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## CONTRIBUTIONS TO THE DESIGN AND IMPLEMENTATION OF AN ADVANCED ELECTRONIC SYSTEM FOR CONTROLLING THE ELONGATION OF THE VERTEBRAL COLUMN

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***Abstract:** The scientific paper promotes an important contribution regarding the design and implementation of an advanced electronic system for the control of spine elongation as well as a dedicated software for command, control and data acquisition for an office chair. The main objective of the "office chair" product is to achieve a controlled elongation of the human spine (which belongs to the user) with the help of levers located under the arms. To achieve the proposed goal, it was chosen to use the digital control of the levers using an electronic system made up of sensors, a display, a microcontroller and an actuator designed to actuate the elements of the seat without harming the user. The office chair operates autonomously or supervised by a computer. If it is desired to conduct studies and research on a special treatment designed by a specialist doctor to be applied to the user, action can be taken in this sense. The scientific work is backed by a working invention patent which has enabled the realization of a carefully thought-out experimental program which has led to the achievement of experimental results worthy of consideration. Finally, the conclusions drawn from the previously mentioned as well as the possible future directions of research resulting from the contributions made are presented.*

***Key words:** microcontroller, experimental program, force and elongation, actuator and sensors, automation.*

### 1. INTRODUCTION

Spine pain due to neurological causes is the second most common in the United States and affects approximately twelve million people with intervertebral disc problems [1].

Intervertebral discs are soft discs made of cartilage that are arranged between the vertebrae of the spine. They have the role of absorbing mechanical shocks and ensuring the flexibility of the spine. Over time, these intervertebral discs wear out, suffer injuries due to mechanical reasons, can become infected or other external causes and cause extreme pain in the spine [2].

To remedy the pain caused by the pressure on the neural elements of the spine, a series of treatments are available, including a non-invasive one such as spinal decompression. The pain caused by compression of the spine puts

pressure on the nerves that pass through the spinal cord. By decompressing the spine, the aim is to reduce the pressure in order to relieve the pain [3].

There are several methods for spinal decompression, but the most commonly used is gravity traction in physiotherapy offices. A table is used through which the body leans, allowing gravity to work by releasing the tension of the spine. Another example for reducing the negative and stressful effects for health that removes the continuous and prolonged compression of the spine when working on a computer or other office-related activity, is the prototype for the invention entitled "Computer chair with an active principle of spine relaxation".

The advantage of using the chair is that the temporary treatment can be conducted

anywhere, at home or at the office, without the need to go to the physiotherapy clinic.

## 2. COMPUTER CHAIR WITH AN ACTIVE PRINCIPLE OF SPINE RELAXATION

The chair presented in figure 1, according to the invention, is intended for people who work a lot on the computer, at the office and at home, and consists of a mechanical assembly and an Electronic Control Unit (ECU) for the mechanical part.

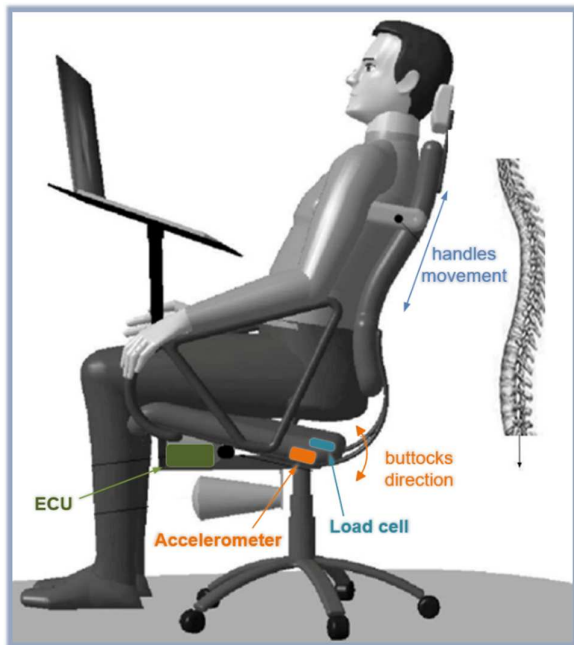


Fig.1. Patent no. 129280/2021

The main purpose of the mechanical assembly is to raise and lower the body through two folding levers that are actuated by an actuator as an execution element, controlled by an ECU that has sensors as feedback for determining the lifting force of the body and the inclination of the chair buttocks.

The ECU displays on the console the actuation force translated into the user's mass on the screen.

The electrical energy supply is made from the electrical grid or from the batteries. [4].

The electronic system takes the commands from the user and supervises the movements of the chair which are made by means of electromechanical actuators. The block diagram for the electronic part is presented in figure 2.

The chair is equipped with three actuators.

The "**Lift**" actuator raises and lowers the seat. It is actually the pneumatic piston that every office chair has, located under the seat.

The "**Buttocks**" actuator tilts the seat of the chair relative to the horizontal.

