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REAL TIME MONITORING DEVICE FOR SAFETY APPLICATIONS

BY

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Abstract. This paper presents a monitoring device for persons working in challenging environments (such as firemen). It is able to detect the monitored person’s heart rate, as well as to transmit information on the environment (distance and temperature) to a data concentrator. Heart rate is read by means of an inductive sensor, while distance and temperature are measured by four groups of sensors placed at an angle of 90° around the monitored person. The information received is grouped and forwarded to a concentrator. The data volume is not significant and it is possible to use low power communication devices with spread spectrum modulation technique (such as LoRa).

Keywords: safety; monitoring; sensors; microcontroller; wireless communications.

1. Introduction

This paper presents a device intended for people who are exposed to risks and life-threatening situations. Firemen are only one of the professional categories that can benefit from using such a device. We are presented every day with various dangers and the people that intervene in such situations obviously risk their lives. Therefore, we believe that persons working in high-

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risk areas of activity should be monitored remotely. Our device provides data on an important element – heart rate – by reading it indirectly through the inductive method. It can also monitor the temperature around the target person, preferably at 360°, in order to provide relevant information on immediate or potential risks. Moreover, measuring the distance around that person (also at 360°) can be useful too in cases where he/she is immobilized or in a critical situation (for instance fainting).

Previous research is known on this topic, referring to devices and applications with monitoring and information functions. The paper "LifeGuard: Wireless Physiological Monitor" introduces the LifeGuard system, which was developed for monitoring the health of astronauts in order to ensure their safety during space flight and extravehicular activities and to monitor their physiology during routine exercise (NASA, Ames Technology Capabilities and Facilities). Another device is a wearable monitor, that provides the capability to continuously record two standard electrocardiogram leads, respiration rate, heart rate, haemoglobin oxygen saturation, ambient or body temperature, three axes of acceleration and blood pressure (Mundt *et al.*, 2005). The next one is a mobile, small, noninvasive, lightweight and robust device, with sensors and electronics, which is able to collect data, then register and forward it wirelessly (Montgomery, 2004). Another paper refers to a monitoring and alert device in case of drowning. (Muhammad Ramdhan, 2018). Finally, a 2019 paper (Pracheta and Bhaskar, 2019) presents a device for monitoring and tracking subjects in real time, which can also transmit information further to a data concentrator.

2. Description of the Circuit

Our device is based on a Raspberry pi zero development board, communicating through a I2C data bus with three types of sensors: an inductive sensor measuring heart rate, a thermal sensor for ambient temperature and an optic distance sensor of the type Time-of-flight camera. In order to simplify the design in this development phase, we chose to send data to a cloud server by means of the WiFi communication of the development board instead of the wireless low power communication with spread spectrum modulation technique (such as LoRa). The final device should be equipped with one inductive sensor and four groups of thermal sensors so as to cover the area around at 360°. The block circuit of the device is presented in Fig. 1.

All the sensors can be connected to the same bus I2C because they have different identification addresses. Thus, the inductive sensor LDC1612 has the address I2C 0x2A (if the ADDR pin is connected to GND), the thermal sensor OMRON D6T-44L-06H has the address I2C with the value 0x0a, and the distance sensor STMicroelectronics VL53L1X has the address I2C with the value 0x29. The I2C communication bus of the Rasperry pi zero development board is implemented through the pins GPIO2-SDA and GPIO3-SCL.

