

Wireless Functional Electrical Stimulation

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Functional Electrical Stimulation (FES) provides various approaches for rehabilitation for patients who suffer paraplegia or stroke. FES allows restoring and maintaining motion and Activities of Daily Living (ADL) can be performed. This gives disabled people the opportunity for independence. These facts served as the motivation to implement a novel wireless device for FES. The aim of this project was the development of a complete system to demonstrate the feasibility of wireless stimulation with four channels.

Introduction

Functional Electrical Stimulation (FES) provides various approaches for rehabilitation for patients who suffer paraplegia or stroke. FES allows restoring and maintaining motion and Activities of Daily Living (ADL) can be performed. This gives disabled people the opportunity for independence. These facts served as the motivation to implement a novel wireless device for FES to demonstrate the feasibility of a four channel wireless stimulation.

Methods

The wireless FES system consists of two stimulators to apply the stimulation with four channels and one coordinator to control the stimulators. The voltage regulated stimulator was supplied by a Li-Po battery and capable of producing biphasic pulses. An Atmega328 microcontroller from Arduino was used. To transmit data, Bluetooth modules were connected with the microcontrollers. To indicate communication and stimulation, status LEDs were mounted. For transcutaneous stimulation, surface electrodes were used. Basis for the coordinator was an Evaluation Board from Keil. The stimulator algorithm interpreted received data and generates desired pulse patterns defined by several variables like Pulsethickness, Inter-Pulsetime and RestOfperiod and more. The coordina-

tor runs with a Real Time Operating System (RTOS) allowing Bluetooth setup and parameter adjustment via joystick.

Results

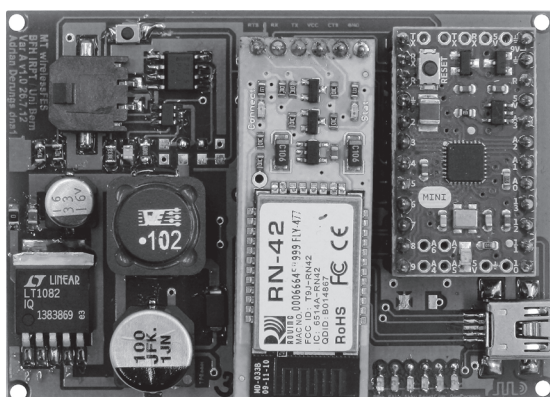
A prototype for wireless stimulation with four channels was developed. Bluetooth had a range of 45 m indoors. The booster output voltage was reliable and stable with acceptable deviations. It was demonstrated that latency for data transmission was 16.82 ms, 20.57 ms and 41.76 ms by baud rates of 115200 Baud, 57600 Baud, and 9600 Baud respectively. Stimulation was as expected for different loads. For resistive loads the current follows the adjusted biphasic rectangular shape and for loads with capacitive elements the current had an exponentially decreasing shape.

Discussion

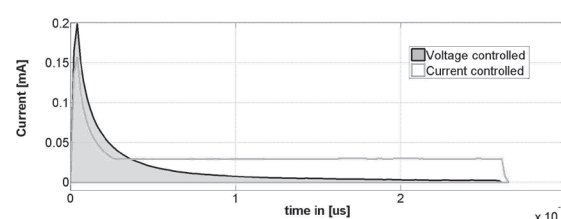
The objective of a mobile stimulation with four channels was fulfilled. The measured output voltage of the booster corresponded with calculations as stated in the datasheet. The required time for data modulation could be determined by calculation and coincided with measurements. Handling of Bluetooth latency is a challenge for further development since its inconsistency. The resulting waveforms can be explained by principles of electrical engineering.



Adrian Derungs



Stimulator providing two channels. Bluetooth module (red) microcontroller (blue).



Comparison of the amount of charge generated by a voltage- (grey) and current regulated (white) stimulation.