The "**Handle**" actuator operates two folding levers for partially suspended support of the human torso from the underarms.

Each electric actuator has an electric current sensor that measures the degree of its charge when it moves. In this way, it is implemented in the firmware, the software of the microcontroller, an extra measure of safety in use because they can appear located especially in the case of the "Handle" actuator that actuates the levers for the extension of the column.

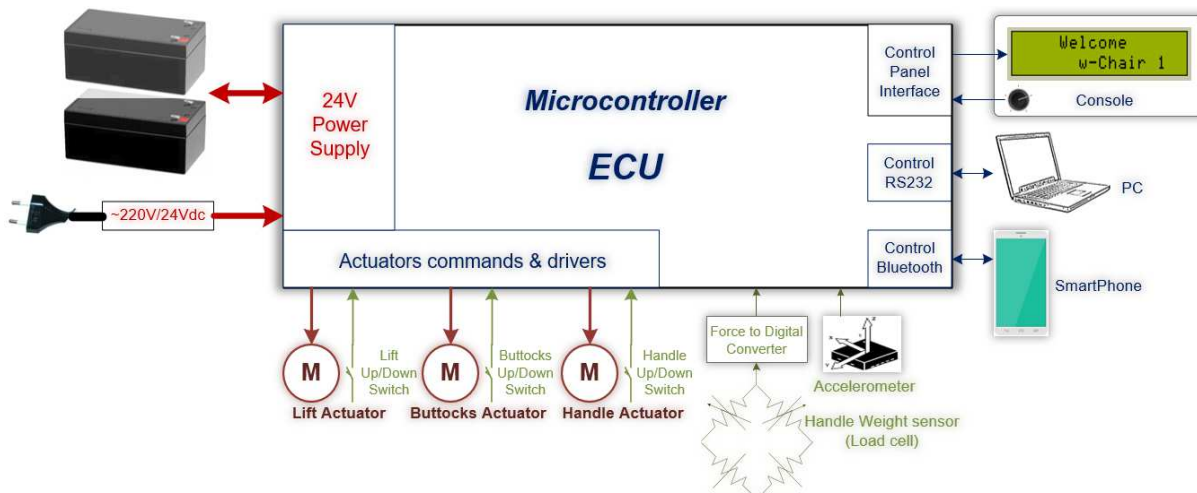


Fig.2. Block diagram of the electrical system from the chair

The role of this actuator is to relax the spine by "hanging" the body from the armpits, but too much lifting force can harm the treatment. In this case, a protection is implemented in the firmware that senses the excessive electric current consumed by the actuator when raising

the body and automatically blocks this action if necessary. A second safety measure is a strain gauge transducer that detects the difference in force between the user's weight and the suspension force of his body.

