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A simple conditioner for resonant intraocular pressure sensor

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Abstract

Intra-ocular pressure sensors embedded in contact lenses will be of great benefit to long-term treatments of glaucoma. This paper focuses on the resonant type of this kind of sensor and proposes a minimal power consuming conditioning. The system is based on the harmonic oscillator principle and uses very few discrete components to realize a proof of concept. After the description of the eye-care professionals identified needs, we present the sensing principle, and give details on the realized circuit. Brief results are given with signal capture from a prototype to validate the concept.

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1. Introduction

Glaucoma is a degenerative optic neuropathy that affects more than 60 millions of people and is the second cause of blindness over the world [1]. It is known that a high intra-ocular pressure (IOP) often rises the risk of the disease. Thus the treatment includes medication aimed to lower the IOP. Unfortunately, the efficiency of these treatments decreases with time, resulting in higher doses and several side effects. Then regular monitoring of IOP must be carried on to adapt the treatment. This is done thanks to a *tonometer*, a quite bulky instrument by eye-care professionals.

The main problem with this procedure is that it can only provide a punctual measure of the IOP whereas it is known to vary on a 24-hour cycle and with significant differences between healthy and glaucomatous subjects [2]. To deal with this, active sensors embedded in contact lenses have been developed [3], notably by the *Sensimed* company. More recently, the *Ophthalmia* company designed a portable IOP sensor in the form of a passive resonant circuit embedded in a soft contact lens (fig. 1). The resonant frequency of the equivalent RLC circuit belongs to the 27 MHz ISM band (fig. 2) and varies linearly with the deformation of the cornea caused by the IOP variations. The conversion rate being approximately 330 Hz/mmHg [4].

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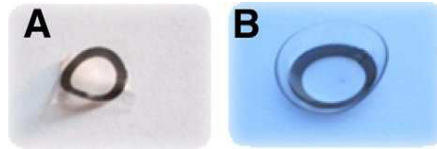


Fig. 1. The passive sensor before (A) and after (B) encapsulation in a soft eye lens. Courtesy of *Ophthalmia* company.

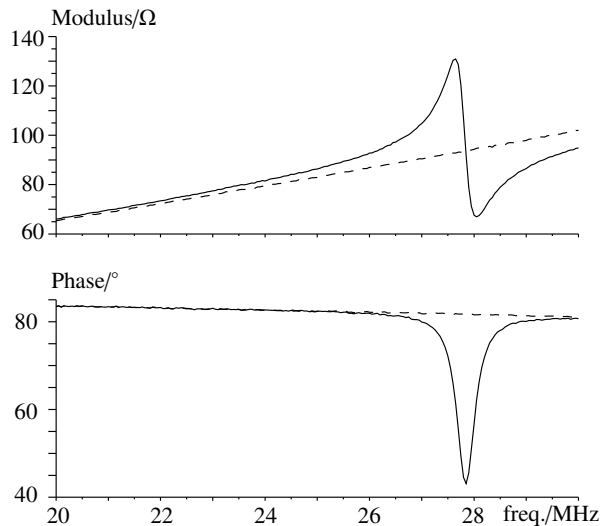


Fig. 2. Measured impedance (modulus and phase) of the sensor-coupled antenna (solid line) and of the non-coupled antenna (dashed line).

2. Conditioning system

To be of wide acceptance, the whole system must perform repetitive contactless measures of the sensor resonant frequency for more than 24 hours, while keeping a relatively small form factor. This implies quick and low-power conditioning. We meet these needs by using a near-field inductive coupling of the sensor with an antenna located on a pair of glasses. The very small electronic circuit and battery can easily fit in the glass branches.

We design the conditioner system as a harmonic oscillator. Thus, a IOP acquisition can be done with a simple measure of the oscillator frequency. The resonant part of the circuit must be the antenna coupled with the sensor. Unfortunately, the equivalent impedance does not present a directly exploitable resonance (fig. 2). Instead, we choose to use the differential impedance (ΔZ) between the coupled antenna and the same antenna but without any sensor. This differential impedance exhibits a maximum that can be use as the oscillator operating point (fig. 3).

This approach leads to the differential structure of the fig. 4. Two identical current sources are connected to antennas. The voltage difference between the antennas then depends linearly to ΔZ . It is amplified and back-fed to the current-source inputs.

An equivalent single-input, single-output model can be deduced from the differential structure (fig. 5). This is the classical positive-feedback closed-loop model of a harmonic oscillator. This structure can generate spontaneous oscillations provided that the Barkhausen's criterion is met.

$$G G_m \Delta Z = 1. \quad (1)$$

This relation is use to adjust the gain G . Practically, the gain must be slightly over-tuned in order for the oscillations to start and to compensate potential weaker coupling.

The circuit itself only uses four large-band op-amps and some matched resistors (fig. 6) to realize a harmonic oscillator. The design mimic the model of fig. 4. The leftmost op-amps form the differential voltage amplifier stage.

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