MEDICAL DEVICE TO HIGHLIGHT RESPIRATORY ISSUES, INFECTION WARNING AND PATIENT ALARMING FOR COVID-19 CASES

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ABSTRACT

On January 30, 2020, the World Health Organization declared the global 2019 novel coronavirus (COVID-19) disease outbreak as a public health emergency of international concern. The incidence of patients with respiratory problems is increasing and may lead to worsening the general health or even to death. Current medical devices used to highlight respiratory problems are not only very hard to achieve, but they are also very expensive. Coronavirus disease (COVID-19), caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), is an infectious disease where the most common symptoms include but are not limited to fever, dry cough and tiredness. This paper addresses the principle of construction of such an equipment from both a systemic approach and by considering the recommendation of its practical realization. Experimental results regarding the monitoring of the body temperature and the breathing rhythm are also presented.

Keywords: sensor, COVID-19 respiratory issue, body temperature, force sensitive resistor (FSR).

INTRODUCTION

Since December 31st, 2019 and as of October 6th, 2020, 35 523 518 cases of COVID-19 (in accordance with the applied case definitions and testing strategies in the affected countries) have been reported, including 1 042 398 deaths [1].

Coronavirus disease (COVID-19) is an infectious disease caused by a newly discovered coronavirus.

Most people infected with the COVID-19 virus will experience mild to moderate respiratory illness and recover without requiring special treatment. Older people and those with medical problems such as cardiovascular disease, diabetes, chronic respiratory disease, and cancer are more likely to develop serious illness [2].

The COVID-19 virus spreads primarily through droplets of saliva or discharge from the nose when an infected person coughs or sneezes, so it’s important that one also practices respiratory etiquette (for example, by coughing into a flexed elbow) [5].

Fever is a common symptom of bacterial and viral infections. Examples include infections that cause colds and flu, diarrhea, and urinary tract infections.

Fever sets in when the body temperature exceeds the normal level by about 37°C. It is a sign that the body is struggling with an older disease and is often a symptom of infection. Both bacterial and viral infections can cause fever [3].

Although the symptoms of fever can make you feel awful, moderate fever is generally not an alarm signal. In fact, a mild fever can be beneficial in fighting the infection. The good news is that the fever will generally improve within a few days and does not require special measures.

IDEAS / PRINCIPLES THAT LED TO THIS DEVICE

"The respiratory system is responsible for the gas exchange between the body and the external environment, providing oxygen and toxic CO_2 evacuation. Although the respiratory process is not a bioelectric signal generator, the measurement, monitoring and therapy of the respiratory system with electronic means have a special importance for assisting this vital functional system. Furthermore, the measurement of body temperature can help detect illness. It can also monitor whether or not a treatment is working, considering the fact that a high temperature is fever"[8].

COVID-19 is a type (strain) of coronavirus. A virus is a very small (microscopic) type of germ that can cause an infection. It can only replicate in a host, such as a person or other living things. You might not always feel sick from viruses; however, viruses can make you seriously ill and cause disease [3].

Coronaviruses are a group (or family) of viruses that cause different illnesses. These illnesses can range from the common cold to more severe diseases, such as Severe Acute Respiratory Syndrome (SARS).

The device is designed to perform breathing and body temperature monitor, as seen in the block diagram in figure 1.

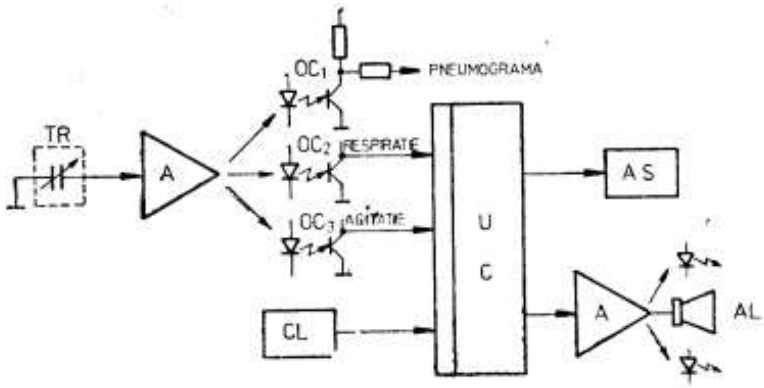

Figure 1 Block diagram of the breathing monitor [11]
CL – clock signal; AS – 7-segment display; AL – alarm

The signal produced by the capacitive transducer (TR) is amplified by the AC amplifier (A), which can highlight the useful signal to impulses from the patient's movement, coughing etc. A peak detector transforms the analogue signal into "breathing" pulses, which are transmitted through the OC_2 optocoupler to the central processing unit, UC.

