Thermistor-Based Respiration Monitor

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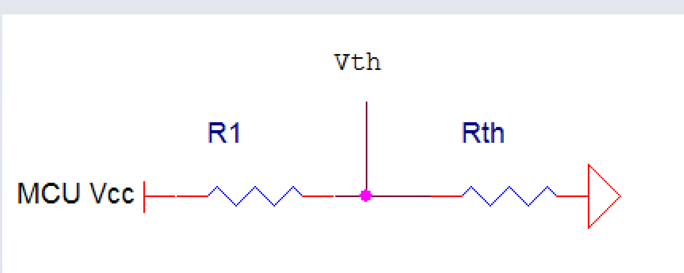
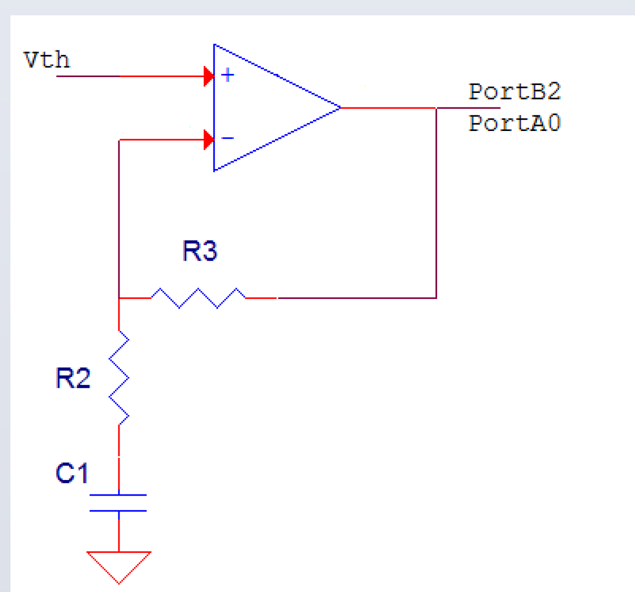
ABSTRACT

Respiration rate is a standard physiological measurement taken for monitoring a patient. Existing respiration monitors used in medical centers are unsuitable for low-resource environments. We have developed a low-cost respiratory monitor to address this issue. This device calculates a patient's breathing rate by detecting changes in temperature through a thermistor when the patient breathes into a mask. Features of the device include an alarm through a piezoelectric speaker which sounds when the patient stops breathing, and a low-battery indicator signal for when the battery powering the device dips below a threshold voltage. The design and implementation involved several different hardware components, as well as software functions. Our initial prototype of the project accomplished our main objectives, and experimental measurements indicate that the device measures a patient's respiration rate with relative accuracy.

HARDWARE DESIGN



A



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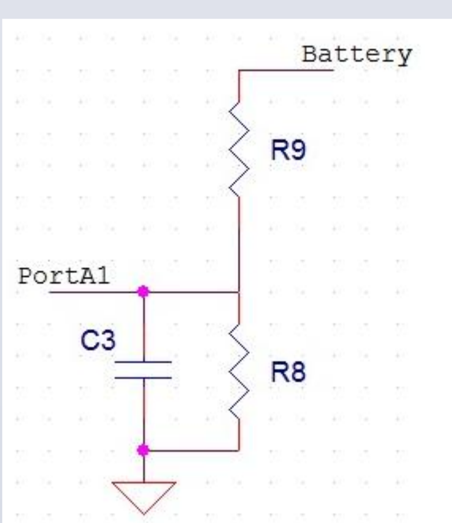

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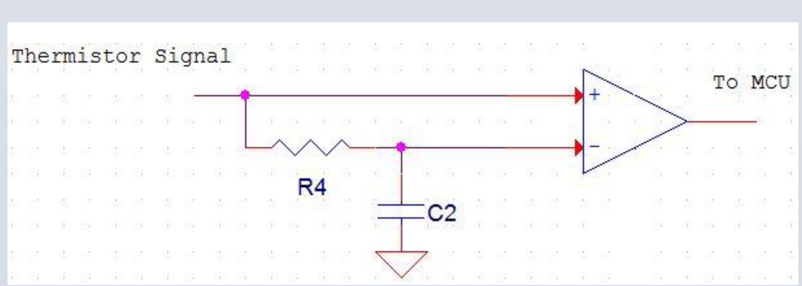


