A Portable Dynamic Support System for Rigid Joint Treatment

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Introduction

Background

- **Scoliosis** is an abnormal spinal curvature symptom and is diagnosed when Cobb angle is larger than 10 degrees [1]. **Bracing treatment** can be an alternative method to adjusting the patient's posture. Bracing treatment is commonly based on the concept of **three points curve correction**: two points give the counter-pressure at each side of the curve and the other one point applies pressure on the curve apex [2].
- In previous study, researchers have designed different device for Scoliosis treatment, they applied Sphygmomanometer [3], air valve, pump [4] and MCU [5] to the device, which are used for control the pneumatic system, but the overall structure took large amount of space, resulting in huge influence on patients daily life. And also the device are **not modular enough** to make customization feasible.

Objective

- Our aim is to develop a **portable** and **customable device** which can be used for coping **with abnormal joint diseases** such as scoliosis.
- We have reduced the total volume of the control system to **less than 200mm³** and made the pump and control system **independent and separate modules**, so that user can replace the pump model as needed, that is, it can be used to treat **other stiff joints**, not just scoliosis.

Methods

PCB module Design

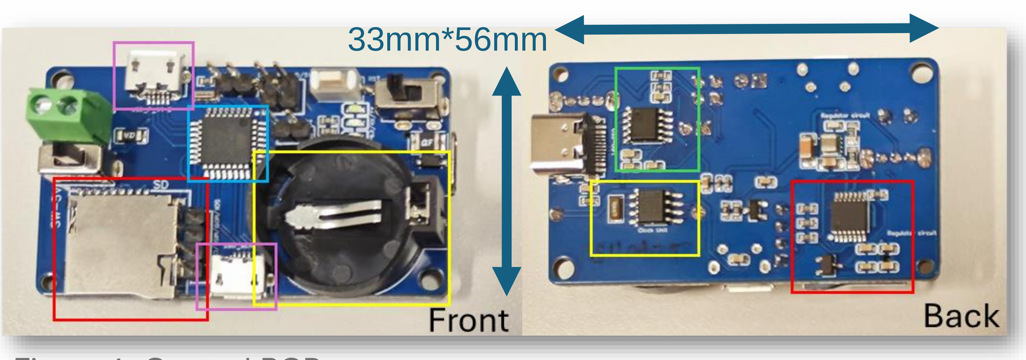

Figure 1. Control PCB

Main Function Block	
MCU	■
Clock Unit	■
TF-Card Memory Unit	■
CH-340K UART Communication	■
I/O (Micro USB)	■

Chart 1. Control PCB Module

- MCU PCB, contains **ATMega328P**, **RTC** and **TF memory** functions. This part is where the **main control chip** located. (F.1, C.1)

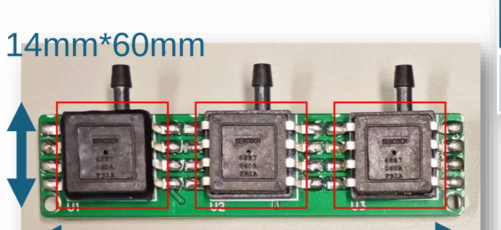

Figure 2. PreSense PCB Module

Main Function Block	
XGZP6887A Pressure Sensor	■

Chart 2. PreSense PCB Module

- Pressure sensor PCB, contains **3 Pressure Sensors.** (F.2, C.2)

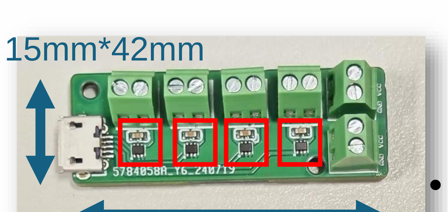

Figure 3. Driver PCB Module

Main Function Block	
DRV8220 H-Bridge Driver	■

Chart 2. Driver PCB Module

PWM Controller PCB, contains **4 PWM Drive** Channel, operated by **DRV8226.** (F.3, C.3)

Container 3D design

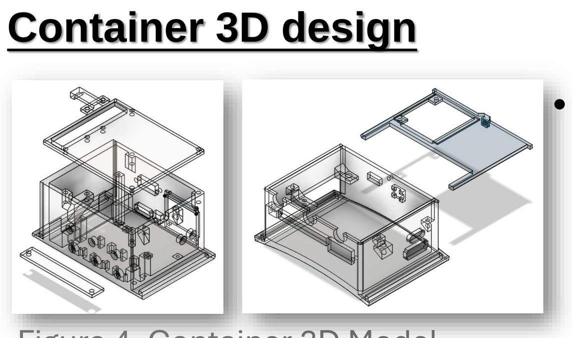

Figure 4. Container 3D Model

Designed the 3-D model for Controller's container on the platform of **Fusion360**, Autodesk **(Figure 4).**

Arduino Program Logic Design

This system appears to be designed to carefully control the pressure within the actuator, ensuring it remains within safe operating limits. Due to **human breathing**, slight changes in air pressure may occur [2], so the program uses **delay control** and **threshold control** methods to prevent frequent changes in the controller from shortening its life. The diagram of program control logic is as Figure 5.

