Development of a Pressure-Sensing Handle for a Stethoscope

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***Abstract*— Acoustic signals recorded with a stethoscope could be significantly affected by the probe-skin interface. The goal of this study was to develop a pressure-sensing device to measure and control the applied pressure at the probe-skin interface. Since placing a pressure sensor directly at the interface would block the transfer of acoustic signals, a custom-made handle was attached to the top of the stethoscope head. A handle was made of silicone rubber with an embedded pressure sensor that measures the force transferring from the hand to the stethoscope head. A microprocessor based device was also developed to provide a numerical readout of the force. This system was successfully built, providing accurate and repeatable pressure measurements. The resulting device should be useful for standardizing the applied pressure at the probe-skin interface for acoustic measurements with a stethoscope.**

Keywords- stethoscope; handle; sensor; and pressure

I. Introduction

Stethoscopes are simple qualitative devices for assessing medical conditions related to heart and lung sounds [1]. The noninvasive properties make it advantageous for children, pregnant women, and people with cardiopulmonary conditions [1]. Originally used for qualitative purposes, there has been an increasing interest in using the acoustic signals from the stethoscope for quantitative analyses such as the diagnosis of obstructive sleep apnea [2].

Our recent study on frequency spectra of breathing sounds, recorded with an electronic stethoscope, showed that the probe-skin interface had a significant effect on the transfer of high- and low-frequency components [3]. With a medium applied pressure, maximum signal magnitude was recorded with well-balanced high and low frequencies. A high applied pressure attenuated certain high-frequency components, and a low applied pressure resulted in an overall reduction of the signal magnitude. This finding prompted us to develop a device for quantification of the pressure applied to the probe-skin interface of a stethoscope.

The purpose of this senior design project was to develop a microprocessor-based pressure-sensing device coupled to a stethoscope such that the user can monitor and control the applied pressure.

II. Methodology

A. Design Approach

Although the purpose is to measure the applied pressure at the probe-skin interface, it would be inappropriate to place a force sensor directly at the interface. This is because the presence of the sensor would block the transfer of acoustic signals. Thus, our approach is to attach a handle on the top of the stethoscope head, opposite to the probe-skin interface. As the stethoscope head is positioned by hand, the applied pressure is transferred through the handle. Therefore, a force sensor embedded in the handle can provide an indirect measurement of the applied pressure at the probe-skin interface.

B. Silicone Handle with Embedded Force Sensor

The handle was made of silicone rubber. Silicone was chosen because of its solid, yet elastic properties, helping to accurately transfer the force through the handle. The shape of the handle was created to ensure ease of use and application of constant pressure. Multiple designs were fabricated to attain an ergonomic handle; slanting edges of the handle allowed for the fingers to rest comfortably during the application of pressure for testing. The silicone handle was wrapped in cloth soaked in glue. This kept a constant pressure on the sensor by preventing the silicone from deforming.

The silicone handle was attached to the probe with an aluminum mount. Two brass standoffs were attached to each end of both the stethoscope and mount; allowing the user access to the electronic controls beneath the attached handle. The silicone was bonded to the aluminum mount with epoxy.

The force sensor was embedded into the handle through a slit in the silicone. Fig. 1 shows the silicone handle with the embedded force sensor as well as the microprocessor-based display. Sensor alignment was achieved by placing

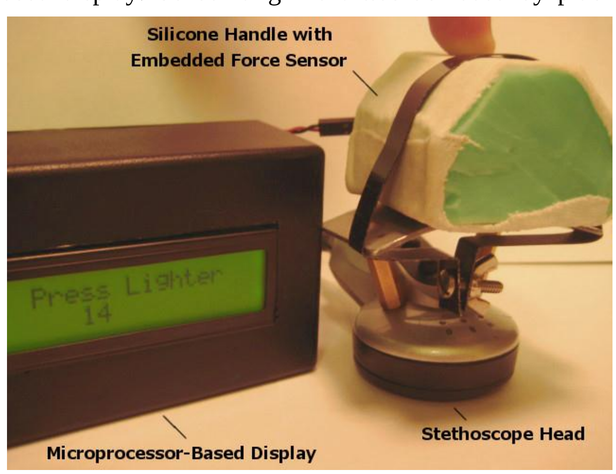

Figure 1. Prototype pressure-sensing device for monitoring applied pressure to a stethoscope head.

the sensor in the center of the handle, allowing the applied pressure to be evenly distributed. The attachment of the handle to the stethoscope allows for a convenient and accurate method for monitoring the applied pressure. Holding the stethoscope head via the handle should not significantly alter the way that the stethoscope is normally used clinically.