D

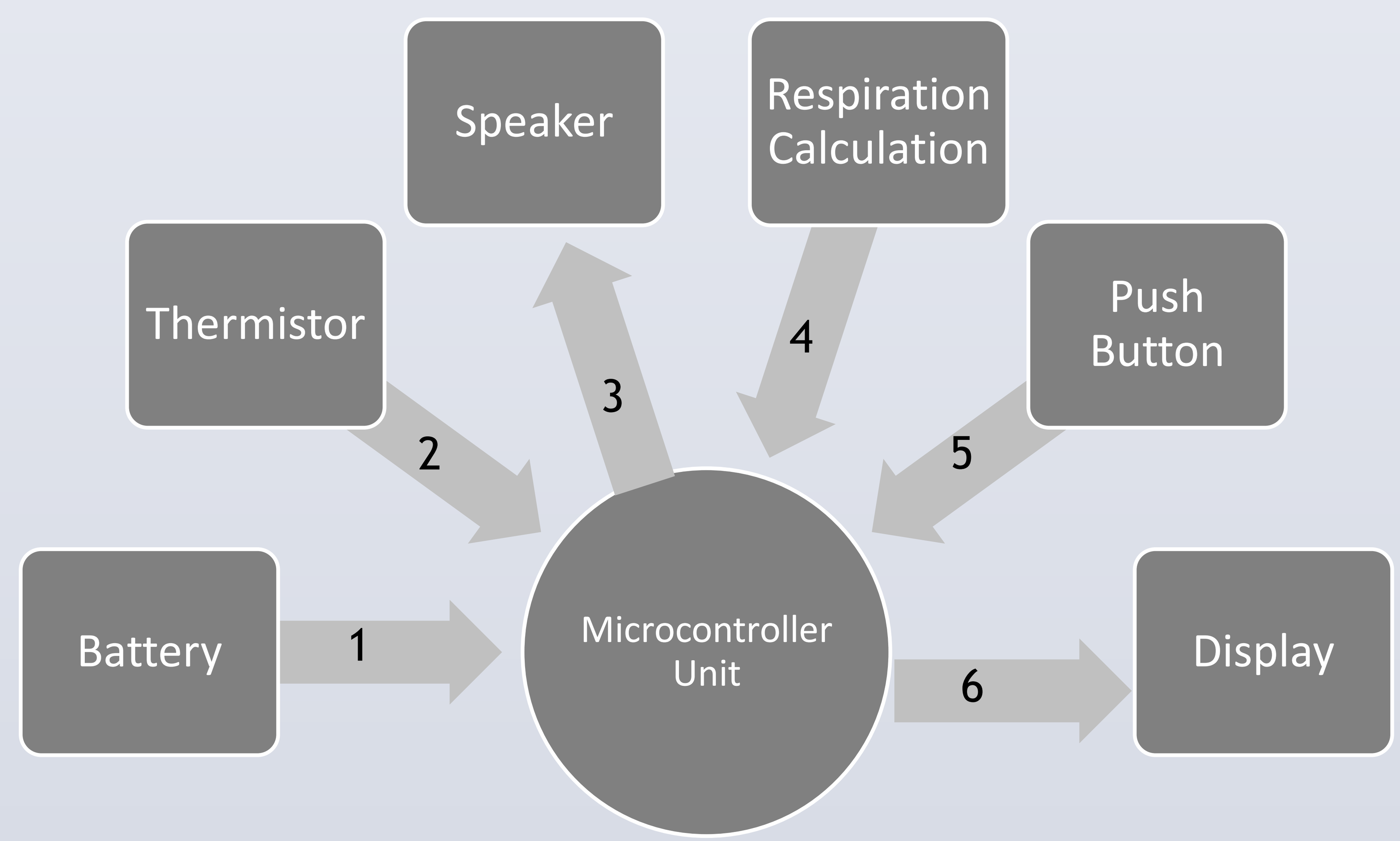
A. **Thermistor Measurement:** The voltage across the thermistor, proportional to the respiration rate of the patient is measured using a voltage divider. Here V_{th} represents the voltage across the thermistor, R_1 is 1.2 kΩ and R_{th} is the resistance of the thermistor, which changes as the patient breaths.

B. **Thermistor Amplification Circuit:** The amplitude of the signal from the thermistor is on the order of 10 mV which is too small for the microcontroller (MCU) to accurately sample. An operational amplifier, with a gain of 4, is used to increase the resolution of the signal. To prevent noise from being amplified a high pass filter with a time constant of 22 seconds is used; R_2 = 10 kΩ, R_3 = 30 kΩ.

C. **Voltage Measurement:** To measure the voltage of the 9 V battery, a voltage divider was used along with a low pass filter, as shown in the schematic. The voltage divider is used to convert the voltage range from 0-9 V to 0-5 V so that no damage is done to the MCU. The purpose of the low pass filter is to eliminate any high frequency signals that might occur. The time constant of the filter is 1 µs and is achieved by setting C_3 to 1 nF and R_8 to 1 kΩ. R_9 is set to 3 kΩ so that the voltage divider outputs ¼ of the original voltage.