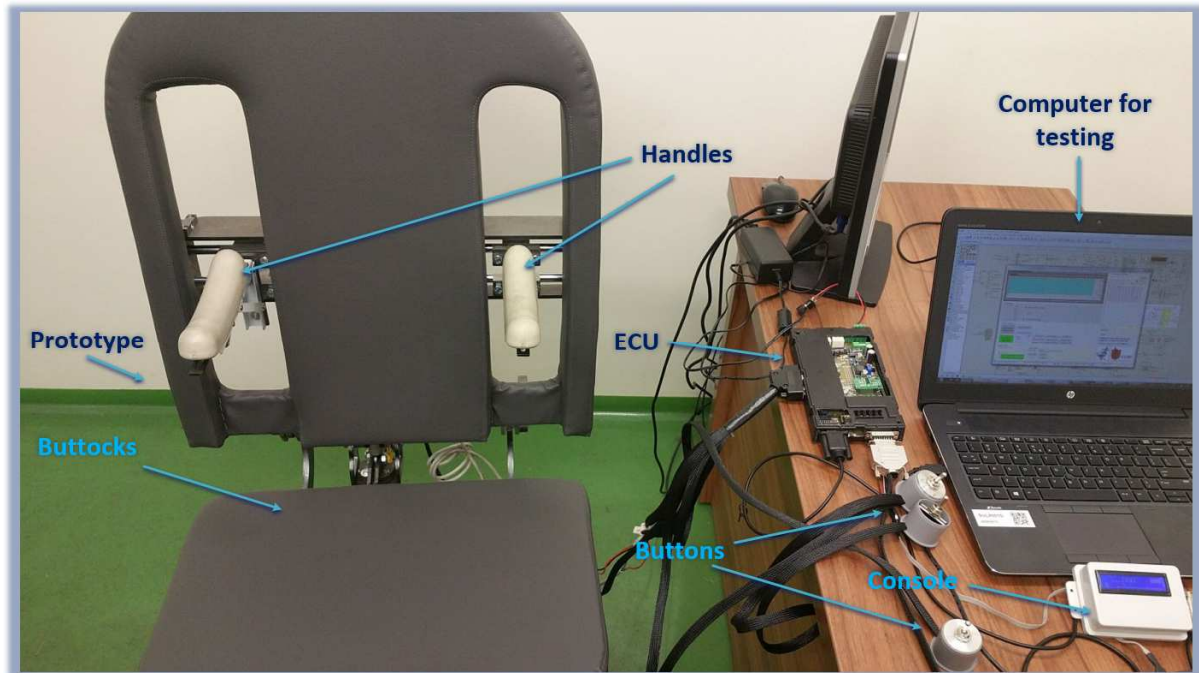


Fig.3. Prototype of the chair

Figure 3 shows the prototype of the chair under laboratory test conditions, which is based on the patent "*Computer chair with an active principle of spine relaxation*" and is owned by the "Lucian Blaga" University from Sibiu.

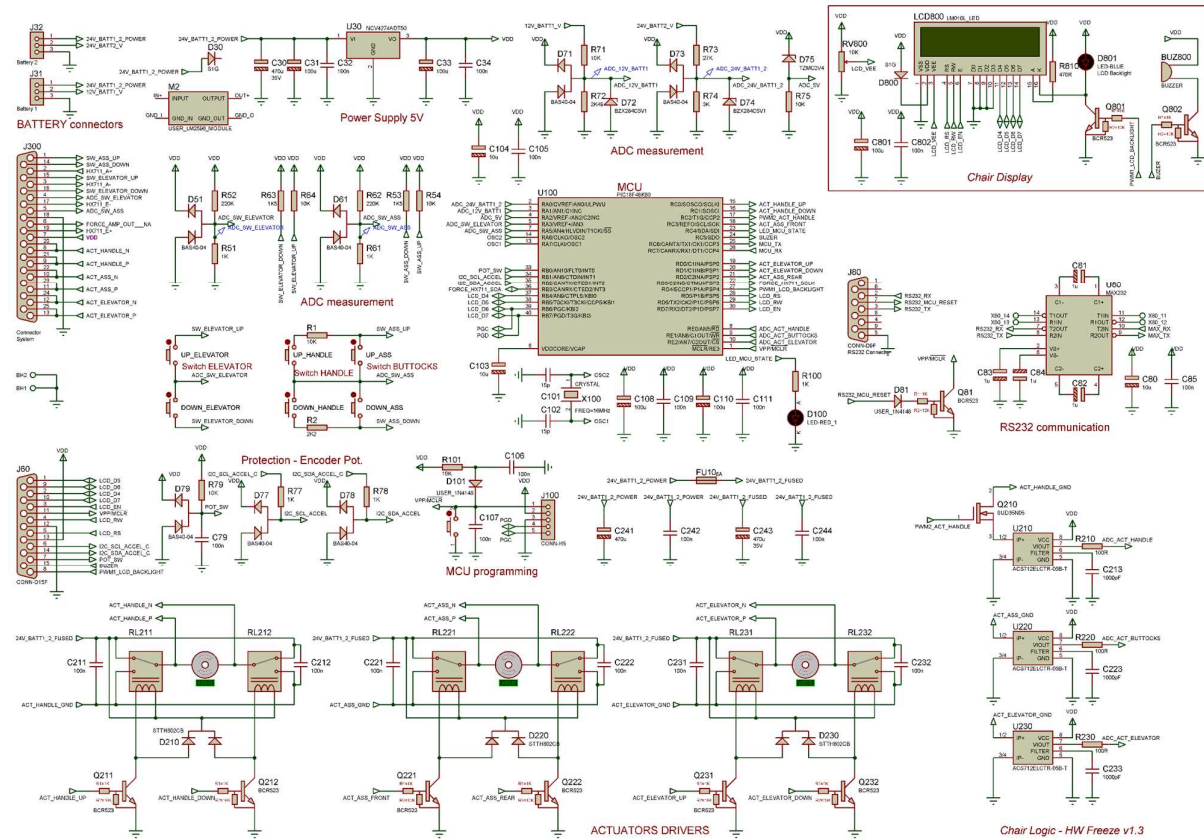
### 2.1. Electronic side

Each actuator has a command button with 3 positions: the middle one, for the normal position, when it is not acted upon, the bottom position when it is desired to act to lower or actuate the lower part of the actuator and the upper position, when it is desired to act to raise the actuator.

The electronic diagram of the ECU is shown in figure 4. The central core of the ECU is the 8-bit PIC18F46K80 MCU (Micro Controller Unit) from Microchip's PIC18F66K80 family. This microcontroller comes in a 40-pin PDIP (Plastic Dual Inline Package) package at a maximum working frequency of 64MHz, with a program

FLASH memory of 64Kbytes with a maximum of 10,000 erase/write cycles and 20 years of data retention, RAM memory of 3648 bytes and EEPROM memory of 1Kbyte (1024 bytes). The number of inputs and outputs through which the microcontroller can interact with the outside world is 35, of which 11 are analog channels (ADC - Analog to Digital Converter) with 12-bit resolution [5].