Parasitic impulses like "agitation" have the same destination via OC_3. Optocoupler OC_1 roughly describes the pneumogram of the investigated subject.

A capacitive transducer is mounted under the patient. The instantaneous value of the transducer capacity, which depends on the position of the center of gravity of the body or on a breathing cycle, is given by the formula (1) [11]:

$$C = C_0 + C_S + C_R \cdot sin(\omega Rt) \quad (1)$$

where: ω R - breathing pulsation

C_0 - transducer slack capacity

C_S - the change in capacity due to the patient's weight

C_R - amplitude capacity variation due to breathing capacity

The transducer can be doubled by one of a resistive type, made with a thermistor that senses the inspired / expired air temperature variations.

COMPONENTS OF THE DEVICE

The functional block diagram of the proposed device is presented in figure 2.

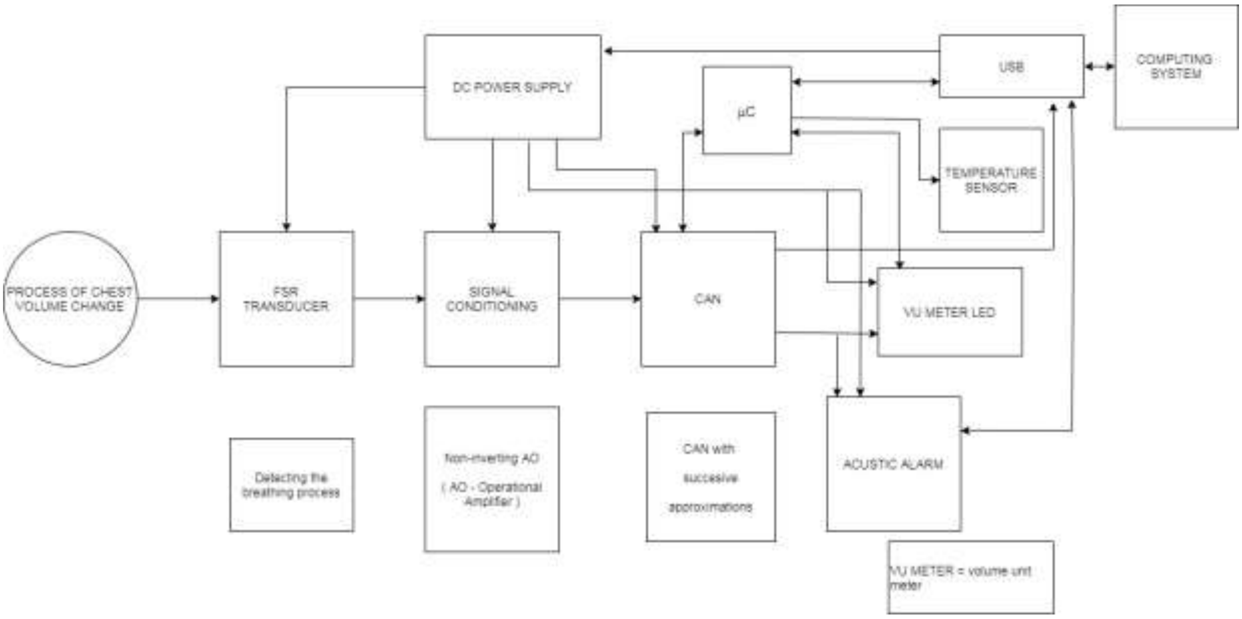

Figure 2 Functional block diagram of the device

At the base of the device there is a Force Sensing Resistor (FSR), a device with a thick layer of polymer that exposes the decrease of resistance with increasing force applied to the surface of the sensor. This sensitivity is optimized for use in contact to electronic devices, medical systems and industrial applications.

FSRs have sensors that allow the detection of physical pressure, squeezing and weight.

They are simple to use and low cost. In the medical device, FSR is used to monitor the pressure resulting from the breathing process.

The process of changing the volume of the thorax is detected by a FSR transducer connected in series with a resistor, so that the force-to-voltage conversion (at the divider level) takes place. The signal conditioner creates a buffer floor (electrical repeater, i.e. a non-inverting operational amplifier). [8]

Operational Amplifiers (AO) are a category of analog amplifier circuits with outstanding performances.

