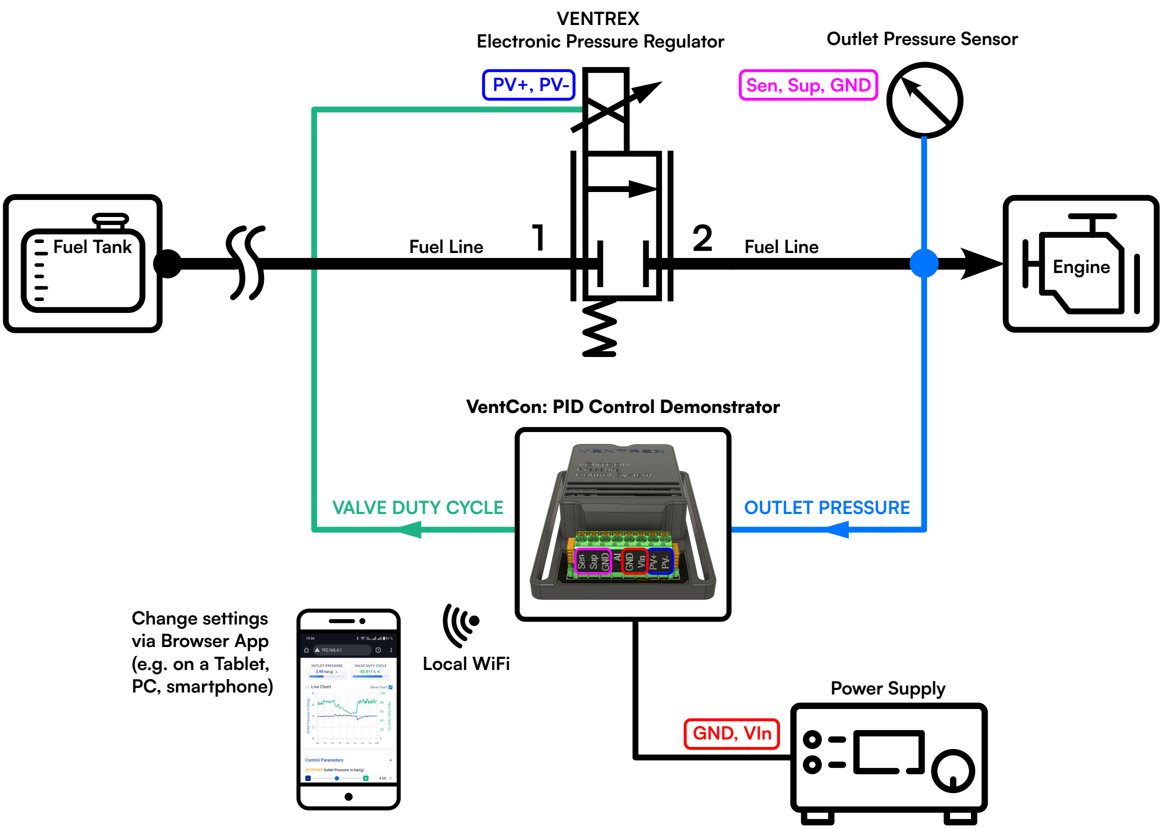
VENTREX

DRIVING MOBILITY FORWARD

VentCon - PID Control Demonstrator

User Manual



Version 2.6.6

February 25, 2026

1 System Overview

Unlike a mechanical pressure regulator, which relies on a diaphragm and spring to maintain its setpoint, the VENTREX electronic pressure regulator uses a software-based feedback control loop. A PID control algorithm continuously compares the measured outlet pressure with the desired setpoint and modulates the proportional valve accordingly.

The VentCon demonstrator showcases this principle: it implements the complete control loop on a microcontroller by Espressif Systems, allowing users to observe and tune the regulator's behaviour in real time. This document covers the system's hardware, functional principles, and browser-based user interface.

