WIRELESS LESS-INVASIVE BLOOD PRESSURE SENSING MICROSYSTEM FOR SMALL LABORATORY ANIMAL REAL-TIME MONITORING

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DNA sequencing of small laboratory animals together with *in vivo* real-time biological information is crucial for various advanced biomedical and system biology research. A miniature, light-weight, long-term, reliable bio-sensing implant system is highly desirable to capture the real-time biological information from a "free" roaming laboratory animal as depicted in Figure 1. Among all the biological signals, blood pressure is one of the most important vital signals, and there is no good solution for its long-term *in vivo* monitoring to date. In this paper we present a wireless less-invasive long-term implantable blood pressure monitoring system as shown in Figure 2. The system employs an instrumented elastic circular cuff, wrapped around a blood vessel to sense real-time blood pressure waveforms. The elastic circular cuff is made of silicone and is filled with low viscosity bio-compatible insulating fluid with an immersed MEMS pressure sensor and integrated electronics. The MEMS sensor measures the pressure waveform in the cuff coupled from the expansion and contraction of the vessel. This technique avoids vessel penetration and substantially minimizes vessel restriction due to the soft cuff elasticity. The measured waveform can be processed by integrated electronics followed by wireless data telemetry to an external transceiver. Figure 3 shows the overall electronic system architecture. The entire electronic system is inside the cuff as depicted in Figure 2 for illustration purpose. In the final design an RF powering coil will be located outside the cuff to minimize packaging complexity. Figure 4 presents a detailed 3-D configuration of the blood pressure measurement cuff, where a rigid silicone isolation ring is used to decouple the sensing cuff, which is located at the structural center, from environmental variations in animal body. This technique can greatly suppress low frequency drift. The overall structure exhibits a radius of 3.2 mm and a width of 3-5 mm. The sensing cuff has a radius of 0.5 mm, a typical dimension of small animal artery. The MEMS pressure sensor and integrated electronics are immersed in silicon oil enclosed inside the cuff, as shown in the Figure 4. An RF powering coil is located outside the cuff with sealed feed-through connections to the electronics. The silicone cuff is fabricated using conventional molding and bonding techniques [1] and is tested by wrapping it around the right carotid artery of a laboratory rat with a commercial catheter-tip transducer inserted into the left carotid artery as a reference shown in Figure 5. Figure 6 presents a measured blood pressure waveform from the monitoring cuff with a reference waveform, indicating a matched blood pressure characteristic with a scaling factor of approximately 0.25. A MEMS capacitive pressure sensor is designed and fabricated using a similar process as described in [2]. Figure 7 shows an SEM of a fabricated sensor exhibiting a dimension of 0.4 x 0.4 x 0.5 mm^3 with a measured nominal capacitance value of 2pF and a sensitivity of approximately 1 fF/mm Hg. Figure 8 presents a micrograph of an IC chip containing all the electronic functions shown in Figure 3. The chip is fabricated by a 1.5 µm CMOS process, occupies 2 mm x 2 mm area, and consumes 150 µA DC current from 2V supply. Initial electrical characterization demonstrates expected functionalities. The assembled electronic system covered by silicon coating is shown in Figure 9, which is then interfaced with the blood pressure measurement cuff as presented in Figure 10. The cuff exhibits a diameter of 6.5 mm, length of 4 mm, and a total weight of 280 mg, and can be used for acute and long-term small laboratory animal real-time implant evaluation, which is planned as the next step.

Word count: 599

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References

[1] P. Cong, et al, Proc. Transducers 2006, pp. 2002-2005.
[2] D. J. Young, et al, *IEEE Sensors Journal*, August, pp. 464-470, 2004.