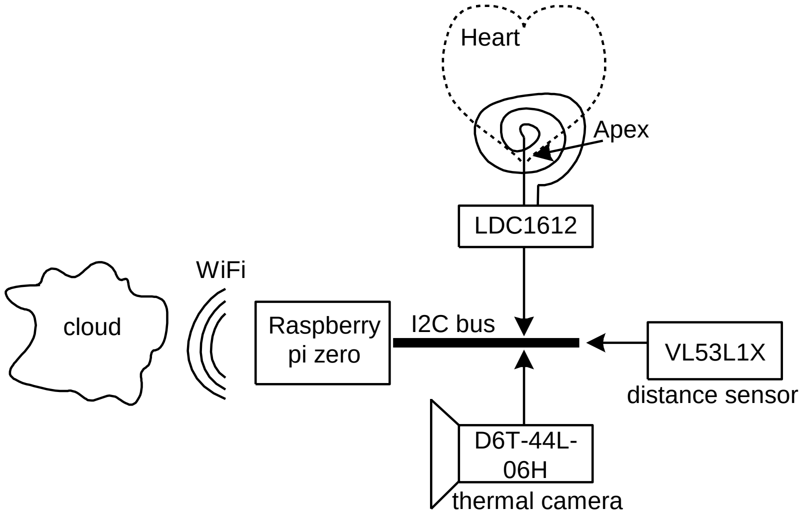

Fig. 1 – Simplified block diagram of the monitoring device.

The inductive sensor

For this sensor, we used an inductance-to-digital converter implemented on the integrated circuit LDC1612, developed by the company Texas Instruments. The converter has a 28 bits resolution and it can read the inductance on two input channels. At the input of this converter there is a coil implemented in a planar configuration, which allows such a coil to be easily introduced in the fabric of clothes. In order to maximize the sensitivity of the inductive sensor to heart activity, the coil was placed in the apex area of the heart. The resulting coil and the contact between the sensor and the human skin make up an LC circuit. It is well known that human tissue contains a high percentage of water, namely the heart and the brain are 73% water, while the lungs are 83% water. Consequently, the magnetic field detected around human tissue varies depending on the amount of water it contains. Thus, when the coil is in close proximity to human tissue – for instance at 1mm – a capacitance of approximately 6pF is created, which influences the resonance frequency of the inductive sensor. Due to increased sensitivity, the capacitance created by the vicinity of human tissue is influenced by the ambient humidity and implicitly by perspiration. It was noted that increased humidity determines the decrease of the permeability parameter μr, which leads to a low inductance value. Planar inductance is calculated through the following equation:

$$L = K_1 \mu_0 \frac{N^2 D_{avg}}{1 + K_2 \varphi} \quad (1)$$

where: L – inductance (nH); D_{avg} – average diameter coil; K_1, K_2 – layout coefficients; φ – fill factor; N – number of turns.

Fig. 2 shows the coil used for this application:

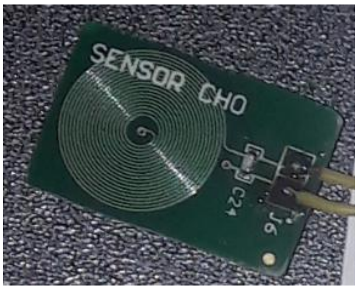

Fig. 2 – Inductive proximity sensor.

The current application uses the channel 0 of the integrated circuit LDC1612. Within this integrated circuit, the registers read are DATA0_MSB, DATA0_LSB, which have 16 bits. The data read by the Raspberry pi zero development board is subsequently stored as vectors and displayed in the application development process window, using data values print out functions. We can see the modifications of the inductance values through numeric conversion; these modifications occur synchronously with the changes of the heart rate (Brezulianu *et al*., 2019).

The thermal sensor

For this application we used the sensor D6T-44L-06H produced by the Omron company. It includes a sensitive matrix with 16 pixels placed in a 4x4 layout. Each sensitive element generates an electromotive force in accordance with the radiant energy. The resulting pixelated image is based on the surface temperature of the image in front of the sensor. This sensor maps the 3D thermal space in front of it. However, this technique is not perfect because, when the distance between the object and the sensor increases, thermal data can be altered by the ambient thermal noise. Fortunately, in the current application, this is not a problem because the focus is on the hot points around the sensor, which could threaten the life of the target person. In this case, we refer to temperatures above 100°C, a value much higher than ambient temperature. The thermal sensor D6T-44L-06H communicates through the data bus I2C with the Raspberry pi zero development board and delivers the thermal information in 16 values groups at a refresh rate of 10Hz.

In order to read the ambient temperature, this sensor should be placed on the upper part of the body. It is recommended to place it on the hat/helmet, together with the distance sensor. Fig. 3 shows a group of thermal and distance sensors.

Fig. 3 – Group of sensors (thermal sensor to the left and distance sensor on the right).