The code of this project written in **C++ language** (based on **Arduino 1.8.19** platform) has been fully open sourced on Github.

Link:
https://github.com/JOHNhaaa-oops/Pressure_Sensor_Actuator

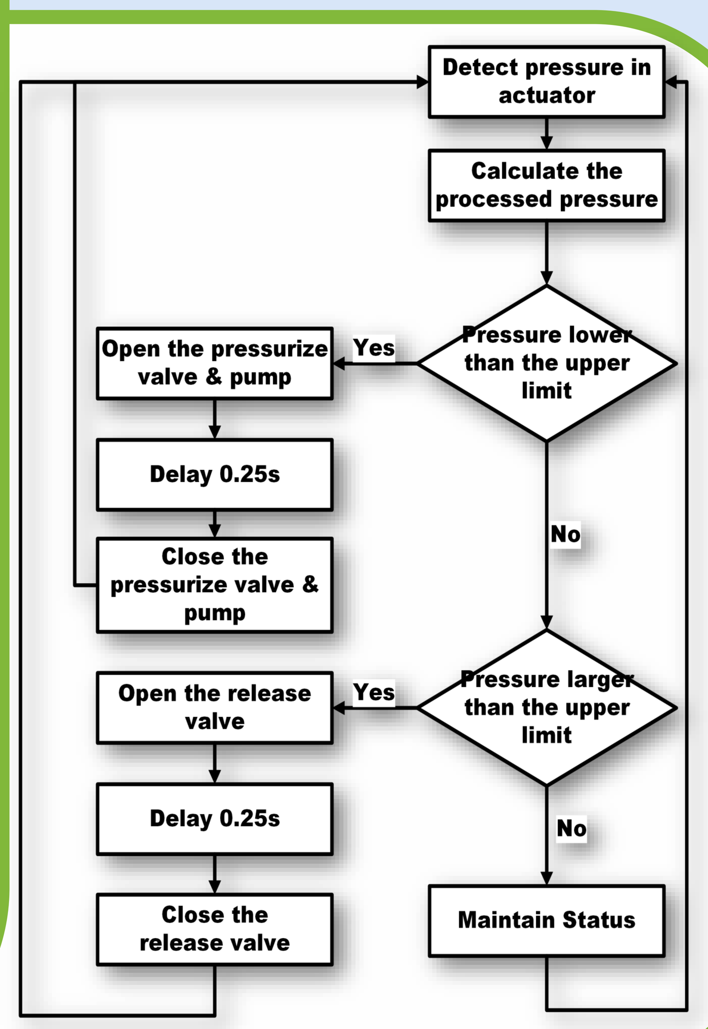

Figure 5. C++ program logic diagram

Overall Structure

Module Layout

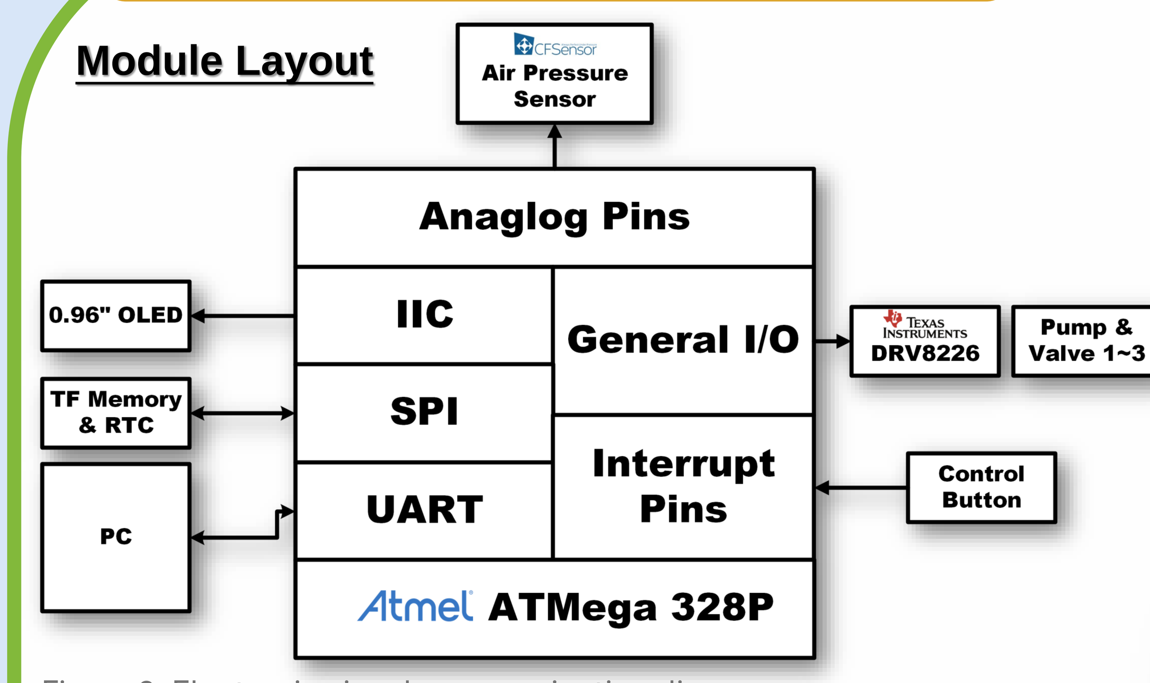

Figure 6. Electronic signal communication diagram

- **Figure 6** shows the control signal network centered on the main control microchip. During the design process, only one pin (D3) of the entire chip is redundant, so that the performance of the main control chip can be fully utilized.
- **Figure 7** shows the air circuit diagram of the device, which can simultaneously control two airbags to float up and down at different or the same air pressure setting values.
- **Figure 8** is a physical parts layout diagram of the assembly of all components.