A temperature sensor measures the body temperature and converts the input data into electronic data to record, monitor or signal temperature changes.

The non-inverting amplifier has 2 resistors: R_i and R_f, where R_f is the reaction resistance, connected between the output and the inverse input, and provides a negative feedback effect with the reduction effect of amplification. [8]

The electrical diagram of the non-inverting amplifier is presented in figure 3.

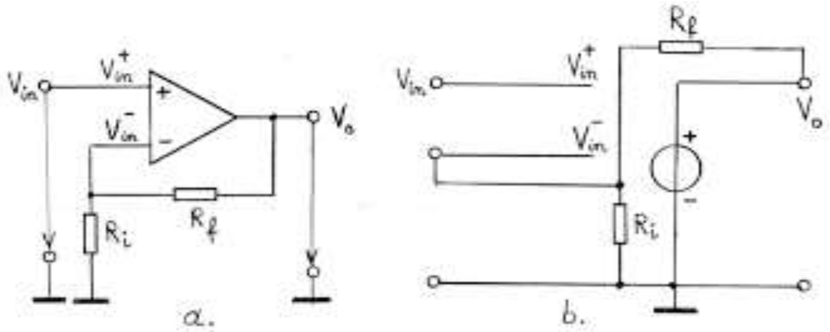

Figure 3 Non-inverting amplifier [9]

A non-inverting AO always has an amplification greater than 1 for non-zero values of R_f and R_i resistors. These were also used: CAN with successive approximations (figure 4), LED VU METER and acoustic alarm. [8]

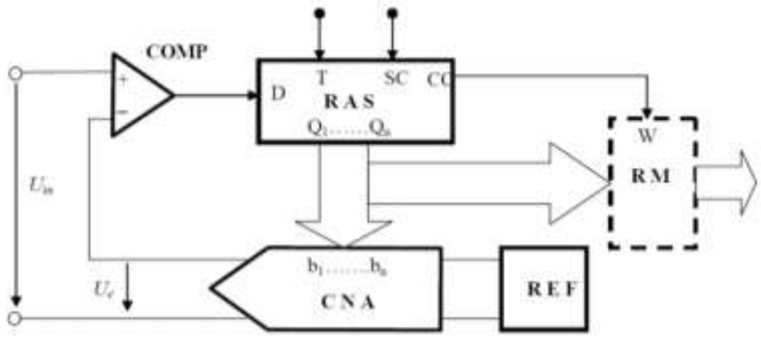

Figure 4 Converter with successive approximations [10]

RAS - register of successive approximations; COMP - comparator; CNA - analog numeric converter; REF - CAN reference source; RM - memory register; RAS-Register of successive approximations (SC - start conversion; CC - full conversion; T – tact)

By overlaying the microcontroller pins, a daughter board was created. A daughterboard is a board that extends the circuitry of another circuit board. Also, the daughterboard plugs into it.

The LED VU METER (vu meter = volume unit meter) shows the breathing intensity but can also be used by the user to check the device functioning.

Monitoring of the respiratory process and the body temperature evolution through an application can be accessed directly by the user. It also creates a database of all events, which can be further processed in an Excel table.

Thus, the user can track health data and by going to the doctor with the event database, they can establish a diagnosis much quicker and easier.

EXPERIMENTAL RESULTS

Once the device is turned on, it will continuously check both the FSR and the temperature sensors.

As it runs, it will simultaneously monitor both of these measurements and will notify the patients if their breathing rhythm and their temperature are within optimal parameters.

If not, for a count of less than 1 breath/minute the device will display a “danger message” and, as soon as there have been more than 60 seconds without any breath detection, the alarm will go off thus waking up the patient and restabilizing their breathing pace.

Likewise, when the temperature sensor detects an abnormally high measurement, the device will notify the patient about it through another alarm so that the patient could take further actions on trying to lower it.

Using a specialized CoolTerm software for the measurements, the final results and a personalized graph specially generated for the patient will all be exported in a log (Excel file), as seen in figure 5.

