Tech Expo, Spring/Fall 2026 – Team 06

HMI for Robotic Arm

Team: Joaquin Colon, Nathaniel Grimm, Vishali Kumaran, Destinee Simon, Angel Torres, Justin Vasquez, Bret Weesner

Mentors: Prof. Jose Garcia

PURDUE UNIVERSITY
Polytechnic Institute

PROPORTION-AIR

Problem Statement

Proportion-Air's electronic pressure regulators deliver precise and reliable control, but they are harder to demonstrate in todays digitally focused industrial environments. As automation shifts toward networked digital systems, analog technologies are often seen as outdated despite their strong performance. This project addresses the challenge of creating a clear demonstration platform that shows how analog regulators can function effectively within modern digitally supervised systems.

Customer Background

Proportion-Air is a U.S.-based manufacturer of precision electronic pressure and flow control systems for industrial automation. Their headquarters are in McCordsville, Indiana. The company produces electro-pneumatic regulators, vacuum regulators, and flow controllers used in industries such as medical devices, semiconductors, robotics, automotive, and food processing. Their products provide accurate, repeatable pressure control and support both analog performance and modern digital integration.

Proportion Air QB2

The Proportion-Air QB2 is a dual-loop electro-pneumatic pressure regulator designed for precise closed-loop pressure control in industrial automation systems. It accepts a 0-10 VDC command signal from the Raspberry Pi and uses both an internal pressure transducer and an external feedback sensor, such as a rotary potentiometer, to maintain accurate and repeatable motion. This double-loop control improves pressure regulation, position control, and overall system stability, making the QB2 ideal for demonstrating analog pressure regulation.

Requirements

The system must provide repeatable pneumatic motion using Proportion-Air's QB2 regulator rand spring-return cylinders while maintaining safe operation and low system complexity. It must convert the Raspberry Pi's 3.3 V output into a stable 0-10 V analog signal for closed-loop pressure control and use rotary potentiometers for accurate position feedback. The design must support HMI integration, remain under the project budget, and be reliable for trade show demonstration and customer training.

Experimentation and Concepts

To identify the best design for Proportion-Air's demonstration platform, the team explored multiple concepts focused on pneumatic motion and closed-loop control. Pneumatic actuation was selected to simplify motion and highlight the precision of analog pressure regulation. Single-acting spring-return cylinders powered by the Proportion-Air QB2 regulator were chosen to provide smooth, repeatable motion while reducing component count, improving safety, and eliminating the need for belts and electric motors.

A dual-acting cylinder system was researched to control both extension and retraction. It offered strong bidirectional control and faster actuation, but required more valves, more wiring, and increased system complexity. Ultrasonic sensors were also researched to provide second loop feedback to track the positioning of each arms' joint. This idea was rejected due to incompatibility between the sensors and Proportion Air's QB2.

Final Design

The final design uses a single-acting spring return pneumatic actuator controlled by the Proportion-Air QB2 electronic pressure regulator to create smooth and repeatable motion. This design was selected for its mechanical simplicity and reduced component count. The Raspberry Pi 4B manages closed-loop control by sending pressure commands, processing sensor feedback, and supporting future HMI integration. Custom CAD-designed components were 3D printed using PLA and TPU to connect the actuators and rotary potentiometers while maintaining reliable motion.

A custom voltage-conversion circuit was developed to scale the Raspberry Pi's 3.3 V PWM output to a stable 0-10 V command signal. LM358P operational amplifiers were used to safely amplify 3.3 V output to 10 V. Rotational potentiometers were mounted to the arms' joints to generate a second loop command signal to smooth the arms' movement. A 10 V supply was applied to each potentiometer, and a circuit was developed to improve output resolution by scaling the potentiometer's signal across a 0-10 V range.

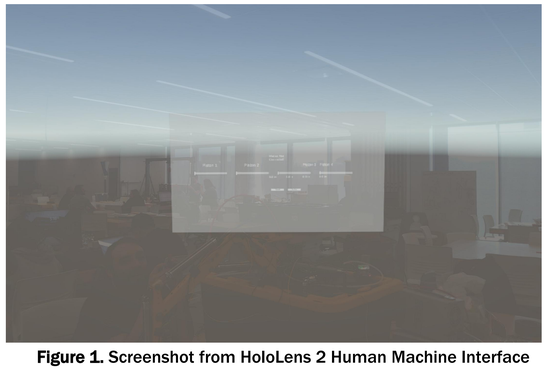

Figure 1. Screenshot from HoloLens 2 Human Machine Interface

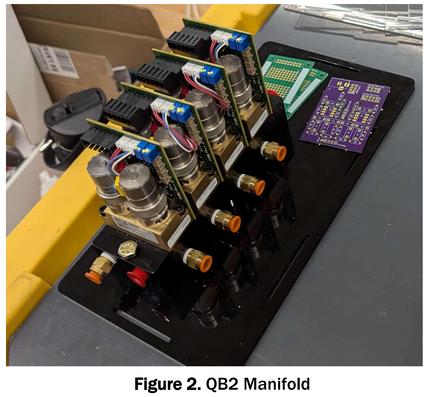

Figure 2. QB2 Manifold

Testing and Results

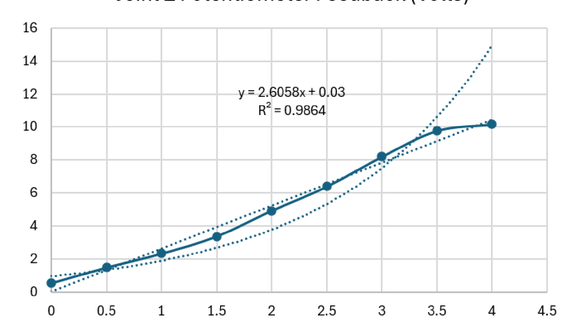

Figure 3. Joint 2 Potentiometer Feedback

Testing focused on validating pneumatic controllability, signal accuracy, and mechanical reliability of the robotic arm system. Pneumatic testing measured the minimum pressure required to extend each spring return cylinder and confirmed smooth, repeatable motion within the 30-60 psi operating range. Electrical testing verified that the Raspberry Pi's PWN output was successfully converted into a stable 0-10 V analog signal for the QB2 regulator using the low-pass filter and op-amp circuit. Rotary potentiometers were tested by comparing physical arm movement to returned sensor values to ensure accurate position feedback and consistent closed-loop control.

Leak testing, voltage checks, and alignment inspections were also performed to improve safety and overall system reliability. Results confirmed that the final design met the project requirement for repeatable pressure control, safe operation, and effective demonstration capability for Proportion-Air customers and trade show engineers.

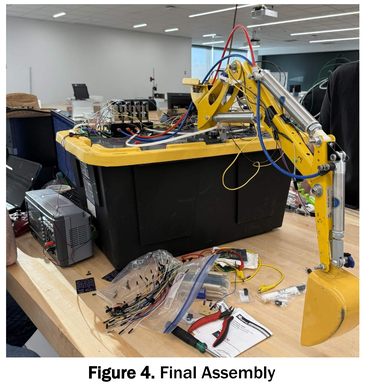

Figure 4. Final Assembly