C. The Electronics

A thin, flexible force sensor (FloexiForce®, Tekscan, South Boston, MA) was chosen [4]. As shown in Fig. 2, a circuit using an operational amplifier (LM324) was designed to amplify the signal from the force sensor. The amplified signal was sent to the on-chip analog-to-digital converter of a microprocessor (PIC18F452, Microchip, Chandler, AZ). The software for the PIC processor was developed in the embedded C language with the MPLab development tool (Microchip, Chandler, AZ). A LCD character display was connected to the PIC processor to show the data. The initial implementation of the software provided a relative value of the applied pressure. This program showed different thresholds indicating the amount of applied pressure with values ranging from seven to fifteen. The base value was set to seven instead of zero to increase sensitivity. The screen displayed “press harder,” “good pressure,” and “press lighter,” respectively, depending on whether the values were 7-9, 10-12, and 13-15 Middle, good pressure, values were determined during preliminary testing in order to preserve both high and low frequencies. This allowed for the amount of pressure to be quantified, keeping each trial consistent and repeatable. The circuit was built on a prototyping board with point-to-point soldering and incorporated into a plastic enclosure.

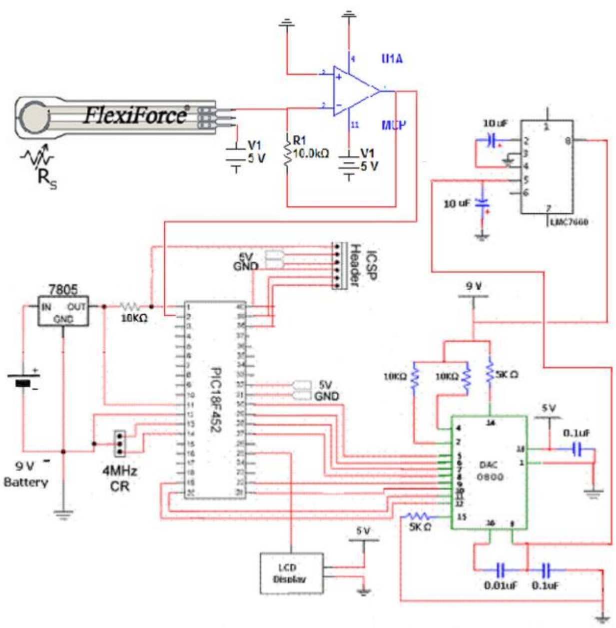

Figure 2. Circuitry for pressure sensing handle display.

D. Sensor Calibration

The system was calibrated by pressing the stethoscope head against a weighing scale. Initial calibration used the voltages monitored by the oscilloscope that came directly from the output of the PIC processor in the amplification circuit. Further calibration was performed by inserting metal spacers into the slot where the sensor was embedded. These spacers allowed the sensor to operate within its optimal range of sensitivity.

III. Results

Calibration using the scale showed that the applied force is in the range of 2-20 N. The medium pressure interval, that provided the best acoustic energy transfer and frequency range, was between 15.7 N and 16.6 N. After testing multiple spacer variations for calibration, it was found that a higher initial pressure produced more sensitive outputs. This led to the final design where an adjustable metal strap was added around the silicone handle and the platform. By tightening the wing nut on this strap, more pressure was able to be applied, allowing for the handle to be calibrated prior to testing. The metal spacers and adjustable metal strap helped improve the sensitivity and the repeatability.

IV. Discussion

This study was conducted to develop a pressure-sensing handle attached to the stethoscope head. The device was intended for standardizing the probe-skin interface for quantitative applications of the stethoscope. The resulting prototype was satisfactory for monitoring and controlling the pressure applied to the stethoscope head. For future work, an IRB approved study involving 30 human subjects will be conducted by using this prototype. Continuing improvements on the pressure-sensing handle will be made with respective to accuracy, repeatability, ease of calibration, shape of the handle, and attachment mechanism.

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