Active Pressure Regulator

MAE 151A · Team 12 · Under Pressure

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Overview:

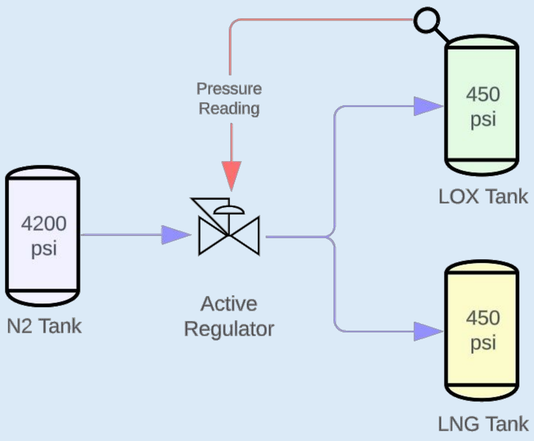
The UCI Rocket Project utilizes gaseous nitrogen to pressurize the rocket's propellant tanks. Pressure regulators are required to control the pressure of the rocket propellant tanks. An actively controlled regulator can be used to maintain precise tank pressures across a broad range of operating conditions.

Summary:

The fixed-pressure pressure regulators that the UCI Rocket Project have been using suffer from a few inherent characteristics; Regulator droop, choked flow effects, the supply pressure effect, and valve hysteresis all contribute to off-nominal regulator output during flight. All of these inadequacies can be resolved with a component that self corrects to maintain a desired outlet pressure, improving engine performance.

Objective:

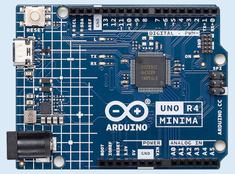
The objective for the Active Pressure Regulator Project is to design a feedback controlled fluid control component capable of actively regulating and delivering GN_2 to the rocket propellant tanks.



Embedded Electronic Systems

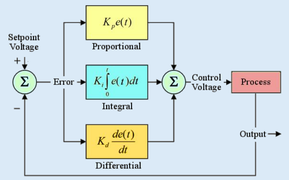
Microcontroller

- UNO R4 Minima includes a 12-bit CAN BUS peripheral
- Many developed importable user libraries with support (Particularly CAN and Servo)



Perfboard

- Secure solder joints and connections
- Straightforward and easy assembly of simple circuits
- Flexible and highly customizable layout



Mechanical Systems:

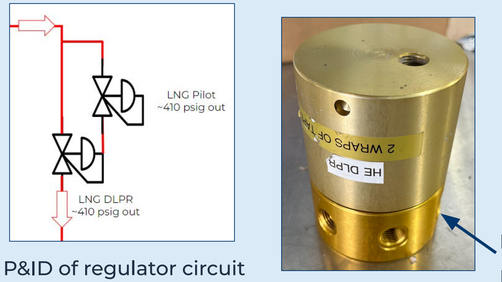
Motor

- Produces up to 5.06 ft*lbs of torque at 16.8V
- Offers 180 deg range of motion
- PWM control

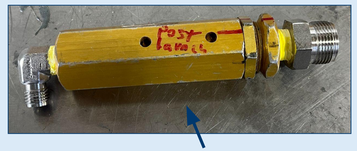
Valve

- Max pressure of 4500 psi
- Max Flow coefficient Cv=0.6
- Threaded pipe connection compatible with UCIRP