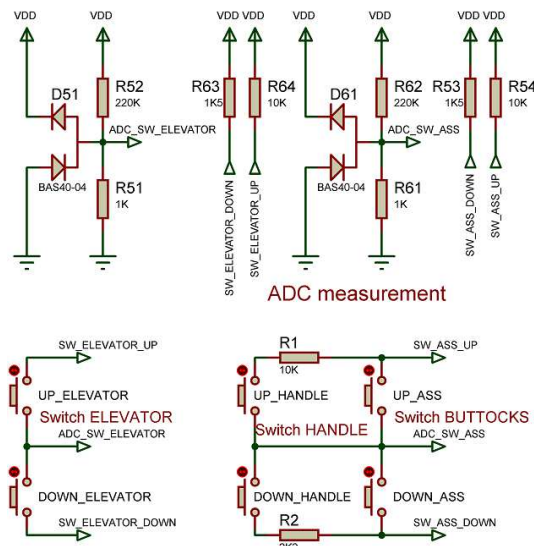
In figure 4, the microcontroller MCU has the designation of U100, and it can be seen that all its pins are used in the circuit. One of the challenges that Electronic Side had to solve was fitting the total number of inputs/outputs of the electronic system (ECU) into the available number of inputs/outputs of the microcontroller. A first step in this regard, was acting on the up/down control buttons of each actuator. Typically, at the microcontroller, each button is linked separately on each digital input line as follows: a resistor is connected in series with the normally open button between VDD and GND.



**Fig.4.** Circuit diagram of the chair's ECU (Electronic Control Unit)

Normally, when the button is not pressed, the digital input is pulled to VDD or GND. When the button is pressed, the digital input line in the MCU is connected to the complementary potential of the button in the deactivated state. Thus, the MCU detects that the button has been pressed. In this case, 6 digital inputs must be used to control the 3 actuators, each in the 2 up/down positions. In order to save inputs in the MCU, the strategy was changed from digital coding of the six states from the control buttons of the actuators to analog coding. Applying the analog coding strategy, theoretically only one analog input is needed in the MCU to code the states of the buttons in voltage thresholds, but for stability and safety reasons, 2 analog inputs were used on the ADC ports in the MCU. Figure 5 was created by extracting the block from figure 4 that contains the circuits for the buttons which control the three actuators (ELEVATOR, HANDLE, and BUTTOCKS). The 2 ADC inputs in the MCU, "ADC\_SW\_ELEVATOR" and "ADC\_SW\_ASS," which are interpreted by FW

(FirmWare - the software running in the MCU) and act on the actuators, receive different voltage values from the 6 buttons, "UP\_ELEVATOR," "DOWN\_ELEVATOR," "UP\_ASS," "DOWN\_ASS," "UP\_HANDLE," and "DOWN\_HANDLE."



**Fig.5.** Circuit diagram of the actuator buttons

The voltage values according to the pressed buttons are centralized in table 1.

Table 1

Voltage values according to the buttons			
Button	Volt. divider	ADC Channel	Voltage [V]
Switch ELEVATOR (normal state)	R52, R51	ADC_SW_ELEVATOR	0.022
Switch HANDLE, Switch BUTTOCKS (normal state)	R62, R61	ADC_SW_ASS	0.022
UP_ELEVATOR	R52, R51, R64	ADC_SW_ELEVATOR	0.473
DOWN_ELEVATOR	R52, R51, R63	ADC_SW_ELEVATOR	2.008
UP_ASS	R62, R61, R54	ADC_SW_ASS	0.473
DOWN_ASS	R62, R61, R53	ADC_SW_ASS	2.008
UP_HANDLE	R62, R61, R54, R1	ADC_SW_ASS	0.258
DOWN_HANDLE	R62, R61, R53, R2	ADC_SW_ASS	1.077

The selection of the buttons is transferred to the MCU through the two ADC ports "ADC\_SW\_ELEVATOR" and "ADC\_SW\_ASS". Further, the firmware in the MCU decides which actuator should be actuated and in which way it should be actuated depending on the values on the 2 ADC ports mentioned earlier. After data processing, the MCU activates the actuators through the digital ports as follows: the ELEVATOR actuator with "ACT\_ELEVATOR\_UP" and "ACT\_ELEVATOR\_DOWN", the HANDLE actuator with "ACT\_HANDLE\_UP" and "ACT\_HANDLE\_DOWN", the BUTTOCKS actuator with "ACT\_ASS\_FRONT" and "ACT\_ASS\_REAR". The command diagram of the ELEVATOR actuator is described in figure 6.

The two digital output ports "ACT\_ELEVATOR\_DOWN" and "ACT\_ELEVATOR\_UP", from the MCU, drive transistors Q231 and Q232. They are of the BCR523 type, specially built for switching, with the command in the base for the 5V signal from

the microcontroller, and the collector current is a maximum of 500 mA.

