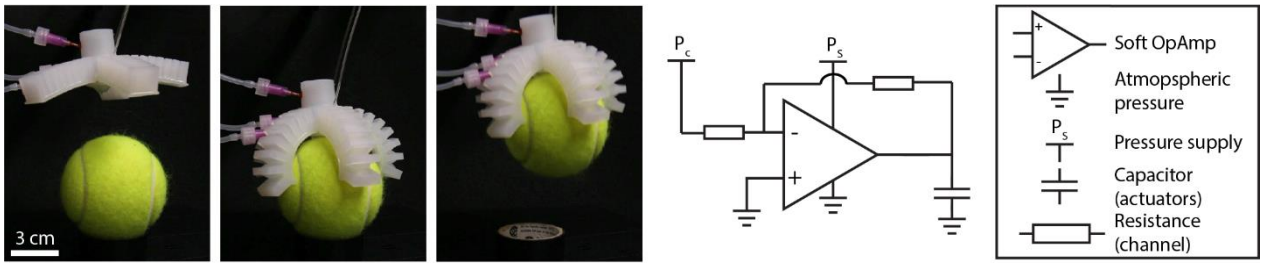
University of Stuttgart
Institute for Adaptive Mechanical Systems

Master's thesis

Thesis Title:
Development of Pneumatic Analog Control Circuits for Soft Robotics Applications

Description:
Soft robots are characterized by compliance and adaptability and offer numerous advantages over traditional rigid robotics. These systems are inherently safer for interaction with humans and can operate in unstructured environments, making them ideal for applications in healthcare, wearable technology, and perform grasping tasks that require high flexibility or gentle manipulation. However, a persistent challenge in this field is the development of efficient and robust control systems that align with the flexible and deformable nature of soft robotic materials. Traditional control elements such as valves and pumps are bulky and rigid and are, therefore, challenging to integrate into a soft robot. A strategy to overcome this problem is to incorporate soft control elements into the hardware of soft robots.



This thesis explores the analogy between electrical circuits and pneumatic circuits to develop innovative analog control systems specifically for soft robotics applications. By establishing a framework for pneumatic analog control circuits, this thesis opens new pathways for designing simplified, scalable, and robust control architectures that seamlessly integrate with soft robotic systems. The research focuses on developing and implementing a pneumatic amplifier that mimics the behavior of an operational amplifier (OpAmp) as a fundamental building block for analog pneumatic control circuits. The development of such an element offers the potential for embodying complex analog pneumatic control functions, such as signal amplification, noise filtering, and feedback control, into fluid-driven soft robots.

Key objectives of this thesis include:

1. Designing, prototyping, and testing a functional pneumatic operational amplifier capable of large-pressure amplification.
2. Developing and analyzing pneumatic analog circuits for feedback control (P-, PI-controller).
3. Integrating these circuits into a soft robotic system to evaluate the performance of the circuit

This project combines design, fabrication, experimental validation, and simple numerical modeling.

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