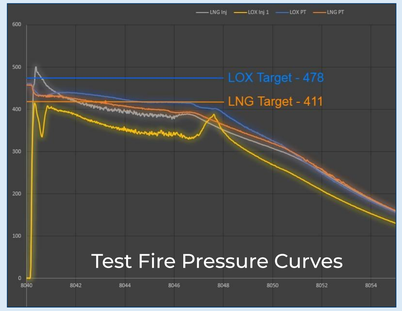
Previous design



Dome Loaded Pressure Regulator



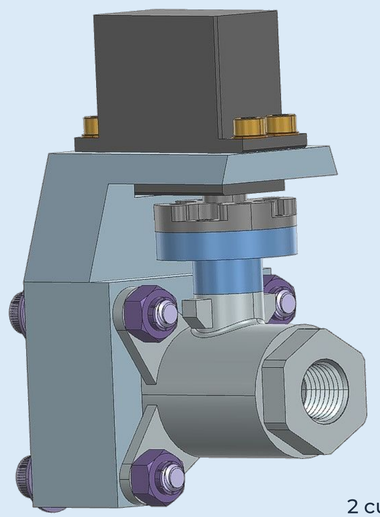
In-line Pilot Regulator



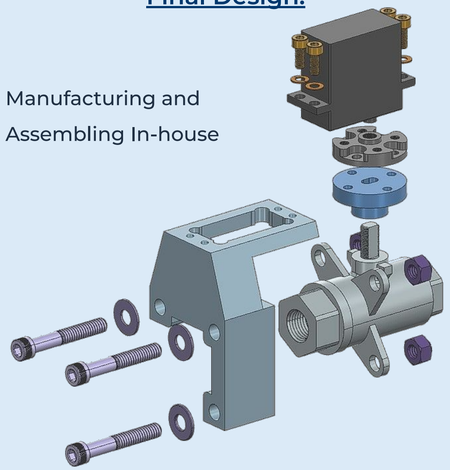
Test Fire Pressure Curves

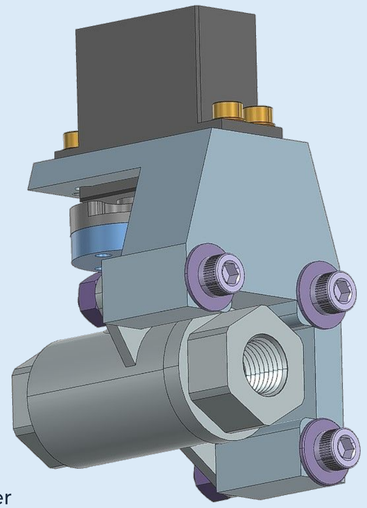
P&ID of regulator circuit

Final Design:



Manufacturing and Assembling In-house

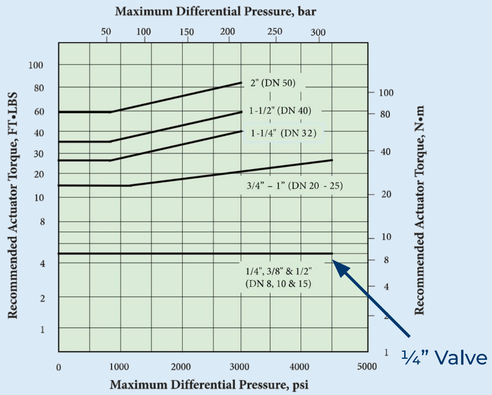




2 custom parts - Motor Mount and valve stem adapter

Engineering Analysis:

- Motor was selected based off maximum differential pressure experienced of 4155 PSI.
- Required torque for actuation is 5 ft*lbs.



Key Features

- Low cost / Majority COTS parts
- Lightweight / Small form factor
- Precise / Fast Response Time
- Safe to Operate / Easy to Manufacture
- Active regulation mechanism adjusts downstream pressure synchronously
- Integrable control system into current communication infrastructure
- Able to withstand high pressure gaseous nitrogen/helium

Future Improvements:

- Accuracy or Flow Rate Upscaling
  - Place multiple units in parallel to increase flow rate for lower max upstream pressure requirement
  - Place multiple units in series to more accurately regulate downstream pressure (coarse and fine pressure adjustments)
- Control Algorithm Tuning, Additional Sensor Integration, Environmental Adaptability, Component and Energy Optimization

Acknowledgements:

[1] V. Lee and S. Roy, "Low-cost, Lightweight Electronic Flow Regulators for Throttling Liquid Rocket Engines," 2023. Accessed: Feb. 28, 2024. [Online]. Available: https://arxiv.org/ftp/arxiv/papers/2401/2401.07444.pdf