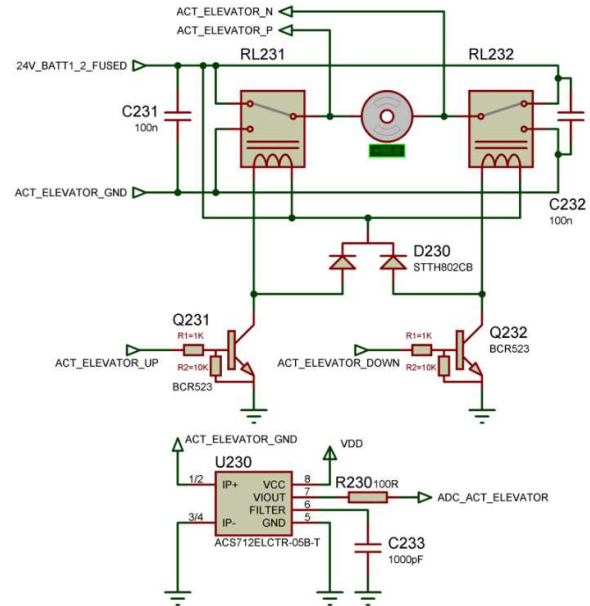


Fig.6. Control circuit diagram of the ELEVATOR actuator

Along with the 2 resistors R1 = 1K and R2 10K incorporated in the same SOT23 package, they make it excellent for digital applications, saving additional components in its base [6].

These 2 transistors control the actuator by means of 2 relays RL231 and RL232 which form an H-bridge. In the middle of the bridge, the actuator is placed at the terminal "ACT\_ELEVATOR\_P" and at the terminal "ACT\_ELEVATOR\_N", and the upper vertical arms of the bridge are connected to the 24V supply line "24V\_BATT1\_2\_FUSED". The lower arms of the bridge are connected to the negative potential "ACT\_ELEVATOR\_GND". The coils of the relays are fed between the positive potential of 24V "24V\_BATT1\_2\_FUSED" and the negative potential of the coils is controlled by the 2 transistors Q231 and Q232, according to the commands from the MCU through the digital output ports. D230, dual center tap rectifier suited diode, has the role of protecting transistors Q231 and Q232 from the self-induced current from relay coils RL231 and RL232. In the normal mode, when the actuator is not operated, it is short-circuited to "24V\_BATT1\_2\_FUSED".

The negative potential of the relay contacts, "ACT\_ELEVATOR\_GND", which connects the actuator, is connected in series with a shunt that continues the connection to Ground. In this way, the current consumed by the actuator is permanently monitored through the U230 electronic shunt. This shunt is of the ACS712ELCTR-05B type and is based on the Hall effect of electric current. The maximum current of this shunt is 5A. The shunt is incorporated in an integrated circuit U230 and has a supply voltage of 5V, and its output is analog [7]. The analog output "ADC\_ACT\_ELEVATOR" of the shunt connects to the MCU through the ADC port. In this way, actuator feedback to the MCU is ensured.

In order to display the force translated in Kg, which the Handle actuator lifts the human body, an alphanumeric display presented in figure 7 has been introduced that displays the information on the screen.

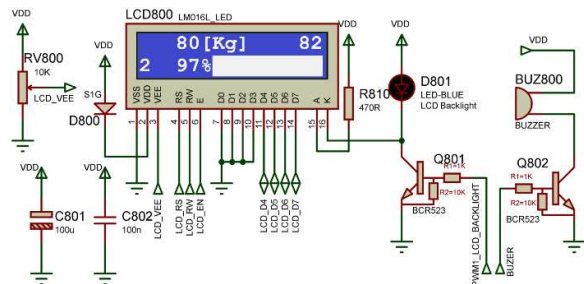


Fig.7. Display circuit diagram

The display used is EAW162B-NLW with 2 rows and 16 columns, the characters being white on a blue background [8]. The display supports the HD44780 LCD controller standard, having a predefined instruction set [9]. In order to save inputs/outputs from the MCU, the multiplexed display control mode was chosen. Thus, instead of 8-bit addressing (lines D0..D7 from the display, pins 7 .. 14) and 8 digital output lines from the MCU, the multiplexed (nibble mode) working mode was chosen in which 1 byte (8 data bits) is transferred multiplexed to the display in 2 steps on lines D4, D5, D6, D7, i.e. "LCD\_D4", "LCD\_D5", "LCD\_D6" and "LCD\_D7". In this way, 4 data lines from the MCU were saved. The control lines from the display RS, RW and E were connected to the lines from the MCU "LCD\_VEE", "LCD\_RS"

and "LCD\_EN". In order to provide an elegant way to illuminate the background light of the display (Back Light), the PWM (Pulse Width Modulation) signal lighting control was chosen for the display. The signal "PWM1\_LCD\_BACKLIGHT" from the microcontroller supplies the Q801 transistor with the PWM signal that controls the Display. For sound signaling of various events such as the discharged state of the batteries or the activation of the Handle actuator with too much force for the human body, a buzzer BUZ800 was introduced which is driven by the transistor Q802 through the output signal "BUZER" from the MCU.