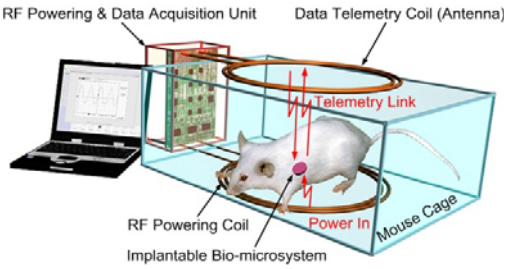

Fig. 1. *In vivo* real-time biological signals wireless monitoring system

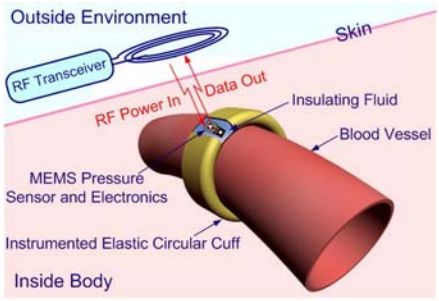

Fig. 2. Wireless less-invasive implantable blood pressure

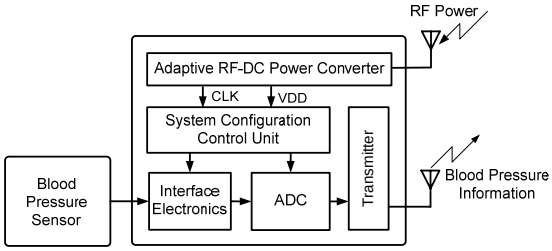

Fig. 3. Implant electronic system architecture

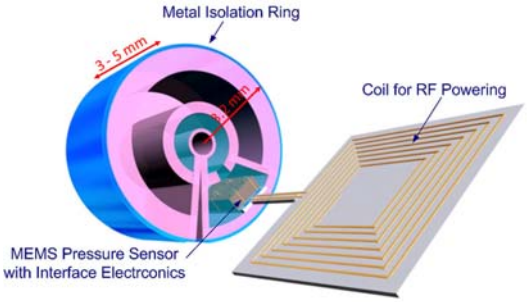

Fig. 4. 3-D configuration of the blood pressure measurement cuff

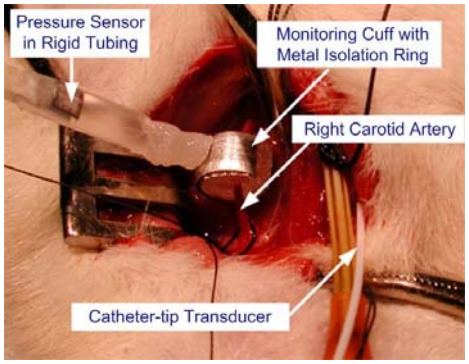

Fig. 5. Laboratory rat implant trial

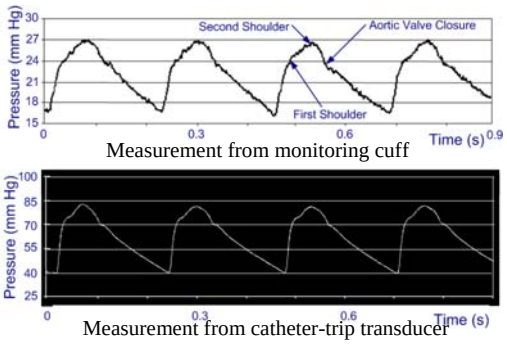

Fig 6. Blood pressure measurement waveforms

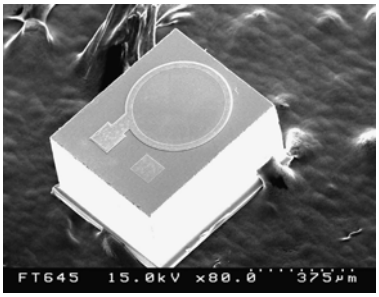

Fig. 7. SEM of fabricated MEMS capacitive pressure sensor

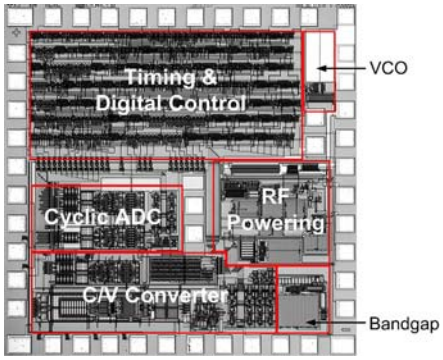

Fig. 8. IC micrograph

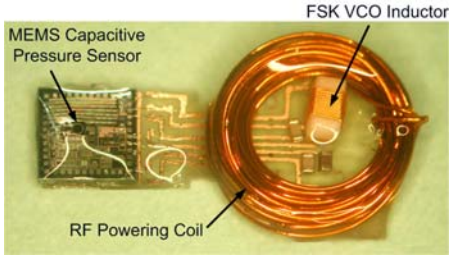

Fig. 9. Electronic system packaging

Fig. 10. Packaged blood pressure monitoring cuff