Wearable Airflow Monitor System

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Introduction

Problem Statement:

- Traditional methods for monitoring respiratory health are predominantly confined to clinical settings.
- Existing methods lack accessibility and convenience for continuous, everyday monitoring.

Introduction:

- Wearable Airflow Monitor System offers continuous tracking of respiratory patterns.
- Captures the pattern of breathing through sensor and interprets into understandable electrical signals, offering users insights into their health
- The system includes circuit that alters the input physiological signals to electric signal that is correlated with user's airflow

Assumptions

- The thermistor has a near-linear response within the temperature
- Ambient temperature and humidity remain relatively constant
- All electronic components (op-amps, resistors, capacitors) are ideal, with no intrinsic noise or offset
- The temperature field around the thermistor is uniform, which means the thermistor's temperature is a good representation of the ambient or target temperature.
- The buffer op-amp (voltage follower) presents an infinite input impedance and zero output impedance, ensuring no loading effect on the Wheatstone bridge and subsequent stages

Sensor

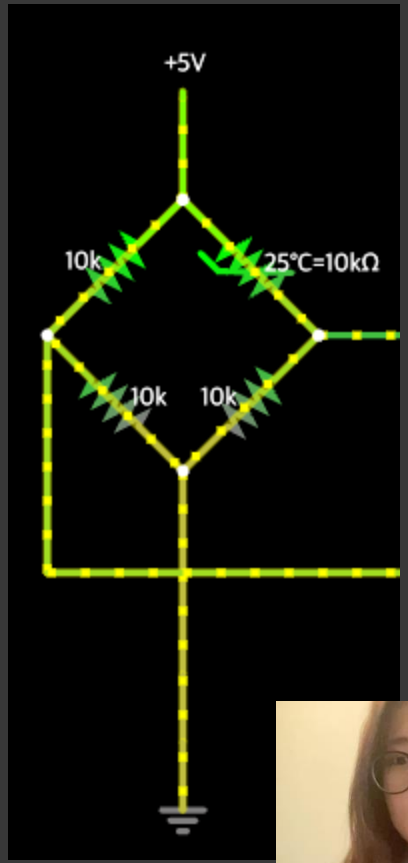
TR91 Series Thermistor - utilized for detecting respiratory movements

- The resistance varies with temperature changes that occur with the user's inhalation and exhalation.
- Base setting: 10kΩ at 25C (room temperature)
- Has high sensitivity
- Can be attached to the body in form of Chest Strap or Band, Adhesive Patches, etc.

Wheatstone Bridge

Wheatstone Bridge - detects minute changes in temperature through variations in the resistance of a thermistor

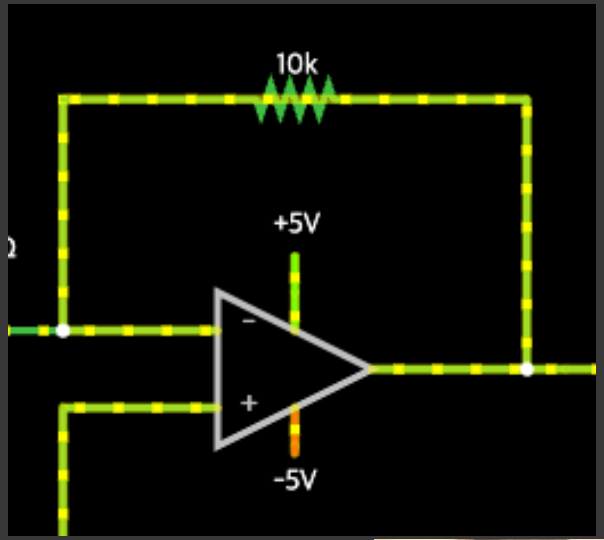
- 3 Resistors, one thermistor as substitute of one resistive component
- Powered by power supplies



Op-Amp

Operation Amplifier - function as voltage follower

- Ensures integrity of the voltage signal from the bridge is maintained
- Isolates the bridge voltage from the rest of the circuit, preventing possible load happening