Pneumatic Circuit

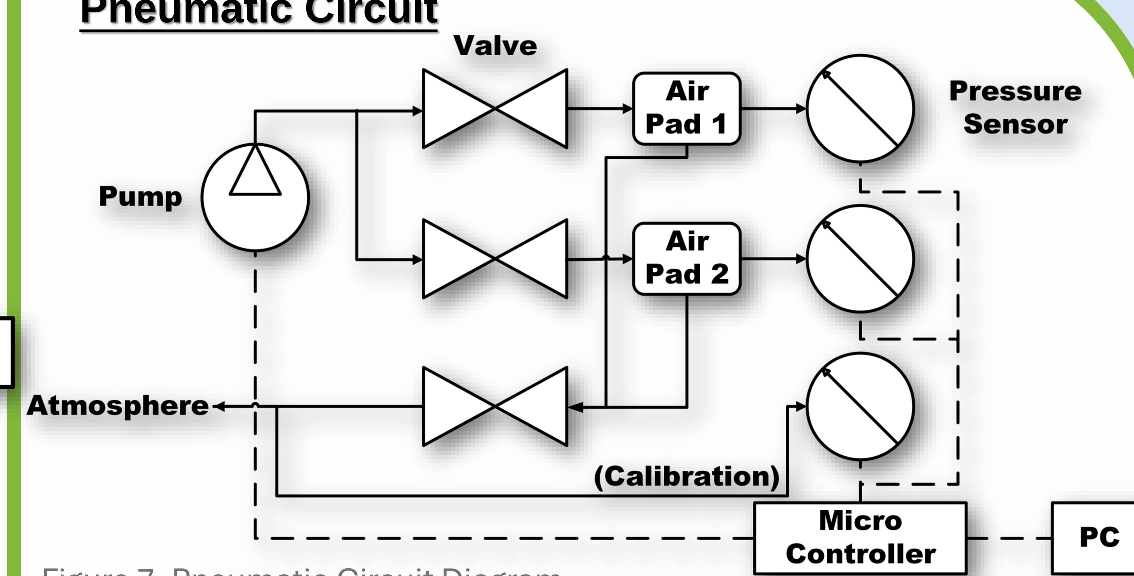

Figure 7. Pneumatic Circuit Diagram

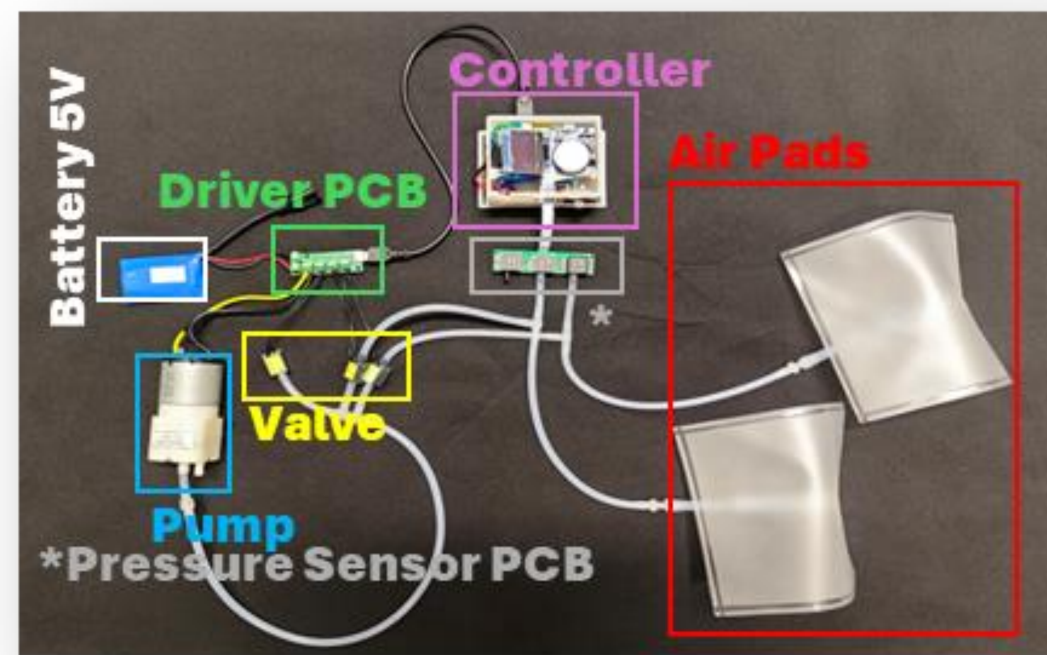

Figure 8. Physical parts layout

Results

