overstress. The reverse current path is ensued not exist and better power conversion efficiency is achieved. Hence, the entire stimulator system only needs 1.8V and 3.3V DC working power and it can be controlled by one analog discovery2. This system is implemented in the tsmc 0.18μm high-voltage process and the measurement verification is completed under the PCB board and agar gum experiment.