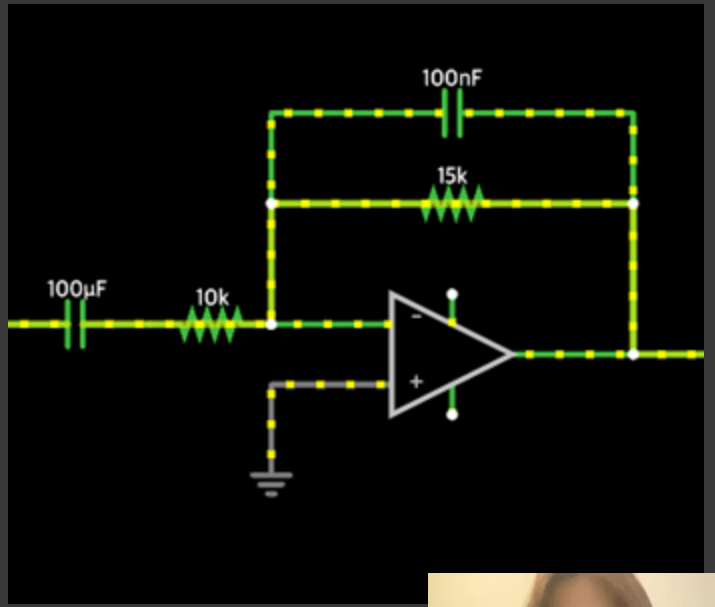


Bandpass Filter

Bandpass Filter - isolates the respiratory signals from unwanted noise and interference

Cutoff Frequency

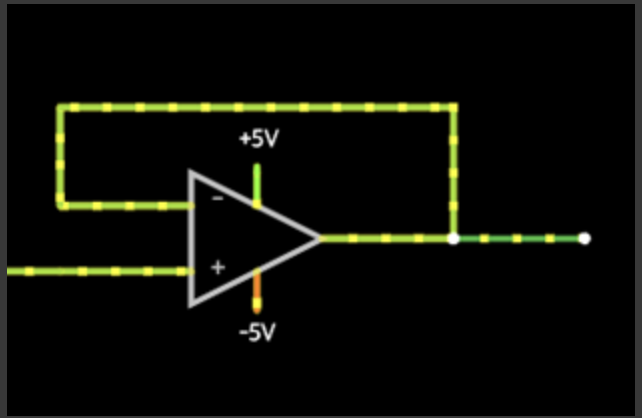
- Low-Pass Filter
  - $f_c = 1/2\pi RC = 1/(2\pi * 15k\Omega * 100nF) \cong 1.061Hz$
- High-Pass Filter
  - $f_c = 1/2\pi RC = 1/(2\pi * 10k\Omega * 100\mu F) \cong 0.159Hz$
- Possible range: 0.159~106.1 Hz



Buffer

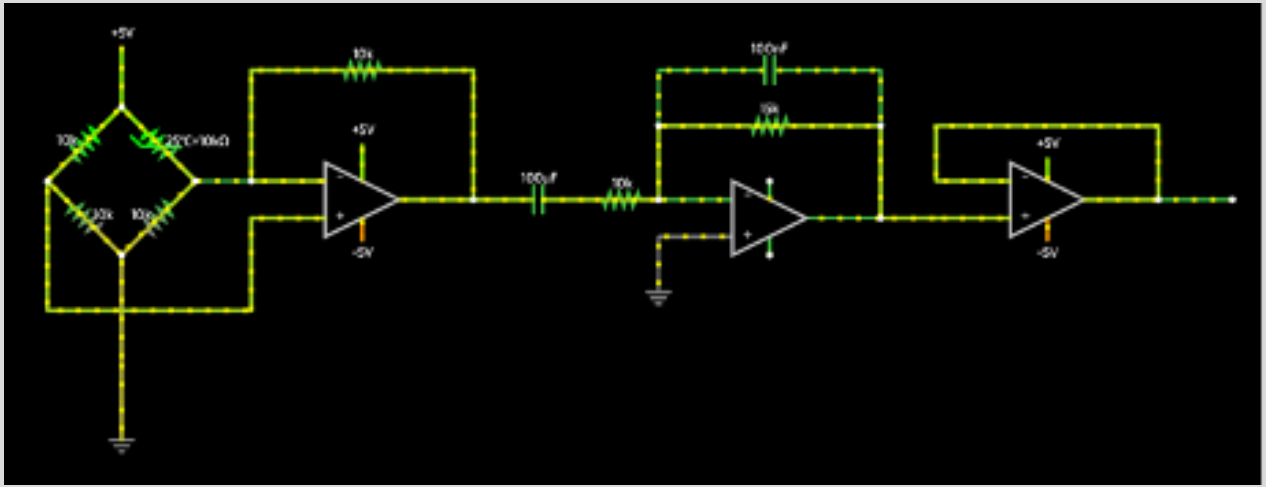
Buffer- maintain signal integrity befor outputting

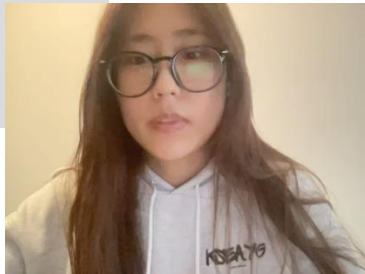
- High input impedance - avoid loading effects
- Low output impedance - drive the output voltage without signal loss



Other components

- Power Supply
  - A 5V power supply was chosen to ensure broad compatibility.
- Resistors
  - 0kΩ were chosen for resistors
    - Matching the resistance values of the thermistor and the other bridge resistors at the baseline temperature ensures that bridge operates within its optimal range.


