MACHINE LEARNING ENABLED WEARABLE STETHOSCOPE - MDR

ECE 445 – 2/19/2018

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High-Level Requirements

The system must be able to

- Use its microphones to capture the heart and lung sounds and filter out the ambient noise
- Take the captured audio input and determine if it corresponds to an illness with an accuracy of ~90%
- Communicate to user's doctor in the event of a detected emergency in a power efficient manner (power efficiency to be determined)

Design

Block Diagram

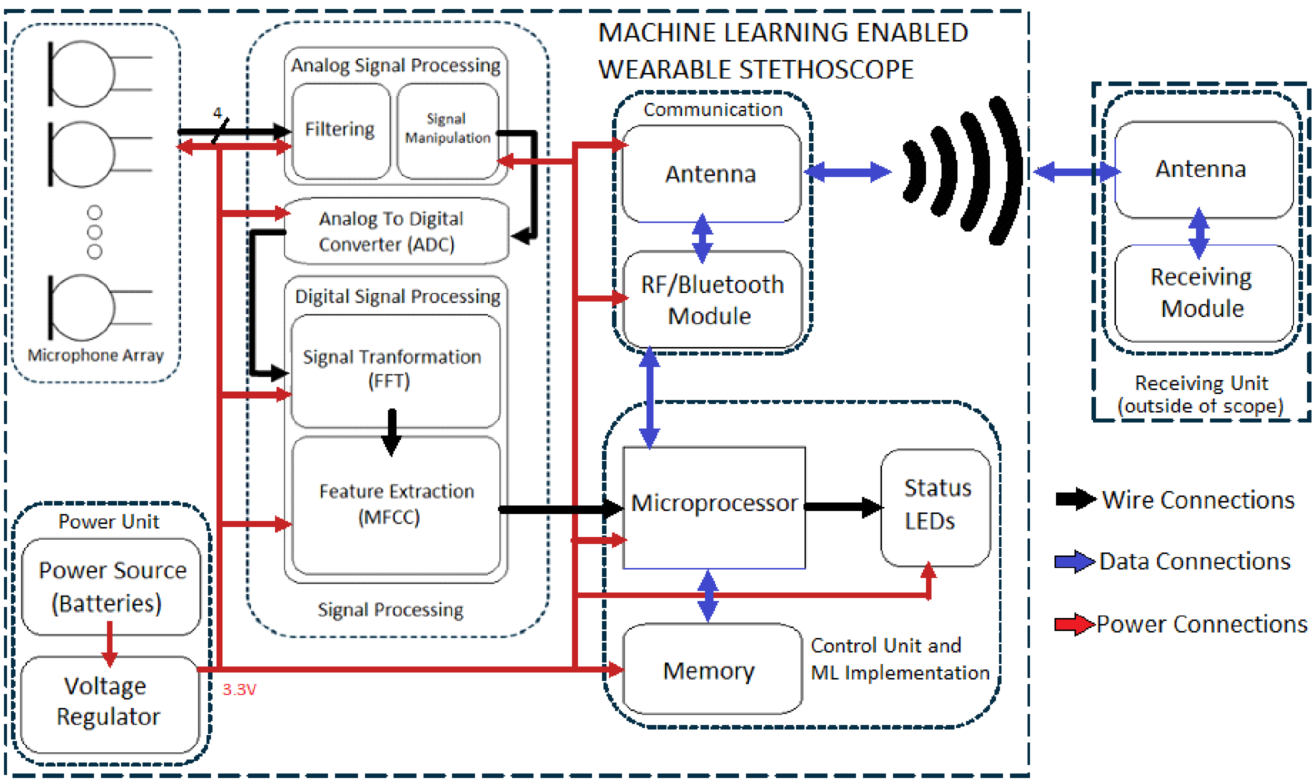

Figure 1: Block diagram design of system

Physical Design

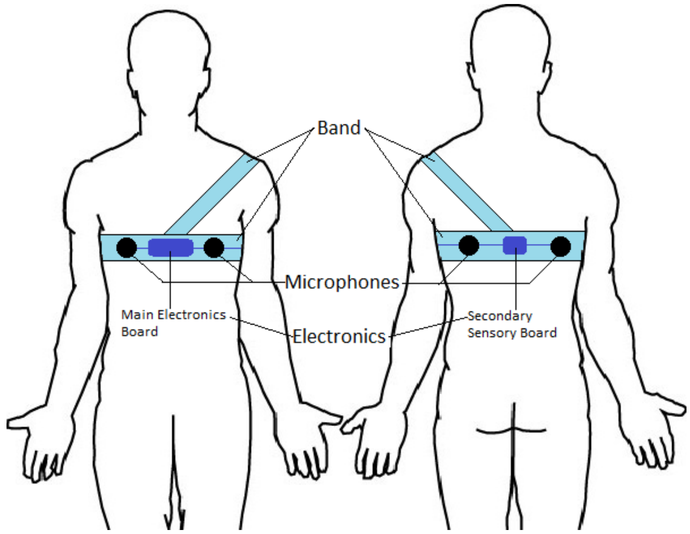

Figure 2: Physics design of system

The physical design of the system will comprise of a band to be worn around the chest with an appendage to help with comfort and placement – shown in Figure 2. The main band is placed around the circumference of the chest and there will be four microphone sensors. We propose the band to be similar to a gauze bandage that is 100% cotton.

Functional Overview

Microphone Array

The microphone array acts as the system's sensors. The sensors are the interface between the organs we are monitoring and the system we are designing. For the microphone array to function as required, it must be able to detect sounds and vibrations in the range corresponding to the conditions we are trying to detect.

Requirements	**Verification**
• Have a response in the frequency range between 25Hz and 25kHz • Operate on 3.3V +/- 0.1V	• Produce audio through the entire range and use an oscilloscope to plot the voltage response • Attempt to power microphones with a Vcc between 3.2V and 3.4V

Power Unit

The power unit provides the power required to operate all the other components in the system. The system is comprised of components which operate at 3-5V. As such, it should be possible to use a single power line to power all the components of the system.

