PREVENTING DEEP VEIN THROMBOSIS USING A WEARABLE SEQUENTIAL COMPRESSION DEVICE

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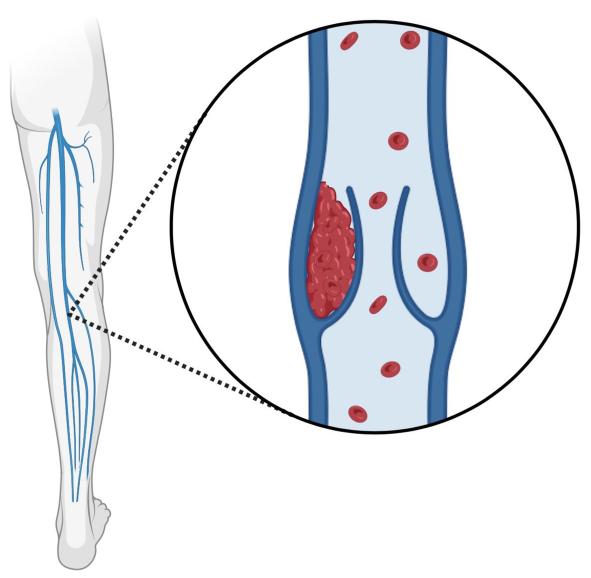
Lung Technologies

Deep Vein Thrombosis

- Deep Vein thrombosis (DVT) occurs when a **blood clot** forms in the deep veins[1]
- DVT impacts pre-operative, post-operative, and bed-ridden patients that suffer from a **lack of movement/poor circulation**
- If untreated, clots can break apart, resulting in a **pulmonary embolism** (PE)
- Existing sequential compression devices (SCDs) **lack compression strength**, are **heavy**, and **restrict patient mobility**



Design Specifications

The device shall:
- Have pressure reading of **80 mmHg**
- Be breathable, non irritable, and adjustable
- Weigh **< 5 lbs**
- Have **replaceable batteries**
- Permit **ankle movements** and patient **mobility**

The device should:
- Switch between **80** and **120 mmHg**
- Have a battery life of **6-8 hours**
- Have an **accessible** internal sleeve
- Fit a **large range** of calf sizes/lengths

Hardware

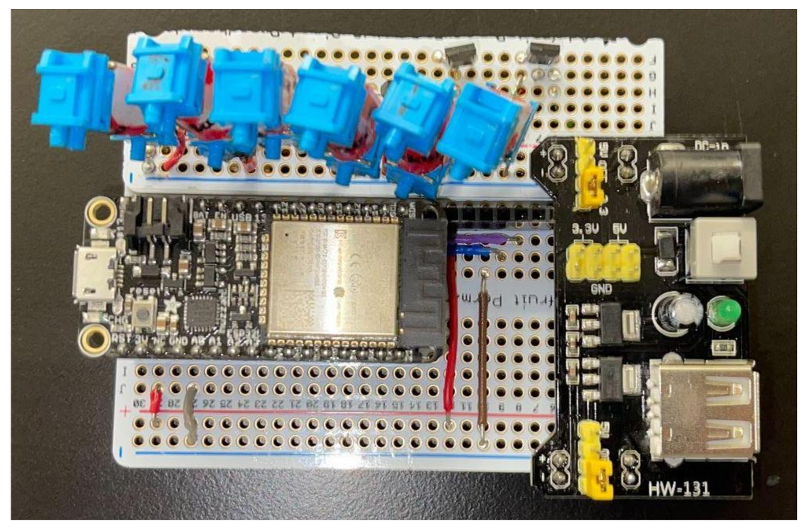
ESP32 Feather Microcontroller

Need a **centralized**, **efficient**, yet **small** microcontroller which can handle many inputs and outputs
- The ESP32 Feather is a relatively **small** microcontroller that can be implementable to a PCB[2]
- It features a dual-core processor