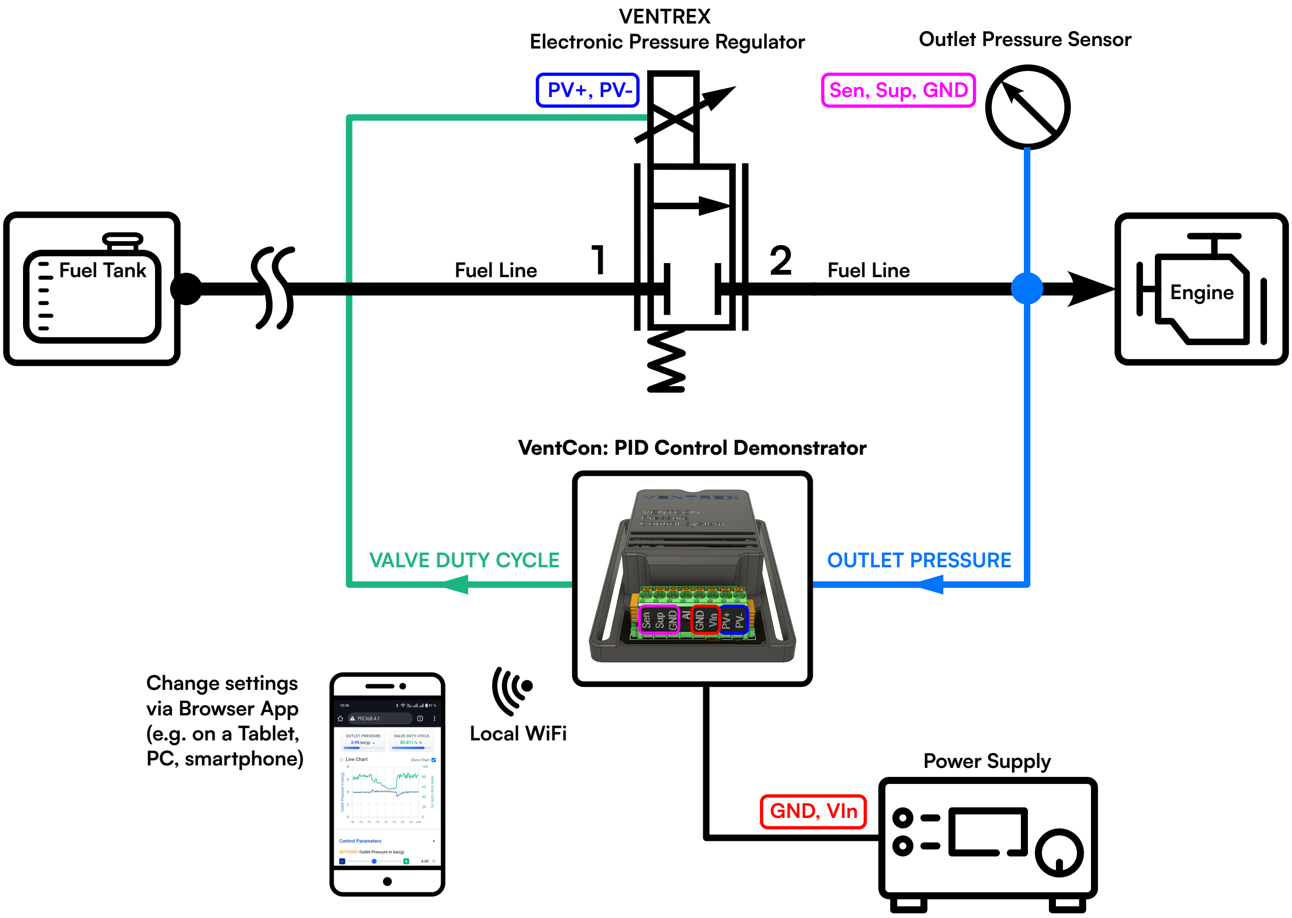


Figure 1: VentCon system overview.

All parameters can be adjusted through a browser-based interface served over WiFi directly from the device—no external software, router, or internet connection is required. The VentCon operates fully self-contained, making it usable in any environment regardless of existing network infrastructure.

> **Important**
>
> The PID control loop runs independently of the WiFi connection. Even if the browser is closed or the device is disconnected from WiFi, pressure regulation continues uninterrupted based on the last applied settings (as long as the power supply remains on).
>
> This also means that upon switching the power supply on, the system will immediately start to regulate the pressure by powering the proportional valve.

2 Getting Started

2.1 Wiring Scheme

The terminal block on the front of the VentCon device (Figure 2) provides connections for the pressure sensor (`Sen`/`Sup`/`GND`), the power supply (`VIn`/`GND`) and the proportional valve (`PV+`/`PV-`).