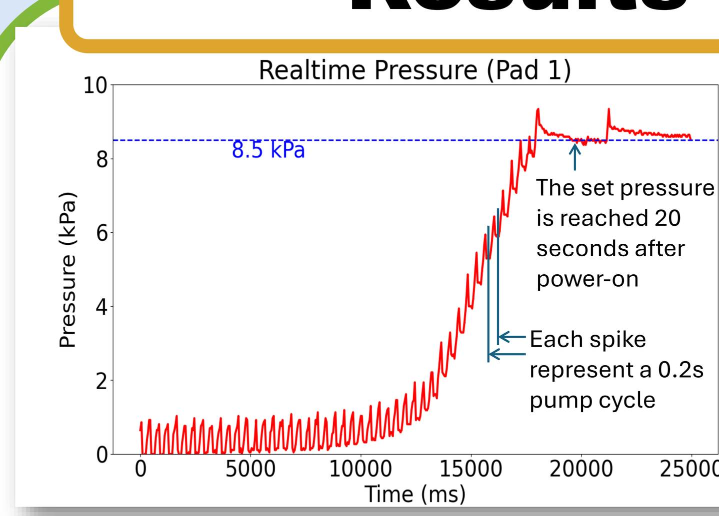

Figure 9. Pressure change (after power on)

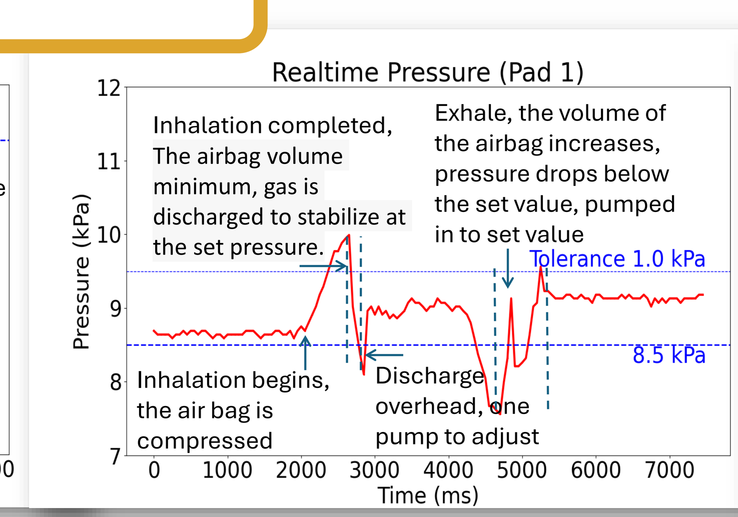

Figure 10. Pressure change (with patient breath cycle)