Power Design

Need an easily **accessible**, **rechargeable**, **lithium** battery that can last at least 3+ hours while not being **too heavy**

- Integrated 3 9V 600mAh Li battery for appropriate **power rating**, and **lightest** solution
- Implemented a HW-131 MB102 Power Supply Module **(step down convertor)** which takes in 9V input and outputs a stable 5V and 3.3V which is necessary to power the rest of the components

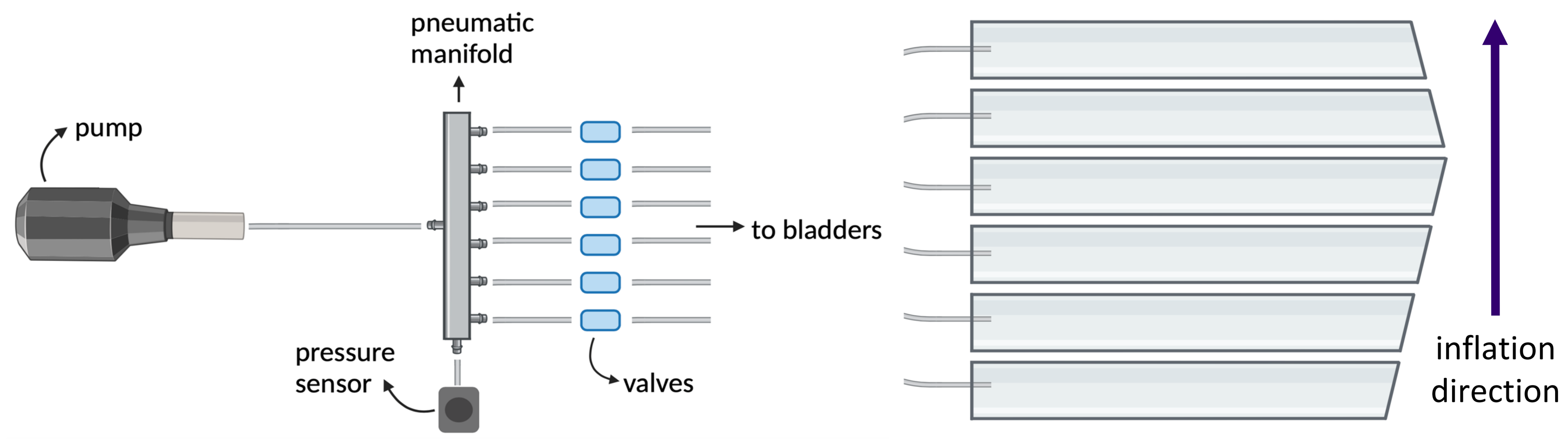


Inflation Sequencing & Design

Problem: Inflation and deflation in the initial prototype operated **too slowly**, potentially allowing backflow of blood

