A Contact Microphone for Cardiac and Respiratory Sound Acquisition

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An electronic stethoscope comprising a contact microphone and USB connectivity has been developed with the goal of recording cardiac and respiratory sounds. While the presented device, MICC, can be used stand-alone, it has been designed with a vision to integrate it into CSEM's cooperative sensors measuring physiological signals of different origins. Such integration is envisaged to reinforce CSEM's technology offer in the medical devices and wearables domain. The device has been benchmarked with a widely accepted clinical electronic stethoscope for cardiac and respiratory sound acquisition.

Stethoscope auscultation is a prevalent clinical practice in diagnosing lung related diseases which make up 5 of the 30 most common causes of death[1]. Despite its widespread use in clinic, digitalization and standardization of this method fall behind. However, an increasing incidence rate of respiratory diseases combined with the need and will to increase the efficiency in medical practice have begun to give a thrust to these belated developments, even with additional expectations such as multi-channel recordings and continuous monitoring, particularly at remote settings.

This article reports the design and development of a contact microphone that aims to address the needs mentioned above. The developed device, MICC, converts the acoustic signals originating from the thorax to electrical signals and transmit it to a computing and storage device via USB. The prominent features of the device are its simple connectivity and small form-factor which does not translate into a compromise in signal quality.

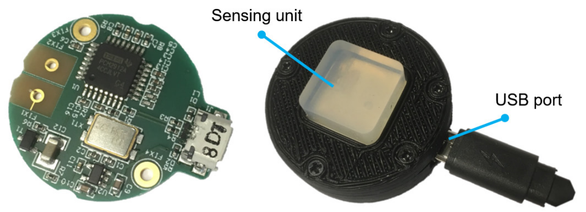

Figure 1: Electronic circuit board (left) of the system and assembled MICC device (right) with a USB cable connected.

Since a sensor satisfying all the requirements of the application is not readily available as an off-the-shelf component, we have developed it in-house. This approach is further motivated by the vision to integrate these sensors into the wearables where handling the motion-induced noise is crucial: Understanding the physics behind the operation of these transducers and mastering the technology to produce them, we believe, are the key tools to cope with the motion artefacts. The transducer, converting acoustic waves to electrical signals, is realized by means of a piezoelectric film (PVDF) which is curved along its machine direction and clamped from its ends[2]. This structure enables control over the sensitivity and the flat-response bandwidth by changing the radius of curvature. While the heart sounds cover a frequency range from 20 Hz to 200 Hz and the lung sounds from 200 Hz to 800 Hz, certain anomalies can create sound signals up to 2 kHz. As the developed contact microphones are intended to be used to detect such adventitious sounds, the curvature of the film is designed such that the first resonance peak occurs at 7 kHz, thus providing at least 2x margin against the non-idealities during fabrication and unaccounted secondary effects.

The piezoelectric transducer, exhibiting a high source impedance, has been interfaced with an impedance converter which drives the data conversion module. The data conversion module (PCM2912A, Texas Instruments) has an integrated USB 2.0 compliant full-speed protocol controller; thus the device can be connected to any portable device acting as a host simply by a USB cable. In addition to data streaming, USB is used to power the device up. The contact microphone and the electronic circuit board have been assembled within a 3D-printed conductive plastic housing to ensure a signal acquisition free of the spurs at the line frequency. Figure 1 exhibits the electronic board and the assembled device to which a USB cable is attached.

Figure 2 compares the spectrums of the cardiac and respiratory sounds acquired by our device MICC and Littmann® 3200 from 3M. Both devices are placed next to each other and 20-second synchronous recordings are performed on the mitral area and right-middle lobe for cardiac and respiratory sound acquisition, respectively. The commercial stethoscope has been used in its "extended" mode, therefore the corresponding filter frequency response [3] is applied on the signals acquired by MICC.

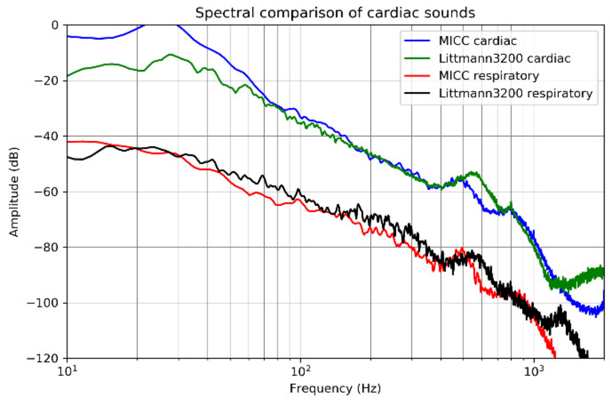

Figure 2: Spectral comparison of cardiac and respiratory sounds acquired by our device (MICC) and Littmann® 3200 stethoscope (amplitude of respiratory signals is decreased for visualization purposes).

In conclusion, we have developed an electronic stethoscope which is capable of acquiring cardiac and respiratory signals with a quality comparable to a clinically accepted electronic stethoscope. The modularity of the design and the form factor enable multi-channel recordings by placing several microphones on a vest. In the next phase, we plan to leverage the established competence of our cooperative sensor technology to integrate multiple units into a garment along with other physiological signal monitoring means such as ECG and electrical impedance tomography (EIT).

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[1] Global Alliance against Chronic Respiratory Diseases https://www.who.int/gard

[2] M. Toda, Contact-type vibration sensors using curved clamped PVDF film, IEEE Sensors Journal 6(5), 1170-1177 (2006).

[3] V. Oliynik, "On potential effectiveness of integration of 3M Littmann 3200 electronic stethoscopes into the third-party diagnostic systems with auscultation signal processing", IEEE 35th Int. Conf. on Electronics and Nanotechnology, Kiev (2015), pp. 417-421.