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A Closed-Loop Neural-Prosthetic Device for Real-Time Epileptic Seizure Control

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Epilepsy is a major neural disorder which affects 1% of the world population. Currently, most patients are treated by antiepileptic drugs or resection surgery. But there are still more than 5% of the patients remain either drug-resistant or not suitable for resection surgery. Electrical neuromodulation provides these patients an effective way for treatment. Several implantable prosthesis devices are developed to deliver continuous electrical stimulation to suppress abnormal brain seizures. They have limited efficacy and require frequent battery replacement surgery. Responsive neural stimulation device can provide seizure-triggered stimulation, but the low seizure detection rate is still a great concern. To overcome the above limitations, an 8-channel neural-prosthetic system-on-chip (SoC) for real-time closed-loop epileptic seizure control is proposed for the implantable system. The SoC is composed of two major blocks: 1) a closed-loop signal-processing path including an 8-channel intracranial EEG (iEEG) acquisition unit consisting of an 8-channel front-end amplifier and a 10b analog-to-digital converter, a bio-signal processor, and an adaptive stimulator; 2) a wireless transmission system composed of a MedRadio-band transceiver and a wireless power supply system. The SoC has low power consumption. The closed-loop signal-processing block detects the seizure pattern on iEEG and provides feedback electrical stimulation. The processor extracts the epileptic features in time-domain entropy and frequency spectrum. It can eliminate the detection errors caused by motion artifact and enhance the detection rate significantly. The wireless power supply system is embedded to supply a continuous and steady power for the implanted device to eliminate the need for battery. Wireless signal transmission is also designed for real-time signal monitoring. The SoC has been applied to animal test with Long Evans rats. The test results show a detection accuracy of 92% within 0.8s detection latency under a power consumption of 2.8 mW. According to the animal test results, a new version of SoC embedded with human epilepsy seizure detection algorithm and aiming at human clinical applications is under design. After the required preclinical trials are completed, clinical trial will be conducted.

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