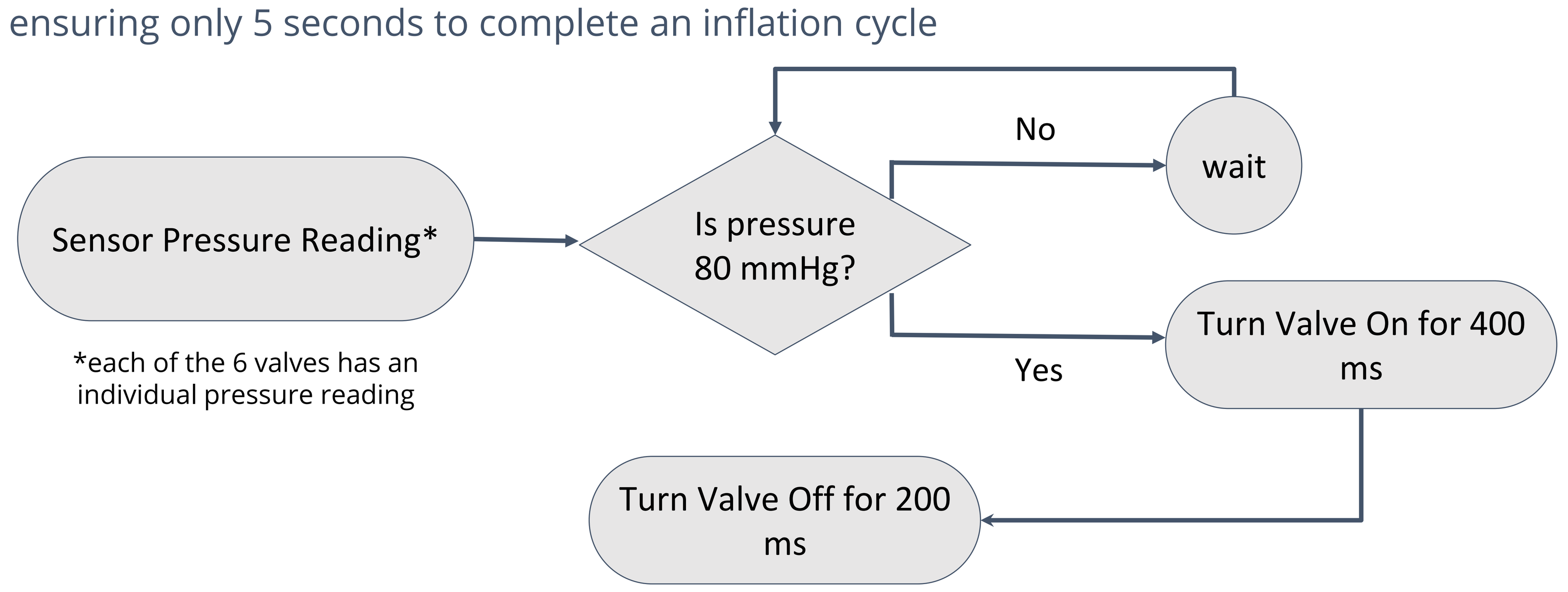
Inflation Mechanism:
- **Sequential ascending inflation** of compression bladders (distal to proximal)
- Airflow to/from bladders **regulated** by **pump-sensor-valve** system

Compression Bladder Fabrication:
- Decreased number of compression **bladders** from **8 → 6**
  - Reduced total weight: smaller manifold and fewer valves
- **Physically** and **chemically** bonded vinyl to form airtight bladders and integrate silicone tubing
  - Inner seal: epoxy (chemical)
  - Outer seal: heat seal and heat shrink tape (physical)



Firmware

Timing with inflation/deflation needs to be **consistent** to reach target pressures, ensuring only 5 seconds to complete an inflation cycle

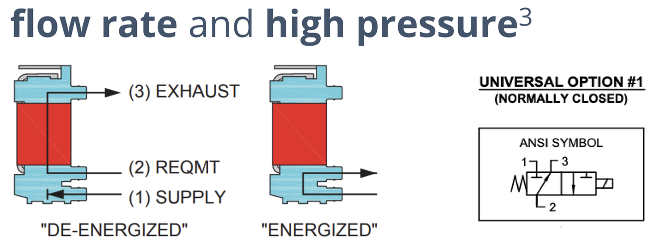


*each of the 6 valves has an individual pressure reading

Motor and Valves

Valves need to **withstand a high flow rate** and **high pressure**[3]

- **3-way** universal valve



- These valves have power consumptions of **0.5 Watts** with **5 V** input
- Supplying valve with motor with **3 L/M** flow rate

Sleeve Design

Problem: The sleeve of the initial prototype used materials that were **too heavy** and **lacked breathability**

Material Selection:

