Heart and Lung Sound-sensing shirt

A shirt was to be made which will detect the sounds of both the heart as well as lungs, and by interfacing the SD card with a microcontroller, the sounds can be accessed by the user on a smartphone and sent to a doctor for analysis. Their requirements included digital microphones that must be able to record heart sounds between 60 - 250 Hz and lung sounds between 50 - 2500 Hz with a Signal-to-noise ratio of 20 dB. To generate 24-bit, 16 kHz WAV files that have noise-free audio without aliasing. The doctor should be able to diagnose the patient's medical condition in at least 69% of cases, which will make it as good as high-end stethoscopes. Microphones are used in the system to sense heart and lung sounds. 6 TDM MEMS microphones will be placed in an array on the chest. Time-division multiplexing (TDM) is a method of transmitting and receiving independent signals over a common signal path using synchronised switches at each end of the transmission line so that each signal appears on the line only a fraction of the time in an alternating pattern.MEMS mics are largely based on electret capsules and typically have onboard preamps and analog-to-digital converters. For both the first heart sound (S1) and second heart sound (S2), is below 150 Hz which indicates that both sounds are caused by vibrations within the same structure, possibly the entire heart. In subjects with healthy lungs, the frequency range of the vesicular breathing sounds extends to 1000 Hz, whereas the majority of the power within this range is found between 60 Hz and 600 Hz. Other sounds, such as wheezing or stridor, can sometimes appear at frequencies above 2000 Hz. Based on this data, the microphones should be able to detect sounds within the frequency range of 50 Hz - 2500 Hz. Four of the microphones are placed on the chest and abdominal area of the shirt to detect heart as well as lung sounds. Two of the microphones are used to capture ambient noise. The digital output from the microphones will be sent to the microcontroller for filtering, noise cancelling, and data processing. The microphones used are Invensense ICS-52000 which are daisy chained.

The microcontroller generates a 16 kHz WS signal and a 4096 kHz SCK signal required to retrieve audio samples synchronously from the microphones. The sounds that needed to be recorded occurred in the 50 Hz - 2500 Hz frequency range. This means a minimum sampling rate of 2 x 2500 Hz = 5000 Hz was required to prevent aliasing following Nyquist's Theorem. The audio data from the microphone is sampled at 16 kHz and the processor has a clock speed of 100 MHz when using the internal RC oscillator, which means we need to divide the clock frequency by $(100 \times 10^{6})/(16000) = 6250$ to achieve the desired sampling rate. Similarly to attain the clock frequency of 4096 kHz we can divide the clock frequency by 100 /(4096000) = 24.414. Taking an integer value of 25. Total Harmonic Distortion of the output is also considered. A higher THD measurement indicates a higher level of harmonics present at the output of the microphone. The THD of the MEMS microphones is calculated from the first five harmonics of the fundamental. As the level of the acoustic input signal increases, the THD measurement typically increases as well. A rule of thumb is that the THD triples with every 10 dB increase in input level.

There is a Power unit that consists of a single power line that supplies 3.3 V to power the microcontroller, microphones, and SD card. There is a 5 V battery and a voltage regulator (LD1117) with an output voltage of 3.3 V to ensure there are no voltage spikes that can damage the components of our system. The microphones, power circuit, and microcontroller will be placed between the inner and the outer layer of a shirt to isolate the patient's skin from the electronics. An external memory will store the patients' data. The data stored will contain the heart and lung audio file of the patient as well as the time it was recorded.

The Digital Signal Processing Unit filters out the ambient noise. For the heart, the frequencies of the sounds we want to detect lie in the range of 60 - 250 Hz, and for the lungs, the signals of interest are in the range of 50 - 2500 Hz. This can be achieved by implementing an adaptive Digital Bandpass filter with cut-off frequencies between 50 and 2500 Hz using the microcontroller. The microcontroller performs data processing by converting the audio samples from the filter to a 1-minute WAV file and saving it to the SD card. The outputs of the microphones contain 24-bit raw audio data sampled at 16 kHz.