The distance sensor

For this application, we used the sensor VL53L1X produced by the STMicroelectronics company. It is a Time-of-Flight distance sensor, based on ST’s FlightSense technology. It uses the 940 nm laser technology, it integrates a SPAD receiving array, physical infrared filters and optics to achieve the best ranging performance. The obstacle detection angle is 27° and it can provide information at a maximum 50Hz refresh rate. This sensor was also connected to the data bus I2C and it was programmed to detect obstacles up to 3.6 meters.

The information provided by this sensor is corroborated with the information from the thermal sensor in order to correct the temperature value in accordance with the distance. Thus, if the obstacle is farther away (more than 3 meters away), the temperature registered is influenced by the ambient temperature.

The Raspberry pi zero development board reads each sensor in turn by means of the data bus I2C, in the following order: the inductive sensor, the thermal sensor and the distance sensor. A 10 Hz sensor reading frequency was found to be satisfactory for local data reading and processing. Here are several code fragments written in the Python language, which are part of the software run on the Raspberry pi zero development board. We have to mention that, unlike the sensors, various types of development boards can be used, and an important selection criteria when choosing it is the high data speed of the I2C bus (Barleanu *et al*., 2012; Duma, 2001; Duma, 2004). For higher processing speed, it is recommended to use FPGA devices (Valachi *et al.*, 2009; Comsa *et al.*, 2012).

```
#!/usr/bin/env python
import crcmod.predefined, pigpio, time, smbus, VL53L1X, os
dis = VL53L1X.VL53L1X(i2c_bus=1, i2c_address=0x29)
dis.open()
UPDATE_TIME_MICROS = 7000
INTER_MEASUREMENT_PERIOD_MILLIS =70
dis.set_timing(UPDATE_TIME_MICROS, INTER_MEASUREMENT_PERIOD_MILLIS
dis.start_ranging(3)
if __name__ == '__main__':
    omron = temper()
    while True:
        inductance_no = ind.get_inductance()
        print("Inductanta:{}nH:{}".format(inductance_no))
        omron.read()
        for i in range(0,len(omron.temp)):
                print" ", '%.0f'%omron.temp [i]
        dist_in_mm = dis.get_distance()
        dist_in_cm = dist_in_mm / 10
        print("Distanta:{}cm:{}".format(dist_in_cm))
```

The values received are displayed in a list in an output window. They can be registered locally or in cloud and different alarms can be set. If the information from the inductive sensor does not vary significantly in several seconds, the “missing heart rate” alarm can be set off. If the information provided by the thermal sensor mostly shows values higher than 100°C around the person wearing the device, then we can conclude that his/her life is endangered. Finally, if the distance to the object is small (less than 50 cm) and the temperature is more than 100°C, we can clearly say that that person is in danger.

3. Conclusions

This paper presents a device with three sensors: an inductive sensor for heart rate detection, a temperature sensor and a distance sensor. It is designed to monitor persons who are involved in risky life-threatening situations as a consequence of their jobs. If the person wearing this device is in imminent risk at work, timely information on his/her state is essential. The sooner the accident is detected, the sooner rescue operations can be put in place. In these critical situations, time is of the essence for the success of the operation; this is why it is critical to monitor constantly the vital information on the state of this category of workers.

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DISPOZITIV DE MONITORIZARE ÎN TIMP REAL UTILIZAT ÎN APLICAŢII DE SIGURANŢĂ

(Rezumat)

În această lucrare este prezentat un dispozitiv de monitorizare a persoanelor care lucrează în condiţii de lucru deosebite (cum ar fi un pompier). Dispozitivul este capabil să detecteze ritmul cardiac al persoanei monitorizate precum şi să transmită informaţii despre mediul înconjurător (temperatura şi distanţa) către un concentrator de date. Pentru detecţia ritmului cardiac s-a folosit un sensor inductive, iar pentru detecţia

temperaturii şi distanţei din jurul persoanei monitorizate se pot folosi patru grupuri de senzori plasati la 90^0 în jurul persoanei monitorizate. Informaţiile primite de la senzori sunt împachetate şi trimise mai departe către un concentrator. Volumul de date nu este mare şi pot fi folosite în această situaţie dispositive de comunicaţie de consum de mic şi tehnica de modulaţie cu spectru extins (de exemplu LoRa).