+5V
10k
10k
25°C=10kΩ
10k
10k
+5V
-5V
100uF
10k
150nF
10k
+5V
-5V



Calculations

- Voltage Output
  - Wheatstone Bridge - Midpoint between two upper resistors and two lower resistors is is +2.5V
  - Op-Amp - Act as voltage follower, Vout maintained to be 2.5V
  - Bandpass Filter - Unless AC input signal has frequency out of range of low and high pass cutoff, voltage output maintained to be 2.5V (2.496V with attenuation)
    - If yes,

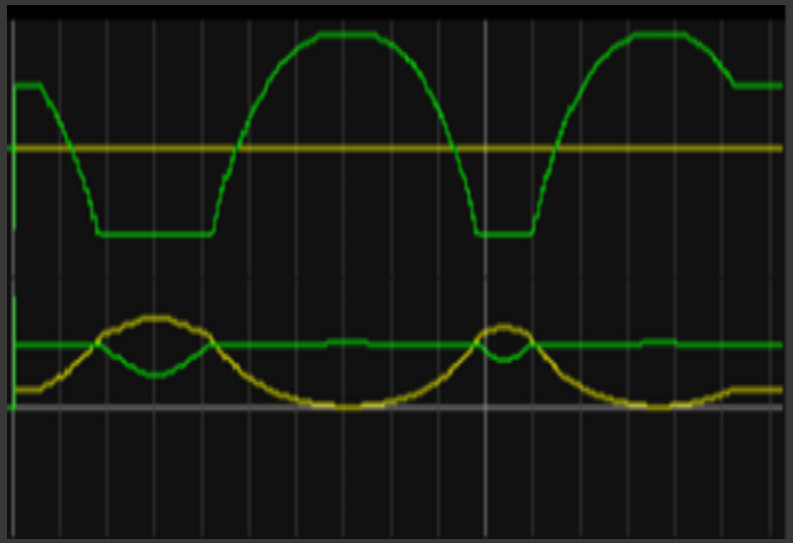
$$V_{out,bandpass} = V_{in} * A * \frac{f/f_1}{\sqrt{1+(f/f_1)^2} * \sqrt{1+(f/f_1)^2}}$$

  - Buffer - has a unity gain, Vout maintained to be 2.5 (2.496V)

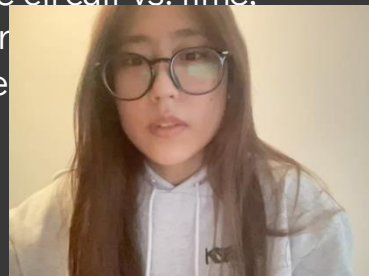
Results

Expected output under base thermistor setting (10kΩ at 25°C) = 2.496V

- By altering temperature reading from thermistor by the Falstad, the following graph outcomed



Above figure - V_out of the circuit vs. time.
Below figure – temperatur
(yellow) and voltage of the



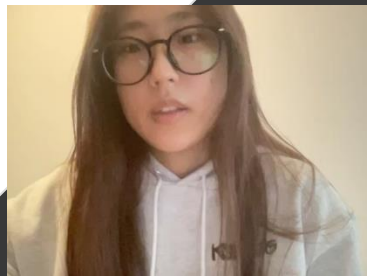
Future Direction and Limitation

Future Direction

- An ADC can sample this V_out and convert it into a digital number that reflects the analog voltage magnitude.
- The digital signal output can be displayed in various forms, such as numerical Readout, Graphical Trend, or Alarms.

Limitation

- The thermistor has its thermal response time. This is the time taken for the thermistor to react to a temperature change.
- Thermistors will respond to all temperature variations within their environment, not just those caused by breathing.
- Airflow rate during inhalation and exhalation was not considered during calculation, may not reflect the actual outcome



References

- [1] Falstad, Paul. “Circuit Simulator Applet.” Falstad.com, 2019, www.falstad.com/circuit/.
- [2] Nicolò, Andrea, et al. “The Importance of Respiratory Rate Monitoring: From Healthcare to Sport and Exercise.” Sensors, vol. 20, no. 21, 9 Nov. 2020, pp. 1–46, www.ncbi.nlm.nih.gov/pmc/articles/PMC7665156/, https://doi.org/10.3390/s20216396.
- [3] “TR91 SERIES 10KOhm@25°c THERMISTOR SPECIFICATIONS.” Mcshaneinc.com, mcshaneinc.com/html/TS91_Specs.html?NewWin. Accessed 21 Mar. 2024.

Thank you