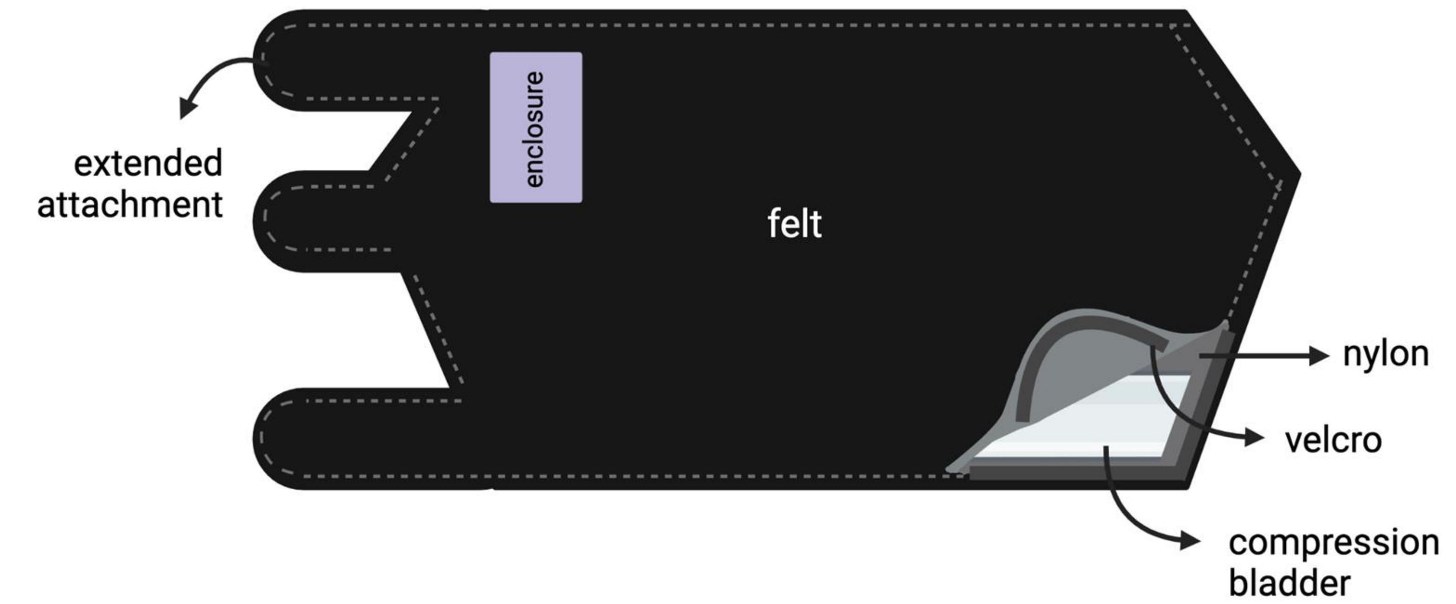
Outer sleeve: **felt** & **nylon** to prioritize **user comfort**

Compression bladders: **clear vinyl** to improve **durability**

Pneumatic Manifold: **lightweight plastic** tube splitter to decrease **device weight**

Enclosure: **PLA filament** for easy **manufacturing** and lightweight **protection**

Additional Features:
- Optimized shape of sleeve to **better fit** shape of lower leg
- Velcro attachments and closures: allows for **access** and **adjustment** of components
- Internal elastic supports: holds compression bladders in place to ensure **proper positioning** within the sleeve



Results & Future Work

Results:
- Designed **6-bladder** SCD, with **80 mmHg** pressure settings
- One inflation cycle completes in **5 seconds**
- Device is **portable**, allowing for patient mobility
- Device allows for calf size up to **21" circumference**
- Battery life of **9 hours**

Future Work:
- Recycle air between compression bladders to **reduce power consumption**
- Create a **monitor** to display pressure applied
- Design **attachment extenders** to accommodate for a wider range of limb sizes
- Write a **user manual**

References & Acknowledgments

[1] Penn Medicine - Deep Vein Thrombosis
[2] AdaFruit - ESP32 Feather Microcontroller
[3] Parker - Miniature Solenoid Valves

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