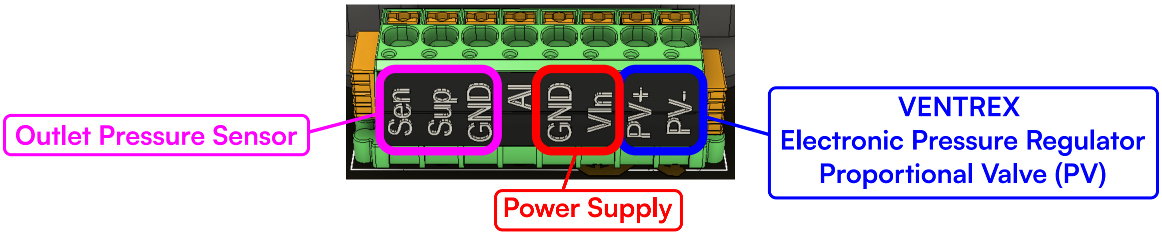


Figure 2: Terminal block connections.

The terminal block connections are numbered as follows (from left to right; see Figure 2).

The **Pressure Sensor** (not included in the demo kit) is connected at three positions:

> Pos. **1)** `Sen` Connect to the analog pressure signal output of the pressure sensor.
> Pos. **2)** `Sup` This connector provides a regulated 5 V to the pressure sensor. Connect to the 'supply voltage' pin of the pressure sensor.
> Pos. **3)** `GND` Connect to the ground pin of the pressure sensor.

The **Power Supply** (not included in the demo kit) is connected at two positions:

> Pos. **4)** `VIn` Connect to the positive terminal of the power supply (red banana plug).
> Pos. **5)** `GND` Connect to the negative terminal of the power supply (black banana plug).
>
> The power supply must deliver a stable DC voltage. It is used to power the entire system, including the microcontroller, pressure sensor, and proportional valve.
>
> **Important**
>
> The proportional valve receives the same voltage that is set on the user's power supply.
>
> For the proportional valve supplied with this demo kit, a 12 V source rated for at least 4 A is recommended. The VentCon device, however, accepts any supply voltage in the range of 12 to 30 V.

Optional external **Analog Input**:

> Pos. **6)** `AI` Used for external analog input (not used in this demo kit, reserved for future expansion).

The **Proportional Valve (PV)** is connected via the provided 2-pin connector (i.e. no user wiring required):

> **Important**
>
> It is recommended that users first familiarise themselves with sensor behaviour, browser interface, and control parameters before connecting the proportional valve (PV). See section 2.2.
>
> Pos. **7)** `PV+` This is connected to the positive terminal of the proportional valve.
> Pos. **8)** `PV-` This is connected to the negative terminal of the proportional valve.

aalberts

2.2 Connecting to the Device via WiFi

It is recommended that before the VentCon device is wired up to the proportional valve, users first connect to the device via WiFi and explore the browser interface. The device used for this can be any WiFi-enabled smartphone, tablet or PC with a modern web browser (e.g. Google Chrome, Safari)[1].

The VentCon device creates its own WiFi access point. No router or internet connection is needed or used. This also means that the device is not able to send or receive any data to or from the internet.

Important

The PID control loop runs independently of the WiFi connection. Disconnecting the browser does *not* stop pressure regulation.

In order to initiate the connection to the device, follow these steps:

Figure 3: QR Code for WiFi connection.

1. Power on the VentCon unit via your power supply (connector see Section 2.1).
2. On your smartphone or tablet, scan the QR Code on the back of the device (see Figure 3). This will connect to a network called `VENTCON_AP`.
   Go to step 4 from here.