The circuit diagram for the force measurement is shown in figure 8.

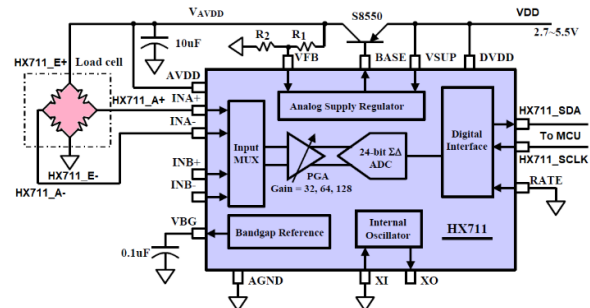


Fig.8. Load cell circuit diagram [10]

The force sensor is actually a tensometric resistive sensor connected in a Wheatstone bridge from a bathroom scale. The sensor is connected to the HX711 integrated circuit which is an instrumentation module and a 24-bit Analog to Digital converter [10] [11].

The reading of digital data from HX711 to a computer system is done serially, the clock signal is sent from the MCU to the "HX711\_SCLK" pin, and then the data is read from the HX711 to the MCU on the data signal "HX711\_SDA" synchronously with the clock signal.

## 2.2. Load cell

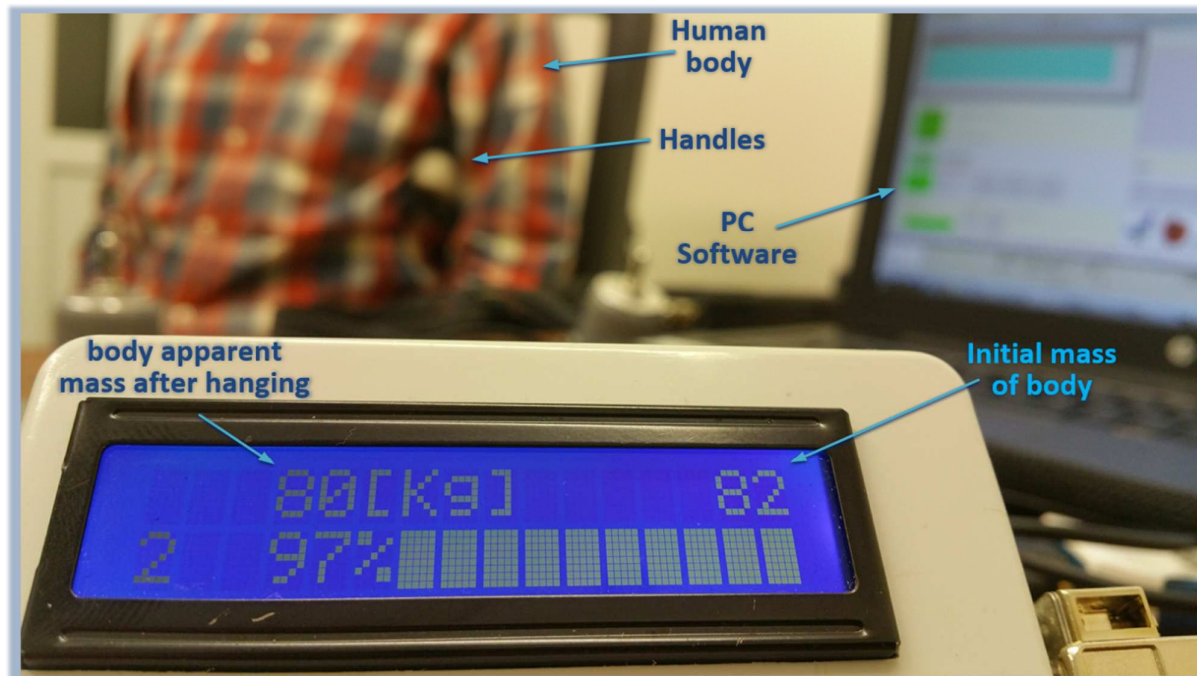
The tensometric resistive sensor has the sensitivity of the equivalent of 1 gram force, i.e., 0.001 Newton. The maximum range is approximately 150 Kgf (Kilogram force), i.e., equivalent to 1470 Newtons.

From here it follows that these gram-level variations can be amplified and detected by the

HX711 instrumentation amplifier and forwarded to the microcontroller for measurement and interpretation. In fact, the force sensor is mechanically located between the movable part of the buttocks and the fixed part of the seat. In this way, the user's weight can be measured precisely.