D. **Analog Comparator:** The respiration rate is measured by using an analog comparator (AC) to compare the amplified voltage across the thermistor to a reference voltage. Since the respiratory signal is approximately equivalent to a sine wave with a DC offset, the reference voltage is chosen to be at the DC offset. To automatically determine the reference voltage for a patient a low pass filter is used, as shown in the schematic. This low pass filter averages the value of the incoming signal, which is the DC offset. To achieve a time constant of 22 seconds R_4 is 100 kΩ and C_2 is 220 µF.

SOFTWARE DESIGN



1. **Take voltage measurements:** The MCU takes a voltage sample across the battery, under battery operation, to keep track of the power level of the device.

2. **Take thermistor measurements:** The resistance over the thermistor drops when its surrounding temperature increases, and does back down when the temperature decreases. Accordingly, the voltage drops when a patient exhales and rises when a patient inhales, which is detected by the MCU.

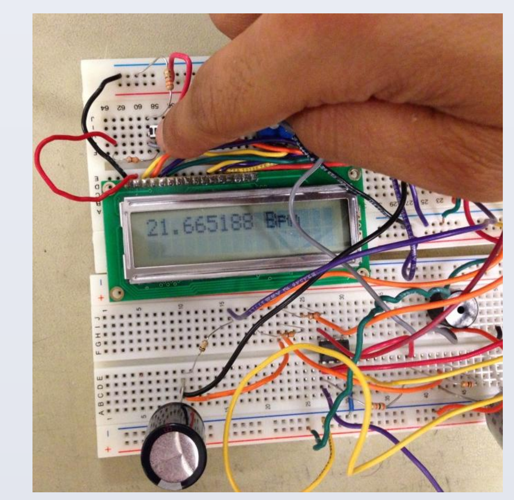
3. **Output alarms:** The device generates two different PWM signals for alarms through a piezoelectric speaker. The first alarm, higher in pitch, sounds when the patient is not breathing. The second alarm is an indicator that the device is running on low battery.

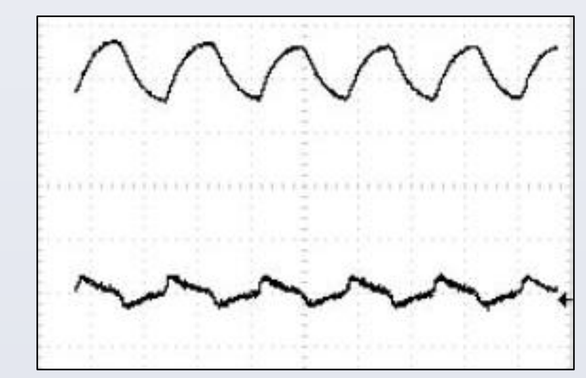
4. **Calculate respiration:** This task does the actual measurement of the respiration rate, which is calculated to be a weighted average of the previous rate and the newest difference in the peaks detected in the respiratory signal.

5. **Turn on display:** To conserve power, the user must hold down a button to turn on the display to read the respiration rate. This prevents the user from leaving the display on by mistake and draining the battery.

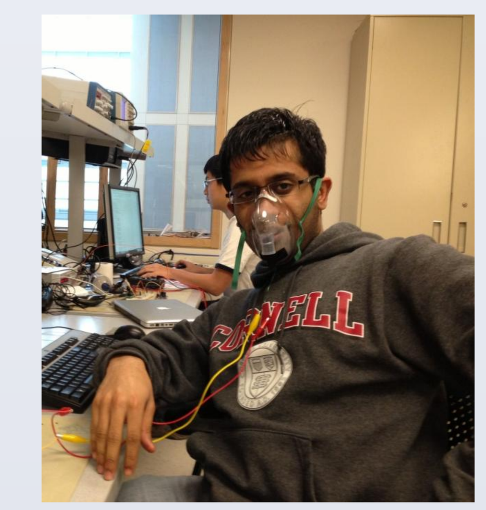
6. **Display respiration rate:** Respiration rate is measured and displayed in breaths/min onto an LCD. This allows whoever is monitoring the patient to see if the patient is breathing too fast or too slowly.

RESULTS





Original breathing signal (bottom)
Filtered and amplified signal (top)



- Measures respiration rate with error of less than 10%
- Takes less than 5 seconds to determine if patient is not breathing
- Calibration and startup time is about 30 seconds
- LCD only receives power when the display button is held down
- Piezoelectric speaker is activated when patient is not breathing or the battery is below 7.5 V. Different sounds are used for not breathing vs. low battery
- Speaker is automatically turned off when the patient begins to breathe again

FUTURE WORK

- Integrating a microphone with device to prevent "false alarms"
- Packaging the device into a more portable prototype
- Further experimentation with respiration rate averaging algorithms
- Developing a sterilization protocol for device

ACKNOWLEDGMENTS

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Full documentation for this project can be found at:
http://people.ece.cornell.edu/land/courses/ece4760/FinalProjects/f2012/htq2_mg573/htq2_mg573/index.htm