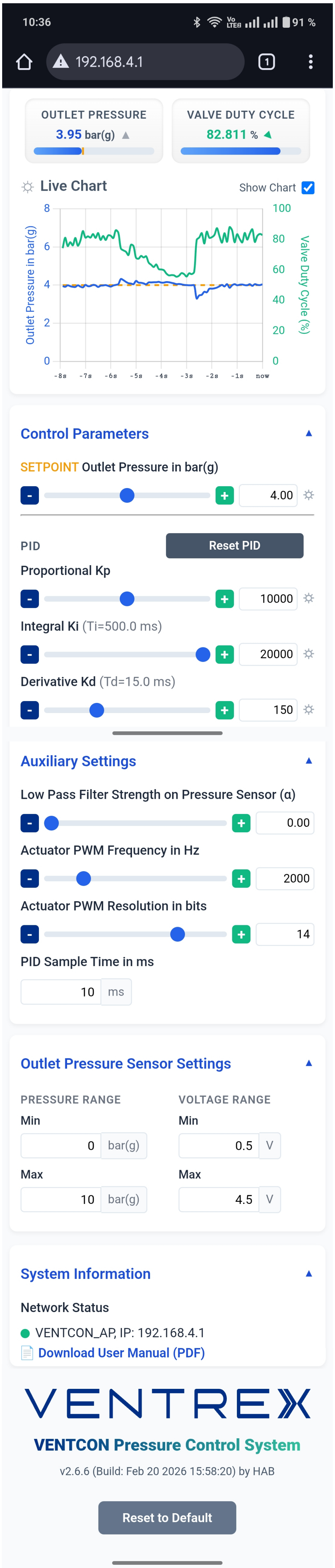
   If your device does not support QR code scanning (e.g. on a PC):
   1. Open WiFi settings on your device.
   2. Connect to the network `VENTCON_AP` using the password `ventcon12!`
3. If your device reports that the network has no internet access, you can safely ignore this notice.
   VentCon creates a local WiFi network only and does not provide internet connectivity.
4. Open a web browser and navigate to
   `http://192.168.4.1` or, alternatively,
   `http://ventcon.local`

3 Web Interface

The web interface is divided into collapsible sections (tap a header to expand/collapse). Figure 4 provides an annotated overview. At the top, real-time status indicators display the current outlet pressure and valve duty cycle as gauges. Below, a live trend chart plots the pressure, setpoint and duty cycle over time. The control parameters section allows adjustment of the pressure setpoint and PID gains (K_p, K_i, K_d). Be sure you know the effects of each parameter before making changes (see Section 4). Additional auxiliary settings, such as the sensor low-pass filter strength, are grouped at the bottom.

A **Reset PID** button clears the controller's internal state, which is useful when the system is saturated or oscillating. Finally, a **Reset to Default** button restores all user-adjustable settings to their factory values after confirmation.

[1]Up to two devices can be connected to the VentCon's WiFi network at the same time. This allows, for example, a smartphone and a laptop to both access the web interface simultaneously.



Browser Address Bar.
IP Address of the Browser App. Alternatively, use http://ventcon.local
The PID control algorithm is working regardless of WiFi connection.

Real-Time Status Indicators.
OUTLET PRESSURE:
The regulated pressure as measured by the sensor. This is the Process Variable that the PID control algorithm is working to get close to the Setpoint pressure.

VALVE DUTY CYCLE:
Measure of electrical current and regulator orifice area. This represents the output signal sent from the PID control algorithm to the regulator valve.

Live Trend Chart.
The gear icon (☼) opens a window to set the chart limits and grid settings.
The 'Show Chart' checkbox disables the chart (use when WiFi is poor)

The blue line tracks OUTLET PRESSURE over time. An OUTLET PRESSURE randomly hovering just above 0 bar(g) indicates a not working or not connected sensor.

The green line tracks VALVE DUTY CYCLE over time.

The orange line tracks the SETPOINT pressure over time. This represents the target pressure for the regulator algorithm and can be set during operation in the Control Parameters.

Control Parameters.
The essential PID control parameters are located here. Each parameter's value is adjusted by either Plus (+) or Minus (-) button, a slider or numerical input.
The gear icon (☼) opens a window to set the slider limits and fidelity.

SETPOINT Outlet Pressure:
This is the target pressure for the PID algorithm.

Kp, Ki, Kd:
These are the weights put on the proportional, integral and derivative path:

Proportional Gain (Kp): Determines the immediate reaction to the current error, applying a correction proportional to how far the Outlet Pressure is from the Setpoint.

Integral Gain (Ki): Addresses past errors by gradually increasing the valve's response over time to eliminate any lingering offset between the Outlet Pressure and the Setpoint.

Derivative Gain (Kd): Anticipates future errors by responding to the rate at which the Outlet Pressure is changing.