Moreover, when the user voluntarily acts on the Handle actuator, by partially suspending the

human body, the partial weight of the human body that comes in contact with the buttocks is measured. The weight difference is taken over by the Handle. From here it follows that the weight difference that is registered by the force sensor is the apparent weight of the human body and can be observed in one example in figure 9.



**Fig.9.** Experiments in the laboratory

In order for the weight recorded by the force sensor to be accurate, a calibration must be performed after power on of the ECU, before the user sits on the seat. In this mode, the force sensor measures a reference value (with the seat empty). For the correct display of the mass of the user who sat on the chair, the reference value measured previously is subtracted from the current value, measured with the user seated. The new value obtained, becomes the initial mass of the human body (Initial mass of body from figure 9). Because the force measured by the load cell is dependent on the position of the buttocks due to the decomposition of the forces, an acceleration sensor was introduced, which measures the tilt of the buttocks. In the firmware from the ECU, the force measurement routine from the load cell makes automatic corrections

based on the position reported by the acceleration sensor located at the buttocks.

### 2.3. Communication protocol

As can be seen from figure 2 (block diagram of the electrical system), the chair can be connected to a computer and/or a smartphone via the RS232 serial port or via Bluetooth. The role of this connection is to control the movements of the chair via smartphone or computer. Moreover, measurements can be made by acquiring data from the chair to the computer. These measurements are used to test and evaluate the chair's effectiveness, as well as to conduct studies and research on a treatment custom created by a specialist doctor for the user.

The communication protocol used is Request-Response type, with fixed data transfer

of 8 bytes per frame and is intensively used for the communication between the prototypes made by the team of inventors from the "Lucian Blaga" University from Sibiu [12].

Without a common language, it is not possible to exchange information between the chair and a computer system.

### 3. SOFTWARE SIDE

Figure 10 shows the Guide User Interface of the computer software that controls and acquires data from the chair.

The software can be operated by doctors, in physiotherapy offices for spine lengthening treatments.

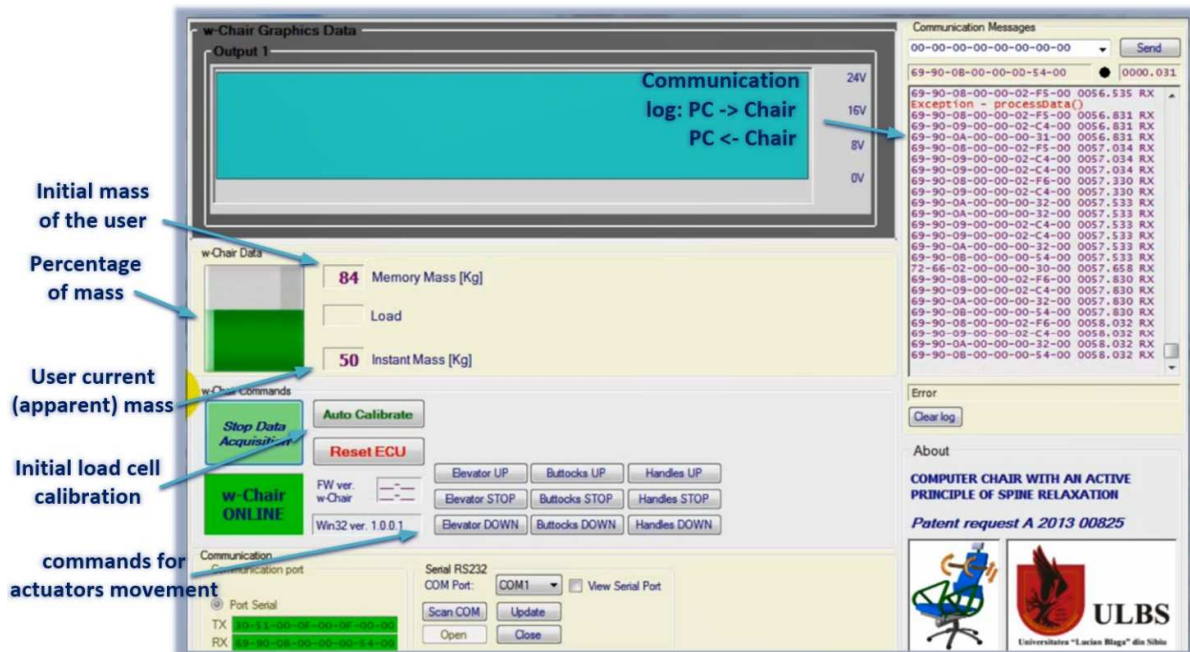


Fig.10. GUI (Guide User Interface) of the computer Software

The user's mass is displayed in real time on the graphic interface and all seat actuators can be operated manually, in the form of a remote control. The load cell can be manually recalibrated by the user. It is also possible to acquire data from the chair for subsequent analysis of its behavior in the early stages of the prototype.

