Externaly-Powered Implantable Device Dedicated to Monitor FES Events and Parameters

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Abstract: This paper describes the design of a low area and low power device which permits both stimulation and monitoring of electrode-tissue interface. The monitoring device uses telemetry in order to avoid percutaneous wires. A resistance to frequency converter (RFC) is proposed and then to 8-bits data translation is done which eliminates the need for an analog to digital converter (ADC). The RFC is composed of a resistance to voltage converter, a voltage to current converter and current to frequency converter which results in many advantages such as reduced area overhead and the RFC linearity improvement. The integration of the measuring device to the rest of the stimulator is based on a selection block. The main application of the proposed system is to recuperate the urinary bladder functions.

Index terms: Electrical stimulation, inductive coupling, bidirectionnel electromagnetic link, electrode-tissue interface. impedance measurement.

I. INTRODUCTION

Research on stimulators evolve very quickly, but ensuring the quality of the stimulation and thereby the safety of biological tissue still to be done. Getting measurement information directly from implanted neuro-stimulators could be essential to check in vivo critical parts of electronics and to characterize the evolution of any interface between the human body and implanted electrodes. Theses electrodes are often submitted to corrosion, displacement, breakdown which result in tissue damage [1, 2].

In order to assess electrode functionality and tissue state, monitoring of electrode-tissue impedance can be achieved which allows to deduce the state of the interelectrode tissue. An early proposed circuit consists in incorporating electrodes, leads wire and contacting tissue in an operational amplifier free-running oscillator [3]. In this paper, a circuit based on a resistance to frequency converter (RFC) with an efficient frequency shift keying (FSK) transmitter using a radio frequency (RF) link is proposed. In the remaining sections of this paper, we describe the proposed monitor and we show the preliminary simulation results of the design.

II. THE MONITORING DEVICE

The proposed monitoring device, included in a bladder implantable stimulator, is divided into the following building blocks (Figure 1): The measuring device which is based on a resistance to frequency converter, the transmiting part which brings the information to the external controller and a selection block to synchronize the stimulation and electrode-tissue interface monitoring. Electrodes and interelectrode tissue are monitored by inserting them in the RFC. The RFC is followed by a frequency estimator (Figure 2).

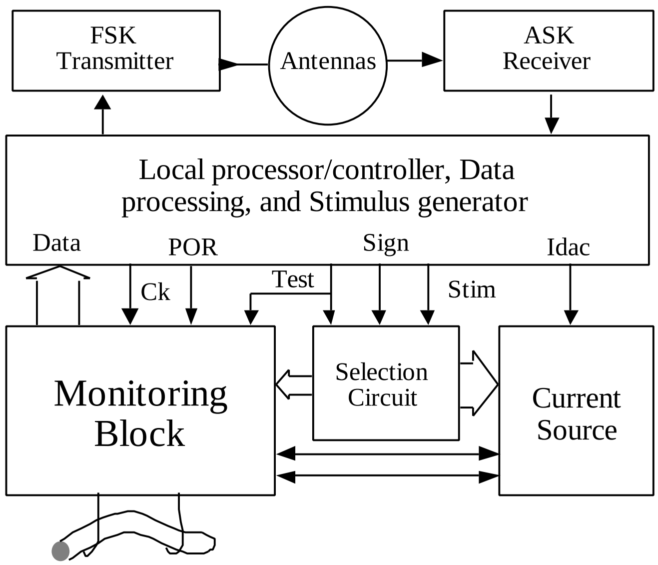

Fig. 1. Stimulator including the monitor.

The entire measuring device has been designed without any resistor which results in a more accurate, cost effective and less area consuming circuit. The interface (impedance) mesearument is completed using the RFC which is composed of resistance to voltage, voltage to current and current to frequency converters.

The resulting impedance value is transmitted to outside the body through a serial to parallel converter and frequency shift keying modulator employed to transmit the data through a standard asynchroneous transmission protocol with one start bit, 8 data bits, one parity bit and 2 stop bits.
The presented system contains also a selecting device to avoid conflict between stimulation and impedance measurement. This selecting device allows biphasic, monophasic, balanced and unbalanced stimulation.

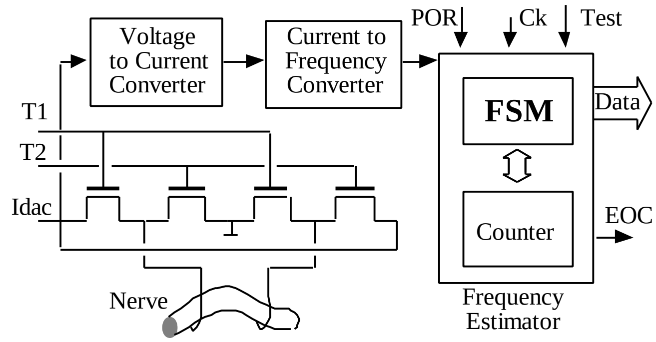

Figure 2. Building blocks of the monitor.

The whole control part has been designed and implemented using VHDL Langage. The modulation is made with two independent oscillators (2.05 and 1.95 MHz) and a 2 to 1 multiplexer. Finally, the power amplification is made with 2-stages class A bipolar amplifier which is loaded by the transmitting antenna.
Area saving on implantable neurostimulator rejects the use of crystal oscillators, and external RC with digital implemented cells in a FPGA (Field Programmable Gate Array) have been done.

III. PRELIMINARY RESULTS

Simulations shows a good compatibity between stimulating and measuring parts. The digital part of a first prototype has been implemented and tested using a FPGA chip and the amplifier have been made with discrete components.
Tests show that even with the on board inductive power supply of the neuro-stimulator, 8 bits data can perfectly be transmitted over 10 cm through human obstacles such as hands. The transmitter is able to reach a maximum bit rate of 50Kb with a global power consumption of 6mW.
A VLSI integrated version of the RFC has been designed and implemented using CMOS 0.35 um technology. It occupies an area of about 0.06mm2 (RFC: 0.002 mm2; frequency estimator: 0.057 mm2; selection circuit: 0.001mm2).
The maximum frequency of the RFC to be converted is 136 KHz. It is possible to detect electrode defaults as shown in Table 1.

Table 1 Measured values and significance.

Electrode and tissue resistance (Ohm)	Frequency (fosc in KHz)	Converted frequency	Significance
100	136	11101000	Short circuit
1 K	120	11001100	Between
20 K	2	00000011	Open circuit

IV. CONCLUSION

A system to monitor electrodes failures and state change of the tissue in the vicinity of electrodes has been implemented and tested. This system promise to allow significant improvement in reliability of implanted microstimulators. The presented system has the advantage of being simple and the prototyping shows that it is efficient and multipurpose. We are about to connect and test this transmitter with a system measuring the impedance of a nerve.

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