Reset PID — This button resets the PID controller's internal state. Useful when the system is saturated or is oscillating.

Auxiliary Settings.

Low Pass Filter Strength on Pressure Sensor:
If the sensor is noisy (i.e. OUTLET PRESSURE), a low pass filter can be configured here.
Valid value range: 0 to 1.

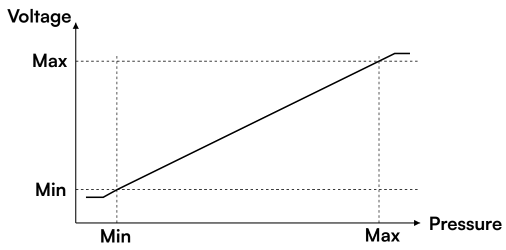
Actuator PWM Frequency:
This setting determines the rate at which the valve's control signal cycles on and off to achieve the desired VALVE DUTY CYCLE. Valid value range: 100 to 10000 Hz.

Actuator PWM Resolution:
This defines the precision of VALVE DUTY CYCLE.
Valid value range: 8 to 16 bits (e.g., 14 bits provides 16384 discrete steps).

PID Sample Time:
Defines the time interval between successive calculation steps of the PID algorithm.

Outlet Pressure Sensor Settings.
Voltage Range and Pressure Range.

The upper and lower limits define the operational boundaries of the sensor, as specified in the sensor datasheet or determined through calibration.



System Information.
Network Status:
The Indicator will be green when connected, red when disconnected.
Also, this user manual can be downloaded from here.

Reset to Default.
Upon confirmation, this button restores all user-adjustable settings on the Browser App to their default values.

3.1 Applying Changes

Changes are **not** applied immediately. After adjusting any parameter, a blue **Apply Changes** button appears at the bottom of the screen (Figure 5). Tap it to send all pending changes to the device. All applied settings are automatically saved to VentCon's flash memory and survive power cycles.

If the **Apply Changes** button is not tapped within a few seconds, the new settings will **not** take effect and the system will continue operating with the previously applied parameters.

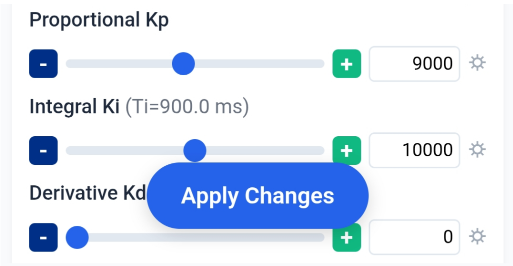


Figure 5: The floating *Apply Changes* button appears when parameters have been modified.

4 PID Control Basics

Figures 1 and 6 illustrate the closed-loop control architecture. The pressure sensor continuously measures the outlet pressure (*Process Variable*). The PID controller computes the error between the *Setpoint* and the measured pressure, and outputs a *Valve Duty Cycle* (PWM signal) to the solenoid valve.

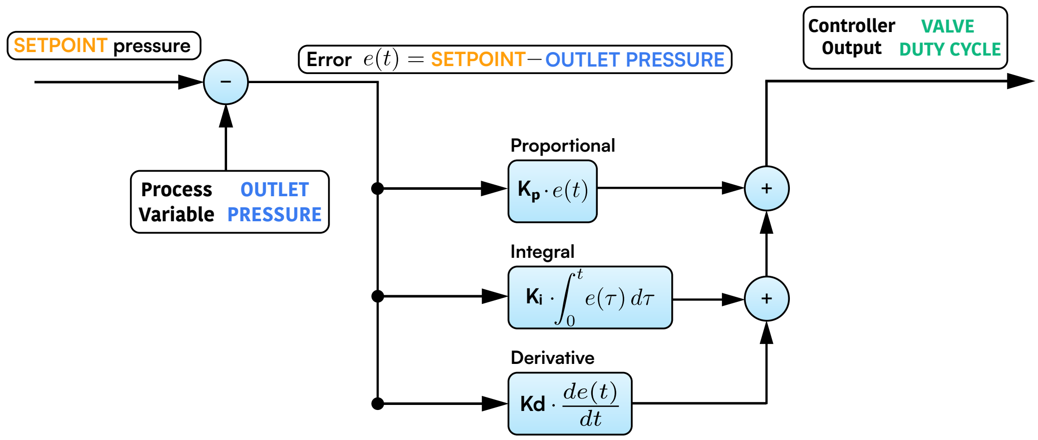


Figure 6: PID closed-loop control block diagram. The Setpoint is compared with the Outlet Pressure; the error drives the Proportional, Integral and Derivative paths whose sum controls the Valve Duty Cycle.