### 4. EXPERIMENTAL RESULTS

Figure 11 shows the effect of the buttocks movement on the force felt by the load cell, which is located under the buttocks. The values from the load cell and from the accelerometer are cyclically sent to the computer at 200 millisecond intervals.

The PC program receives them and saves them in an excel file as raw data, which is then analyzed, and graphs generated for a better

understanding of the phenomenon, as shown in figure 11.

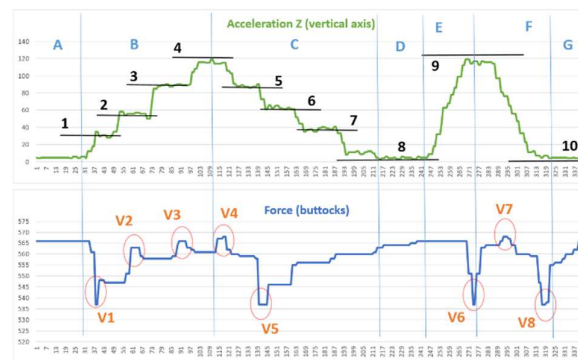


Fig.11. Digital experimental data correlated with seat movement and measured force

The green graph represents the data from the accelerometer according to the movement of the buttocks. These are synchronous with the blue graph which represents the force felt by the load cell located at the buttocks. The data acquisition



lasted 67.4 seconds because 337 samples were acquired at a frequency of 5Hz (200 ms).

Due to the reverse physical orientation of the acceleration sensor in the buttocks, the value 0 corresponds to the top position of the buttocks, and the value 120 corresponds to the bottom position of the buttocks.

In area B and C, buttocks go down and then go up in steps. In area A, D and G, the buttocks are in the highest position. In area B, the buttocks go down in steps and in small pauses in points 1, 2, 3 and 4. In point 4, the seat is completely down. In zone C, the buttocks goes up in steps and in small breaks in points 5, 6 and 7. In zone D, the buttocks is at the top of all (point 8). In area E, the buttocks descends without pause from top to bottom completely at point 9. In area F, the buttock goes up from bottom to top without pause, and in area G, the seat is up again at point 10.

On the graph from the load cell, areas V1, V2, V3, V4, V5, V6, V7 and V8 represent inertial spikes from the beginning and end of the movement on the buttocks.

## 5. CONCLUSION

Now and in the future, the activities and concerns are and will be predominantly intellectual and sedentary, especially during the pandemic, when most of the activities took place from home, in front of the computer. Long work at the office causes the well-known back pain caused by damage to the spinal column. The current prototype creates controllable and measurable conditions for stretching the spine right at the work chair in the office or at home and not only at the medical office or in spas, where the suspension force is not measured in terms of value, but is appreciated sensory and experimentally. Stretching the spine has the effect of reducing back pain by moving the vertebrae away. In this way, injuries to the spine that can occur for many reasons are avoided, especially due to some vicious positions.

Thanks to the firmware program in the ECU, the seat can be automated so that, at preset regular intervals, it notifies the user with sound signals, and acts on the extension of the column

with the HANDLE actuator. Even if the electrical actuation is under the control of the user, there are implemented, in the form of automation, 2 electronic protections mentioned earlier in order not to harm the user by the excessive actuation of the force of elongation on the spine. This functional prototype was highly appreciated at the international invention exhibitions by the jury and visitors, and in 2018, having been exhibited at the "EUROINVENT" exhibition in Iasi, the "Lucian Blaga" University in Sibiu took the grand prize "for the outstanding invention exhibited at EUROINVENT 2018".

"Happiness lies, first of all, in health"  
(George William Curtis)

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### **Contribuții la proiectarea și implementarea unui sistem electronic avansat pentru controlul elongației coloanei vertebrale**

Lucrarea științifică promovează o contribuție importantă cu privire la proiectarea și implementarea unui sistem electronic avansat pentru controlul elongației coloanei vertebrale cât și a unui software dedicat pentru comanda, controlul și achiziția datelor pentru un scaun utilizat la birou. Obiectivul principal al produsului "scaun de birou" este în fapt realizarea unei elongații controlate a coloanei vertebrale umane (care aparține utilizatorului) cu ajutorul unor pârgii situate sub subțiori. Pentru atingerea dezideratului propus, s-a ales folosirea controlului digital al pârgiilor utilizând un sistem electronic format din senzori, un afișaj, un microcontroller și un actuator menit să acționeze elementele scaunului fără a vătăma utilizatorul. Scaunul de birou funcționează autonom sau supervizat de un computer. Dacă se dorește realizarea unor studii și cercetări asupra unui tratament special gândit de către un medic de specialitate care să fie aplicat utilizatorului se poate acționa în acest sens. Lucrarea științifică se bazează pe un brevet de invenție lucru care a permis obținerea unor rezultate experimentale demne de luat în considerare.

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