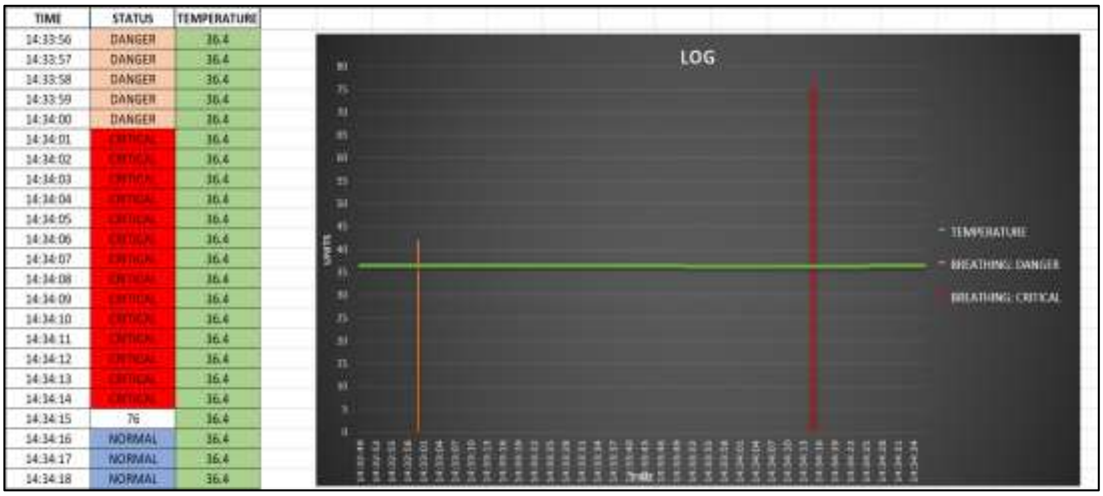

Figure 5 The exported log

CONCLUSION

The device presented in this paper, designed for highlighting respiratory issues, infection warning and patient alarming, aims to offer a solution to major flaw of the products currently available on the market, which is the price.

It can be built with existent components (all parts are commercially available) following instructions on white papers that are generously available from device component manufacturers. Further developments and improvements can be certainly brought.

Although the device's prognostic is not to be trusted over the doctor's one, its users are able to monitor the evolution of the respiratory process and body temperature which are both among the most common symptoms of COVID-19 and may prevent death.

This device is mostly recommended to asymptomatic patients or mild symptoms, who due to the overcrowded and underequipped hospitals are sent home to fight alone against this disease.

REFERENCES

[1] Zhou F, Yu T, Du R, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. Lancet, 2020.

[2] South A.M, Diz D, Chappell M.C. COVID-19, ACE2 and the cardiovascular consequences. Am J Physiol Heart Circ Physiol, 2020.

[3] Ye Z, Zhang Y, Wang Y, Huang Z, Song B, Chest CT manifestations of new coronavirus disease 2019 (COVID-19), 2020.

[4] Lazarus, R.S., Folkman, S., Stress appraisal arid coping. New York: Springer, 1984.

[5] Kiecolt-Glaser, J.K., Fisher, L.D., Ogrocki, P., Stout, J.C., Speicher, C.E., Glaser, R., Marital quality, marital disruption, and immune function. Psychosomatic Medicine, 49, 1987.

[6] Rabin, B.S., Cohen, S., Ganguli, R., Lyle, D.T., Cunnick, J.E., Bidirectional interaction between the central nervous system and immune system. CRC Critical Reviews in Immunology, 1989.

[7] Jabaaji, L., Grosheide, P.M., Heiftink, R.A., Duivenvoorden, H.J., Ballieux, R.E., Vingergoets, A.J.J.M., Influence of perceived psychological stress and distress on antibody response to low dose DNA hepatitis B vaccine. Journal of Psychosomatic Research, 1993.

[8] Ștefan-Radu Bala, Ionuț Banu, Tania-Ioana Cîmpeanu, Răzvan-Andrei Dumitrescu, Bogdan-Gabriel Duță, "Economical device to highlight respiratory sleep problems and patient alarm in severe sleep apnea", Petroleum - Gas University of Ploiesti Bulletin, Technical Series, Vol. 71 Issue 1, pp. 59-64, 2019.

[9] Florin Mihai Tufescu, Dispozitive şi circuite electronice, Editura Universităţii "Alexandru Ioan Cuza", 2002.

[10] Tiberiu Teodor Cociaș, Sistemul cu MicroProcesoare, Curs 05, Convertorul analog numeric, Universitatea Transilvania din Brașov, Laboratorul de Vedere

Artificială Robustă și Control, disponibil la https://rovislab.com/courses/smc/Curs_05_ADC.pdf.

[11] Hariton Costin, Electronică medicală, Capitolul 5 : Aparate pentru monitorizare și pentru laborator clinic, disponibil la https://dokumen.tips/documents/cap5curs.html