Requirements	Verification
• Generate 3.3V +/- 0.1V • Can operate at currents 0-200mA • Batteries provide 2500mAh of power	• Measure the output voltage from the voltage regulator and verify that it stays within 3.3V +/- 0.1V • Use a constant current circuit to draw 200mA from the power supply and voltage regulator • Connect the battery to a discharging circuit. Verify that at the maximum current (200mAh), it runs for 12.5 hours

Analog Signal Processing

The analog signal processing takes care of filtering out noise coming from outside the frequency range for which we are interested in. It also amplifies the signal strength for the region. This sub-unit takes its input from the microphones and manipulates the signals before sending them to the Analog-To-Digital Converter (ADC).

Requirements	Verification
• -3dB response below 25Hz and above 300Hz for filtering out heart sounds. (Figure 1) • -3dB response below 50Hz and above 2500kHz for filtering out lung sounds. (Figure 2)	• Use signal generator to generate signals at 25Hz and below. Measure frequency response to verify -3dB below. Do the same for signals above 300Hz. • Use signal generator to generate signals at 50Hz and below. Measure frequency response to verify -3dB below. Do the same for signals above 25kHz.

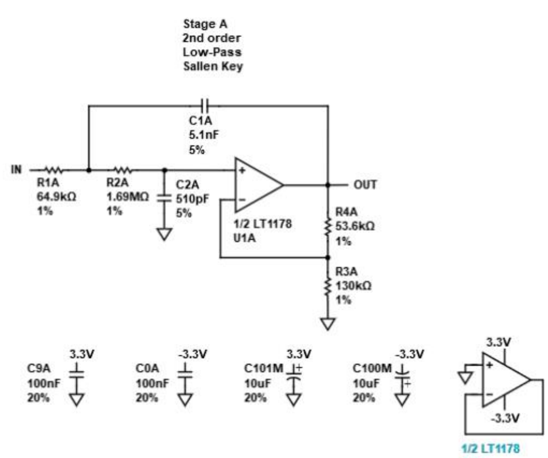

Figure 1: Low Pass Filter

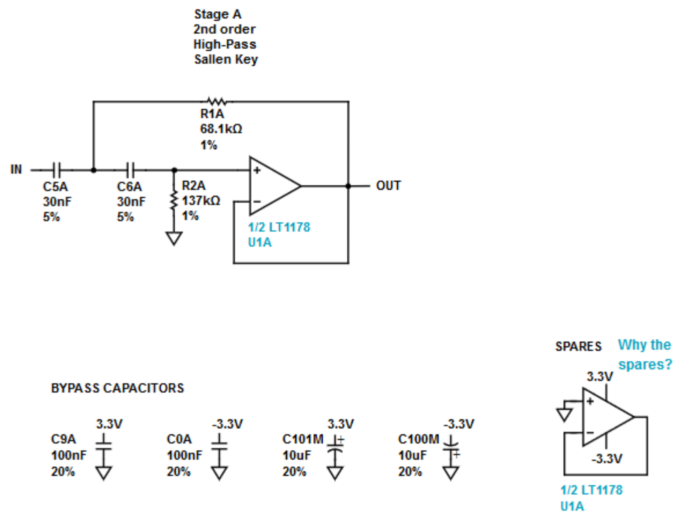

Figure 2: High Pass Filter

Digital Signal Processing

The digital signal processing unit handles the processing of the converted and filtered signals into meaningful data to be used by the control unit (microcontroller) to detect and diagnose abnormalities. This unit will have to do this quickly and reliably. It will either be done through special circuitry or through a dedicated microprocessor that will handle the computations. Its output is the input for the control unit.