The algorithm uses the *Parallel Form* (non-interacting form) of the PID algorithm. Each control action is computed independently and summed.

Proportional (gain K_p): Output proportional to the current error.
Higher K_p gives a more aggressive response but can cause overshoot.

Integral (gain K_i): Accumulates past error to eliminate steady-state offset.
Too high a value causes oscillation (integral windup).

Derivative (gain K_d): Damps the response by reacting to the rate of change of the error.
Reduces overshoot but amplifies sensor noise if set too high.

The mathematical representation of the PID controller is given by the following equation:

$$y(t) \;=\; K_p\, e(t) \;+\; K_i \int_0^t e(\tau)\, d\tau \;+\; K_d \frac{de(t)}{dt}$$

$y(t)$	is the controller output (Valve Duty Cycle)
$e(t)$	is the error (Setpoint – Outlet Pressure)
K_p, K_i, K_d	are the tunable gains.

Term	Role	Focus
K_p	Present	Reacts to *how far* you are from target
K_i	Past	Reacts to *how long* you have been away
K_d	Future	Reacts to *how fast* you are approaching/leaving

Table 1: PID term summary.

4.1 Tuning Guide

Follow these steps for initial tuning. Observe the **Live Chart** after each change.

1. **Set a Stable Operating Point.** Choose a moderate setpoint (e.g. 6 bar(g)), let the system settle.
2. **Start with P-only control.** Set $K_i = 0$ and $K_d = 0$. Begin with a low K_p and increase gradually. Find the value where the pressure just begins to oscillate steadily (*ultimate gain*), then back off slightly.
3. **Introduce Integral action.** Slowly increase K_i to remove the remaining steady-state offset. Stop increasing when further gains cause oscillation.
4. **Add Derivative action (if needed).** If the response overshoots or is slow to settle, increase K_d cautiously to add damping.
5. **Iterate.** Make small single-parameter changes and observe. The goal is a fast, smooth response with minimal overshoot.

4.2 Example: Step Response

Figure 7 shows a typical step-response recording where the setpoint is changed from 4 to 6 bar. Figure 8 demonstrates the controller rejecting a mass-flow disturbance while maintaining the setpoint.

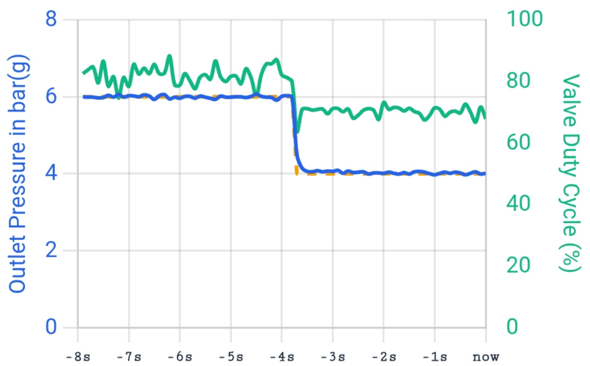


Figure 7: Setpoint step from 4 to 6 bar.

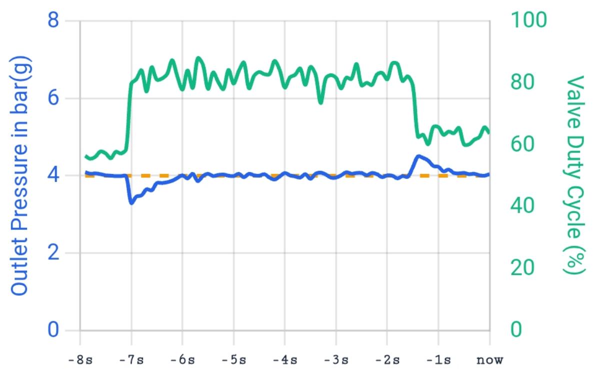


Figure 8: Disturbance rejection under varying mass flow.