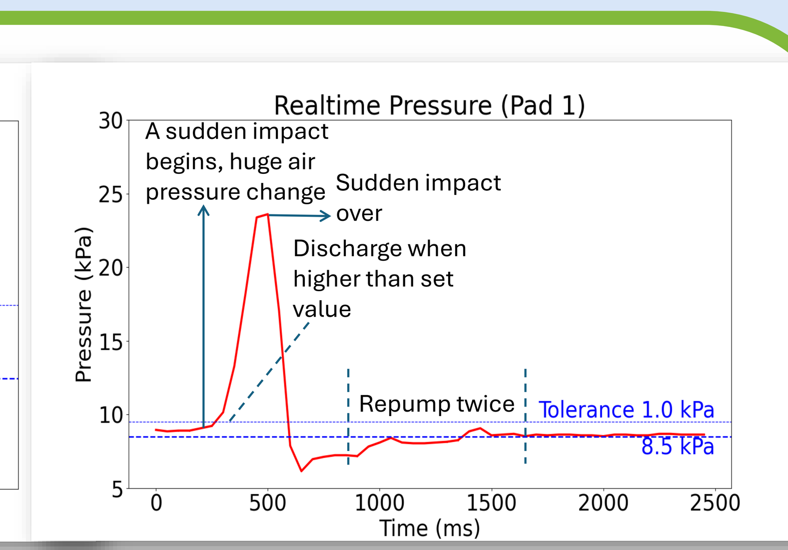

Figure 11. Pressure change (with sudden impact)

- The real-time air pressure in the airbag is monitored and plotted by PC to observe control effect in different states. **Figure 9** shows pressure rising to the set value with spikes caused by pumping cycle during start-up. **Figure 10** depicts pressure changes from the user's deep breathing, where inhalation causes compression and deflation, while exhalation restores the original state. **Figure 11** demonstrates the deflation valve opening when pressure exceeds tolerance during sudden impact, then gas is refilled.

Discussion/Future

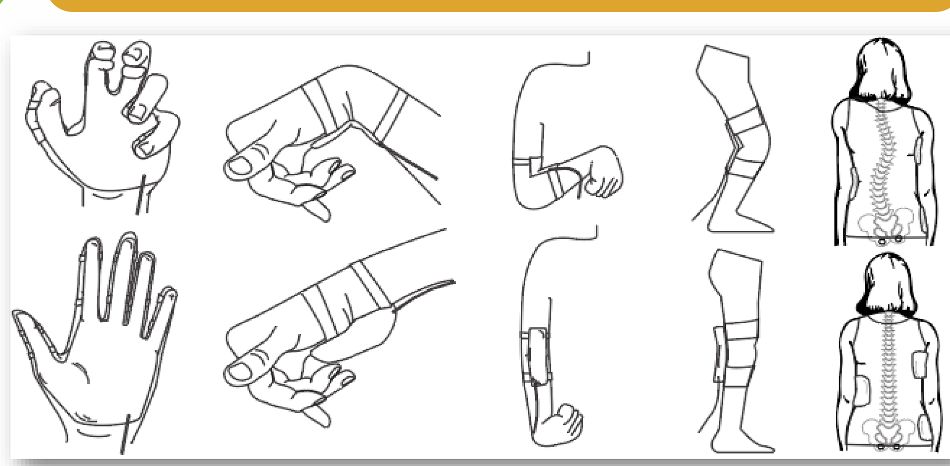

Figure 12. Application of treating rigid joints

This project introduced a **pneumatic systems** which can beneficially **treat stiff joints** (Figure 12) by dynamically adjusting pressure based on sensor feedback to provide precise, gentle manipulation within safe, comfortable limits for patients.

Discussion

- **Portability** is the main strength of our device. The portability of pneumatic control systems plays a vital role in medical rehabilitation equipment. A convenient device can allow patients to access care and monitoring outside of clinical settings, improving access to healthcare and enabling continuous monitoring, leading to **earlier detection and intervention of medical issues** [6].
- While the ATMega328P is used as the main control chip due to familiarity, its limited computing power and memory are a disadvantage.

Future

The **IoT** holds significant promise for medical devices and healthcare applications, enabling **remote rehabilitation, telehealth**, and **proactive disease management**, reducing the need for in-person visits [7]. Future designs can consider main control chips with IoT connectivity, such as the ESP-32 which integrates **Wi-Fi** and **Bluetooth antenna**.

Reference

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