Requirements	**Verification**
• Processor speed needs to be larger than 2.8MHz.	• Complete an FFT transform of a measured heartbeat (file size of 1.4Mbits) in less than half a second (which would be the processing time for a >2.8MHz processor).

Analog to Digital Converter

The ADC will then take the output from the analog signal processing unit and convert it into digital readings. These will allow for the processing required that cannot be done through analog signals alone. The conversion to digital enables the transformations for features to be generated (MFCC). The analog to digital converter will have to be quick and have a large enough accuracy to prevent bias. It will also require a good bit-width so as not to quantize the readings too much.

Requirements	**Verification**
• 10 Bit ADC with 60ksps • 4 Analog Input Lines for ADC	• Generate a signal with Nyquist frequency requirement >60Hz. Use ADC to look for biasing of signal. • Generate 4 independent

	signals. Read values converted to digital for all signals, compare to input signals.

Microprocessor

The microprocessor will be the unit which does all the computations necessary for the machine learning algorithms to do the diagnosing. It will also handle the preparation of the data for sending through the communication unit and will choose the data to be stored in the memory.

Requirements	Verification
• Can receive and transmit through UART at a rate of >10Mb/s • Can receive and transmit through SPI at a rate of >10Mb/s	• Send a 100 Mb random message through the UART port. Verify signal received is the same as signal sent. Verify that it took less than 10s. • Send a 100 Mb random message through the SPI port. Verify signal received is the same as signal sent. Verify that it took less than 10s.

Memory

The memory will be both embedded and external. Due to the sensitivity of the type of data, medical data, it is crucial to store the history of the patient. Therefore, there needs to be a means of permanently storing the patient history gathered by the device.

Requirements	Verification
• Write/Program memory at 1MB/s • Have a total usable memory of >48 MB • Operate on 3.3V +/- 0.1V	• Record the time it takes to write a large file (~20MB). Attempt multiple times. • Try to fill the memory with >48 MB • Attempt to power chip with a Vcc between 3.2V and 3.4V

Communication

The communication unit interfaces our device to the outside world, where actionable information can reach the right people and lives can potentially be saved. The communication unit will need to consume little power and ideally it would be powered on only when a message needs to be sent.

Requirements	Verification
• Able to communicate through UART or SPI • Have at least 500 kBit/s data communication rates (due to small size of files) • Operate on 3.3V +/- 0.1V	• Check in manufacturer datasheet for UART or SPI pin capability. Verify by sending simple message to chip. • Program to send a file of known size from Bluetooth chip to a microcontroller. Measure the time for transmission. • Attempt to power chip with a Vcc between 3.2V and 3.4V

Ethics and Safety

There are a few safety hazards to highlight with our proposed project. Starting from the simplest, there is a chance that the battery in the band can overheat, resulting in user discomfort or worse, an exploding battery. In order to avoid this, we are taking extra precaution in testing our circuitry in the safety lab and making sure the battery does not overcharge. Another circuit-related hazard in our project is potential water damage to the device. Getting water onto the band can result in shorting the circuits, ultimately hurting the user as well. Our product is not yet intended to protect against water, so here it is incredibly crucial that the user is aware of the product's flaws, which correlates with IEEE Code of Ethics #3 [7].

The material of the band is another important concern to the individual using the wearable stethoscope. Certain materials have the ability to induce an allergic reaction or create an uncomfortable rash on the individual where the band is placed. To avoid any kind of reaction, we plan on coating the device with a gauze bandage. Gauze bandages are prevalent in the medical world and are used specifically to protect the body. In order to decrease the chances of getting textile contact dermatitis from the gauze bandage, we are using a gauze bandage that is 100% cotton and dye-free [8].

The last safety concern we want to highlight is that our device will not be 100% effective. With our goal of 90% efficiency, there is a 10% chance that the device fails to detect a lung or heart problem for a user that may be completely dependent on the device. The initiative we are taking with this safety hazard is ensuring that, again, we follow the IEEE Code of Ethics #3 and to be transparent about the product's success rates as well as the potential flaws mentioned above [7].

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